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The Second Industrial Revolution

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The following is a transcript of a talk that Professor Russ Ackoff regularly gave to a large number of different audiences during the 1970's…

Many believe that it is, quite simply, the best introduction to Systems Thinking ever written. And its continued relevance decades later is remarkable.

The talk makes two great – and fundamental – points, each with important implications for organizations.

> First, that the nature of systems thinking differs from classical, linear problem-solving in that, rather than resolving problems by trying to 'take them apart', it suggests looking at them in terms of context, fit, environment and the *inter-relationships* of the system's elements.
>
> Second, that sub-optimization of (any kind of) system is the result of a focus on *local goals* – and that such a focus, by definition, almost guarantees such sub-optimization.

Over the years, these two principles have been invaluable in addressing organizational problems of all kinds – underlying, among other things, the socio-tech movement, the Total Quality movement and much of the best work in process improvement and organization design.

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The Speech / Essay

One of the great advantages of being a professor is something called students and the great thing about having students around is that, although they seldom know the answers to the questions that you have asked, they sure know the questions. As you must be aware by reading the papers and talking to young people, they are asking many questions about many things these days and their questions are anything but superficial.

I have noticed over the last year an increasing number asking questions like "What in the world is happening to the world?" And they go on to explain and say, "You know, we just read Alvin Toffler's *Future Shock* or Dennis Gabor's *Inventing The Future* or Barbara Ward's *Lopsided World* or C.P. Snow's *Two Cultures",* and so on through a very large number of books which have appeared, carrying the basic message that we are in a stage of crisis and fundamental change in society.

Then the students normally go on to say that these authors are describing the symptoms of fundamental dislocation in society, but that they don't provide us with any fundamental understanding of what is going on. The students keep asking, "You got any clues?" Well, they kept asking this question long enough that I felt obliged to try to get an answer to it, and this led to my current effort to answer that question in a book [*Redesigning the Future*, John Wiley & Sons, 1974].

It is essentially that topic that I would like to discuss with you. What the kids are asking for, fundamentally, is something that we unfortunately don't even have a good word for in English, but the Germans do. There is a marvelous work in German – *weltanschauung* – which, literally translated, means "a view of the world". But that translation doesn't capture the meaning very well. It's more than a view; it's a conception and understanding of what is going on.

In the old European tradition there was a great compulsion to attempt to grasp the significance of world events. Today we seem to be content to describe them without explanation. I am going to present a thesis; defend it; and then try to show you some of its consequences for business and management (if it's true) – a thesis about "What in the World is Happening in the World?"

Briefly put, the thesis is that since World War II we have entered into a period which will be to the future what the Renaissance was to the past. We have moved into a new age that is fundamentally different from the age from which we have just come – an age that began with the Renaissance and ended essentially with World War II (but like other ages it doesn't end on a date, it fades away). And we are attempting to deal with problems generated by a new age with techniques and tools that we have inherited from an old one. These are the dislocations of our culture. It will be a while before we catch up and bring these two things into consonance.

I would like to characterize both the old age and the new age for you. Some of this will be very familiar, although the names I use for them will be a little new to you. Then I will look at those differences in two ways: first, the intellectual differences between the old age and the new

age, then the hardware or technological differences between them. Then we will attempt to make some analysis of what the crises in the current age are all about.

Machine Age Thinking – Three fundamental ideas

The period out of which we are coming is a period that I am going to refer to as the Machine Age. We are going to look at the software side of it first – at the intellectual contents. The intellectual contents of the Machine Age essentially rest on three fundamental ideas, which have formidable titles but the content of which are familiar to you.

Reductionism – the search for ultimate parts

The first of these ideas is an idea called "Reductionism". For several centuries we had a view of the world which argued that everything we experience, perceive, touch, feel or handle is something which is made up of parts. Those parts are themselves wholes which are again made up of parts. So one of the fundamental questions to which the Machine Age addressed itself was the ultimate limit of taking things apart, because it was an age that was preoccupied with taking things apart. And the answer was that if you take anything and start to take it apart, you will ultimately reach indivisible elements – and that's the basic doctrine of reductionism. Everything is ultimately made up of indivisible parts or ultimate elements. That might seem like a simple notion of no great significance to you, but it dominated all of the major thought and theories for several hundred years.

For example, the physicists believe that if you take any object and break it up and keep doing that you will ultimately reach a thing called an atom. An atom is an indivisible particle of matter. You cannot get any smaller. That's it; that's ultimate reality.

Those of you who took a course in chemistry in high school will recall that your first couple of sessions were devoted to something called Mendeleyev's Tables. In Mendeleyev's Tables, you learned what the basic elements of matter were. Of course, as practicing chemists, you pay no attention to that any more. But the fact is that chemistry was based on a theory that ultimately there are fundamental components of matter out of which everything else is made.

When biology emerged as a science in the nineteenth century, the first thing the biologists did was look for an ultimate component of life. They found something called the cell. A cell could be taken apart but when it was taken apart it no longer had the property of life. So the cell was the ultimate component of life.

This approach was used for the behavioral sciences as well. When people began to think about mind as a phenomenon to study, they also started to take it apart. The first historic effort in this direction was by a great German mathematician and philosopher of the late Renaissance, Leibnitz, who argued that the mind consisted of psychic particles which he called "monads". He wrote a great book called *The Monadology* in which he defends his theory. Fortunately, that theory didn't last very long.

It was replaced by another theory of an English philosopher and psychologist, John Locke, who argued that mind consists simply of experience and experience is made up of basic components provided directly by the senses. He called the components supplied by the senses

"simple ideas". These were things like sensations of redness or of size or shape, and these sensations could not be broken down to further components. They were the ultimate units of experience.

Modern psychology still largely accepts that atomistic view of knowledge. Even more recently, when Freud came along and developed a theory of personality modeled completely on the atomic theory of physics, he argued that there were three ultimate particles of personality. He called them the id, the ego and the superego, and they were imbued with force just as matter is imbued with energy in physics. He called that force the libido.

The reductionist approach has been used not only in the sciences but in business. When a person wants to create a business, the first thing he does is to start to take it apart to see what the ultimate components are of which the business must be composed.

So the first unifying idea of the Machine Age was that everything consists of parts, and in order to deal with the thing you have to take it apart until you discover its ultimate parts. Further, we *ought* to try to do so, because it is only in this way that we can understand the whole. And that idea gave rise to the second fundamental idea.

Analysis – thinking by taking things apart

The second fundamental idea was that the most powerful mode of thinking is a process called "analysis". Analysis is simply based on reductionism. It argues like this. If you have something you want to explain, or a problem you want to solve, you start to take it apart. You break it up into its components and hopefully you get it all the way down to the ultimate components, or at least to the simplest components as you can possible find. Then you explain these components or you solve these problems and when you have got them solved or explained, you aggregate those solutions or explanations into a total solution or explanation. So analysis is a form of "up/ down/ up again" thinking. It tends to explain things by the behavior of their parts.

When a manager is confronted by a problem, he goes through a process which is technically referred to in the jargon of management as "cutting the problem down to size". Cutting the problem down to size is simply treating it analytically. It's reducing it to a set of solvable problems; solving the component problems and then assembling those solutions into a total solution.

Thus, analysis became the dominant mode of thought; in fact, even today, we use "analysis: and "thinking" as synonymous terms. It is very difficult for many people to conceive of an alternative to analysis. I am going to show you in a few moments that one has begun to emerge.

Mechanism – assuming linear "cause-and-effect" relationships

The third basic idea of the Machine Age was an idea from which the name of this age derives. The idea is called "Mechanism". Mechanism is based on a theory that all phenomena in the world can be explained by resorting to only one relationship – that of "cause and effect". It works this way: when we say that one thing – let me call it an "X" – is the cause of another thing called "Y", we are really saying two things about it. One is that "X" is necessary for "Y" – "Y" will not occur unless "X" occurs. The second is that "X" is sufficient for "Y" – if "X" occurs,

then "Y" has to occur. We attempt to develop a concept of the world in which all things are related by necessary and sufficient relationships of cause and effect. This has two very important consequences. The first is that, when we try to explain something, call it "Y", and we find its cause, "X", then we don't need anything else to explain it, because the explanation is complete. If "X" is necessary and sufficient to cause "Y", then nothing else matters.

Therefore, the concept of the *environment* was irrelevant in classical science. This is apparent if you look at the concept of a laboratory. A laboratory is deliberately constructed so that anything outside of it is irrelevant, and the whole effort of science is to break the world up into relations which could be studied in isolation, independently of their environment. Using modern language, the approach gave rise to what we would call a "*closed system"* view of the world.

That became apparent when we look at how we conceive of the world as a whole. During the Machine Age, the world was conceived of as a machine, a machine operating in accordance with unchanging laws that were dictated by the structure of the world. The figure which was actually used was that the world is like a hermetically sealed clock – it keep ticking away without change over time in accordance with the laws that derived from the structure of the clock. The only debatable issue was whether this was a self-winding clock (that had to do, of course, with the existence of God). There was no argument, however, about the world being basically a machine.

The First Industrial Revolution

These three ideas together – that the world is a machine controlled by cause-and-effect laws; that to understand it we had to break it into its parts; and then explain its parts and put those explanations together and thus understand the whole – gave rise to what we now call the "First Industrial Revolution"

The First Industrial Revolution was a product of Machine Age thinking. It came about essentially in the following way. There were two fundamental beliefs of the Machine Age. The first was that the world was a machine created by God to serve his purposes. And the second was that Man was created in the image of God. From that it was a very small step to say, "Why shouldn't Man create machines to serve his purposes?" He began to ask and answer this question in the latter part of the Renaissance and this gave rise to the First Industrial Revolution.

But the form of that revolution was dictated by the application of these three ideas to the process of work. Because the First Industrial Revolution dealt primarily with the process we now call Mechanization, or the replacement of man, as a source of work, by a machine. Work was defined as the transformation of matter from one form to another, or the transformation of matter into energy, or the transformation of energy from one form into another. In other words, work was conceived of in physical terms and, therefore, mechanization was about the use of machines to perform physical work. Man was replaced as a source of energy by machines. And the way he was replaced was the result of the atomistic way we analyzed work.

In order to understand work, we took a job to be done and broke it up into its parts. That process actually came to be called "work study", or "analysis". We kept dividing work up into smaller units until we reached ultimate individual components which we called work elements. These were operations that were so simple that they could not be further subdivided conceptually. When we reached this point, we set these operations in a network diagram of some

kind to show how, by a flow through these components, we would eventually produce a finished product.

The assembly line, the mass production line, was the epitome of this way of thinking. But it had several important consequences to it. Once we identified these components of work, we attempted to mechanize them, and we did mechanize a number. There were some that we didn't have the skills to mechanize, at least initially, so we put men to work on these tasks, with a very important consequence. We developed man-machine systems for doing physical work in which the work was conceptualized in such a way as to facilitate mechanization, and as a result we set man to doing work that was designed for a machine. In this process, we completely dehumanized the work process.

All of this should be reasonably familiar to you, because it is part of the culture in which we have been brought up. What I am really interested in is what has been happening to all of this since World War II. As I tried to indicate earlier, what has been happening is nothing less than a fundamental cultural revolution. So let's take a look at each of these three ideas, and then at the First Industrial Revolution, to see what has been going on.

Emergence of Some New Ideas

In 1942 a very important and very much ignored book was published. It was ignored for two reasons that are very easy to understand. First, it was written by a woman and, second, she was a philosopher. Now who in the world would ever pay attention to a female philosopher? Her name was Susanne Langer and the book was called *Philosophy in a New Key*. In that little book, Langer presented the results of an analysis of what had been going on in science between 1920 and 1940. She reached two fundamental conclusions.

The first was that science was undergoing a basic change, in which the concept of an atom, which was fundamental to the physical sciences, was being replace by a new kind of element called a "symbol". Now the curious thing about a symbol is that it has no matter, nor is it imbued with energy. Whatever it is, it has nothing to do with what physicists worried about for several hundred years.

This new concept didn't shock very many people, because they didn't read the book, but some did, including one of her students, a man named Charles Morris. In 1946, Morris produced a book in which he said Susanne Langer's perception was correct, but she was wrong in the conclusion she drew from it. There was a fundamental change going on in science, but its preoccupation was not with symbols alone but with something larger, of which symbols were a part. In his book, called *Signs, Language and Behavior*, he proposed that the new organizing concept was something he called "language".

That idea only lasted a year, because another book was being written, which was to be the first of a series of books that were very important and shocking to our culture. It was a book written by, of all things, a mathematician at Bell Telephone Laboratories named Claude Shannon. It appeared at the end of 1947 and was called *A Mathematical Theory of Communication*. The introduction and conclusion were written by Warren Weaver of the Rockefeller Foundation, who pointed out that Shannon had discovered that the new organizing

concept of science was not language, but something larger of which language was a part – something called "communication".

Now that book was very important, not for the reasons that Weaver guessed, but because the notion that communication was the organizing concept of science was displaced before the book appeared, and for a curious reason. One of Shannon's principal collaborators, another mathematician at MIT, disagreed with his thesis and was writing his own book at the same time. They finished on almost the same date, but in order to beat Shannon to press, his friend took the book to France to be published, although it was published in English.

The book did beat Shannon's to press and it was famous for two reasons: first, for its misprints (it probably had more than any other book ever published in the English language) and, second, for its content. The name of that book was *Cybernetics* and it was written by Norbert Wiener. In it, Wiener proposes that the new organizing concept of science was control.

Before we go any further, notice what has been happening in this very short evolution, because we already have evidence of a process which is completely contrary to the fundamental tenets of the Machine Age.

An element called a symbol was proposed as the basis of science, and within a few years somebody came along and said "No, that's wrong. The new element is something larger – language – which contains the previous element." The philosophical concept was going up, not down. This didn't take elements apart, it put them together into something larger. Then Shannon came along with something larger still – communication – because language was only one form of communication. Wiener came along and put communication into yet a larger context – control – because communication is a necessary part of control but not all there is to it. And we didn't understand what this process was all about until 1951, when suddenly science went through what the psychologists would call an "Ah-ha! experience".

The Systems Age

Science suddenly found out what it had been up to when a book was published by a German biologist, Ludwig von Bertalanffy, living in Canada. In its title, he used the word which everybody recognized as the new organizing concept of science, and that was the word "systems". It is for this reason that I am going to refer to the new period as the "Systems Age".

Thinking in terms of "systems"

Let's take a look at this new concept and see why it constitutes a major revolution. We can look at it two ways. We can look at it the way a professor would and try to define it's meaning precisely, and I'll do that first. I don't know how much that will illuminate, so I will then give you a poetic definition of it which, like most poetic definitions, may be much more illuminating than the scientific one.

Let's look at this "system" first in a rather rigorous way. The system consists of a set of parts – a collection of elements – which must satisfy three conditions.

- First, the performance of a whole is affected by every one of its parts – that's a basic characteristic of a system. If you think of a corporation as a system, which it is, this means that every department can affect the performance of the corporation. That is the first condition for membership in a system. If you have a department which has no effect on the performance of the corporation, the one thing you can be sure of is that it is not a part of the corporation.

- The second essential characteristic of a system is that the way any part affects the whole depends on what at least one other part is doing (i.e. interdependency). Or, put another way, no part of the system has an independent effect on the whole. Now again, coming back to the corporate context, what this says is that the way the marketing department affects corporate behavior depends on what other departments do.

- To take a trivial and obvious example, suppose a marketing department decides to try to increase the sale of one of your products by decreasing price. Will you get increased sales? It clearly depends upon what production does. If you don't produce any more, no matter what you do to the price, you can't sell more. And that's all the second condition says, that the way that any department affects the whole will depend on what at least one other department does.

- Now the third condition is the most complex one – and the most important. It says that if you take these elements and group them in any way, to form subgroups, these subgroups will be subject to the same first and second conditions as the original elements were – i.e. each subgroup will affect the performance as a whole and no subgroup will have an independent effect on the performance of the whole.

If you put these three conditions together, a surprising thing emerges. That's the poetry in it. Because it turns out that a system is an ***indivisible whole***. And it's in the difference between an indivisible ***part*** and an indivisible ***whole*** that the roots of the "Second Industrial Revolution" lie.

From "Reductionism" to "Expansionism"

The first essential difference is the conversion of our preoccupation with the parts of which things are made to a preoccupation with the whole – and the wholes of which they are a part. We can refer to this new point of view as "***expansionism***" – based on the concept of a system. It has given rise to a new kind of thinking which I will call "***synthesis***" – or as it is more popularly known, the "***systems approach***" or "*systems thinking*". By the way, there are two books which have appeared in the last two years on the subject, both of which are extremely effective. One is called *The Systems Approach*, by C. West Churchman and the other is called *Systems Thinking*, by Fred E. Emery. They deal with this fundamental revolution and our new mode of thinking.

Let me describe that shift and then show you its significance. Remember, in ***analysis***, if you had something you wanted to explain, you took it apart, explained the parts, and put the explanations of the parts back together again. In ***synthesis***, when you want to explain something, you do exactly the opposite. You don't look at the thing to be explained as a whole to be taken apart, but as a part of a larger whole. You then attempt to explain the whole of which it is a part, and then extract an explanation of the thing you started with from an explanation of the whole.

This is "up-and-down-again" thinking, as opposed to "down-and-up-again" thinking. This kind of thinking has some very important consequences, not only for management but for administration and our whole concept of control of society. It leads to one very important counter-intuitive hypothesis which has a very fundamental impact on our notion of how to run things in this world.

An Important Counter-Intuitive Hypothesis – re Sub-optimization

Let me give you this theorem – which can now be proven – and it's corollary. The theorem goes as follows:

> If you take a system and take it apart to identify its components, and then operate those components is such a way that every component perform as well as it possibly can, then there is one thing of which you can be almost certain – the system as a whole will not perform as well as *it* can.

Now that is counter-intuitive to Machine Age thinking – but it is absolutely essential to systems thinking, for a reason I will explain in a moment.

The corollary is this:

> If you have a system that is performing as well as it can – then none of its parts will be.

Now think of what that means in a corporation. If you take a corporation and break it up into marketing, production, purchasing, public relations, law, finance, personnel and so on – and get each of these departments behaving as efficiently as it can, the corporation will probably not be. If we get the corporation performing as well as it can, none of its departments may be. And that understanding requires a very different attitude toward how to run the show.

A Thought Experiment ["Ackoff's Car"]

Let me try to give you a feeling of why that is so by giving you an example, rather than trying to give you a generalized proof. I would like you to go through the following thought experiment, which should be easy for you to perform because you are familiar with all the components.

I read in the *New York Times* recently that there are 142 makes of automobiles available in the United States. So let's get one of each and bring them into a large garage – 142 cars.

We'll hire ourselves a good group of first-rate automotive engineers and ask them to do the following: "Inspect those 142 cars, test them, do any damn thing you want to, but come out and tell us which one has the best carburetor". So the engineers run a series of tests and they come out and say the Buick has the best carburetor. So we make a note: Buick carburetor.

Then we say "Fine, now we would like you to do the same thing on transmissions". So they test the transmissions and they come out and say the Mercedes has the best transmission. And we make a note: Mercedes transmission.

We say "Okay, take the distributor". And they run through the tests and they come out and say the Dodge has got the best distributor.

Then, one by one, we do every part until we have every part required for an automobile and we have identified the best part available. When that is done, we tell the engineers: "Now take those parts off those cars and assemble them, because then we ought to get the best possible automobile".

But do you get it? We don't even get an automobile. And for a very obvious reason.

Because it turns out that ***the parts don't fit*** – and that's what systems thinking is all about. It says that the performance of the whole is not the addition of the performance of the parts – but it is a consequence of the ***relationships*** among the performances of the parts. It is how performance relates, not how it occurs independently of the other parts. That is what systems thinking is all about.

So synthesis is a different way of thinking and of looking for explanations. It tries to find it by looking at wholes – larger wholes – of which things are a part, rather than by taking things apart.

A Different View of Cause-and-Effect

The third idea, teleology, has an exciting intellectual history. Let me try to sketch it out for you very briefly.

In 1898, there was a philosopher of science at the University of Pennsylvania who began writing a book that, like Langer's, was almost completely ignored. It made two fundamental points about the nature of science. The man's name was E.J. Singer Jr. He pointed out two things. First, he pointed out that science didn't follow its own doctrine – that we were using the term "cause and effect" in two very different ways when we say that striking a bell in a vacuum will not produce a sound and when we say that oaks come from acorns. When we talk about the bell and the sound, we are talking about cause and effect in the sense of being both necessary and sufficient – but when we talk about an acorn and an oak, we are clearly not talking about classical cause and effect.

It is true that you cannot have an oak without an acorn. An acorn is clearly necessary to an oak, but it is not sufficient. If I take an acorn and put it on the bottom of the ocean, I won't get an oak tree. I won't get an oak if I put an acorn on top of a rock or in soil with no water – all sorts of other things are necessary. Therefore, an acorn is a necessary but not a sufficient cause.

Singer argued that this is another kind of relationship. He sometimes referred to it as "probabilistic causality" or "non-deterministic causality" – but he finally chose to call it "producer-product" because we say that an acorn is a producer of an oak rather than a cause of it.

"This is another way of looking at the world," Singer said. It is not incompatible with looking at it through the eyes of cause and effect, but it is a different way. It is another slice through the same thing.

Then he went on to look at the consequences of looking at the world as though the relationships between things were producer-product rather than cause-and-effect. Two very important consequences emerged.

The first is that if you start to look for the producer of an oak – which is your "Y" – and you find the acorn which produced it, you still have not explained that oak simply by identifying the acorn. You also have to talk about the climatic conditions, the soil, and all the rest of it. You must consider the ***environment***.

The Issue of Purpose and Free Will

So Singer discovered the relevance for the environment the moment one changes one's concentration from cause-and-effect to producer-product. More important, he was able to resolve the principal paradox of the Machine Age: how do we explain free will or purposive behavior. If the world is a machine, completely dictated by laws that never change, how can anything have free choice? Science struggled with this one for centuries and came up with three answers, none of which were satisfactory.

The first was that the question was meaningless. Well, all that meant was that they didn't know how to answer it, so they decided to ignore it. There was a whole school of thought called "logical positivism" which took this position.

The second position said that, while the question was not meaningless, it was an illusion. We don't really have freedom of will. We're like ants on the trunk of an elephant who think they are steering the elephant. God in His infinite wisdom has embedded in us this illusion so that life is more enjoyable, but the fact is that an objective observer who knew all that had come before any event, would know exactly what the person involved would do in that event because his behavior was completely determined. And this led to a concept of pre-determinism or fatalism. We really have no choice in life, only the illusion of choice.

The third answer which science gave was "Yes, this is a meaningful problem but it falls out of the domain of science" so they threw it into what was frequently referred to as the "scientific outhouse" called "metaphysics" and said "Let the metaphysicians worry about this". They did, and of course they got nowhere with it.

Now what Singer showed was that, if you begin to look at the world through the eyes of this producer-product relationship, a very fundamental change occurs. Free will and purposeful behavior become compatible with science. You can study and explain them scientifically, which you could not do with the mechanistic view.

Therefore, he called this view of the world "teleological" – that is just a Greek word which means "purposeful". It is a purposeful view of the world as opposed to a mechanistic view of the world.

The view that Singer developed was ignored for fifty years. Then an amazing thing happened, as so frequently happens in science. A German biologist by the name of Gerd Sommerhoff wrote a book, published by Oxford University in 1950, called *Analytical Biology*., in which he made a complete rediscovery, independently of Singer, of exactly what Singer had observed.

Sommerhoff used different words. He didn't use the term "producer-producer" but "directive correlation". He had a whole new vocabulary, but the content was identical and he was equally ignored. Unfortunately, in his case, it lead to a personal crackup and a great personal tragedy. It was a shame, because it was only four years from the time he published that book until science

suddenly understood what the hell was going on, and that discovery occurred for a very serious reason.

Norbert Wiener, to whom I have already referred, had as his principal collaborator a physiologist in Mexico named Arturo Rosenblueth. In the middle 1950's, when they were trying to develop some of the notions of cybernetics, they made an incredible discovery, (which they published in a paper that appeared in the *Philosophic Journal*, of all things). They pointed out that historically, when we wanted to understand man, we treated him as though he were a machine – that was what the Machine Age was all about. We looked at men as thought they were a complex kind of machine and we tried to explain them as machines. But what Wiener and Rosenblueth showed was that if you wanted to understand the new self-controlling machines, you had to look at them as though they were men. They argued that the only way you could get to understand such machines was by considering their purposes.

Well, that was a shocking notion, because science was completely unprepared to deal with purposes. And it was at this point that the work of Singer and Sommerhoff was rediscovered and a gradual conversion was made to a new way of thinking about the world in which the concepts of purpose and freedom of choice could be dealt with objectively ands scientifically.

So these are three new ideas that have begun to emerge which have very important consequences, some of which we will look at in a moment. That's the software side. Meanwhile, what has happening on the hardware side ?

The Hardware Side – the mechanization of mental work

Interestingly enough, on the hardware side, there were three important things going on. We can think of them as an arch which is ultimately the bearer of the weight of a new age called the Systems Age. This arch consists of three stones and, like many building, it took a large number of years to build. Two stones were put in over a hundred years ago, but we couldn't put the weight on top until somebody came up with the keystone and dropped it in the middle. That didn't occur until World War II.

Telegraph/ Telephone/ etc.,

Let's take a look at these three stones. The first of them was laid back in the middle of the 19th century, when a machine appeared that was completely different from any other machine previously developed. It was the telegraph, and it was quickly followed by an improvement called the telephone.

Think of the telephone for a moment. It has nothing to do with the transformation of matter from one form to another, or the conversion of matter into energy, or the conversion of energy from one form to another. It had nothing to do with physical work.

Yet nobody recognized that at the time. Because the telephone is a machine which transmits symbols. Now we have a word for the process of transmitting symbols – we call it communication. So what we have here is the emergence of machines that could communicate. The telephone was followed by the wireless, the wireless by radio, radio by television, and now we are on the verge of a whole new technology based on the laser.

But these were machines which were out of place. They were exploited, but they were conceptually out of place because they had nothing to do with physical work.

Instruments

At the same time, a second class of machine was appearing, which is the other side of this arch, that had the same characteristics. It was during this period that electricity began to emerge as a new source of power. And electricity had a characteristic which made it quite different from other forms of power. You couldn't look at a wire carrying electricity and tell how much was going through it, or what pressure was going through it, or what resistance it was meeting. We couldn't observe the properties of electricity, so we developed machines which could – and these were called instruments.

You are familiar with many instruments – just look in your automobile. You have an oil gauge, a speedometer, an odometer. These are all devices whose operations *generate symbols*. These are symbol-generating machines, but they generate a particular kind of symbol – a symbol which represents the properties of objects or events. So that the gas gauge, for example, tells you how much gasoline is in your tank.

A symbol which represents the property of an object or event is called a datum and, therefore, in contemporary language, these were data-generating machines. In psychological terms, we refer to the process of data generation as "observation".

Computers – the "thinking" machines

So these instruments were machines that could observe, but they did no physical work. They were around for a long time and nothing very much happened. But in 1944 an event occurred at Harvard, and independently two years later at the University of Pennsylvania a device was born called the ENIAC, which was the first electronic digital computer. This was the third big event – the keystone – because it was a machine which *manipulated symbols*. It did it in a very curious way; it manipulated symbols logically. It is for this reason that it is called a "thinking" machine or a "logic" machine.

If we put together these three technologies – and we never would have put them together until this time because we were preoccupied with taking things apart – if we put machines that can communicate by transmitting symbols from one place to another together with machines that can generate symbols and observe what is happening and with machines that can logically manipulate the data generated, then we have all the components necessary for what we call *mental work*.

Mental work is the manipulation of symbols, whereas physical work is the manipulation of matter. Therefore, what we have is a second – or post-industrial – revolution, which consists of the mechanization of mental work, which we have now come to call *automation*. And this is a revolution which is fundamentally different in kind from the one that preceded it. It is not merely an extension of the earlier revolution because it is the mechanization of something entirely different. It mechanizes what man does with his head rather than what he does with his body.

This then is the revolution I referred to in the beginning, which has arisen out of a change in three fundamental ideas, generated a whole new technology, and given rise to a whole new way of viewing the world. I would like finally to show you the consequences of this view of the world, and their implications in management.

Fundamental Issues of the Systems Age

Every age has what might be called its organizing problems, the fundamental problems which we perceive as a result of the way we look at the world. When we have a change of age, we have a change in the problems that we see as fundamental – and that has begun to occur. I am going to argue that we have begun to recognize four fundamental problems of the Systems Age., which we are still trying to treat with methods and techniques developed in the Machine Age, and that it is that dislocation which is producing our contemporary crises. So let me identify those four problems for you and show you how they come out of all of this

Issue 1: Looking at Problems as Interactive Sets

When management first began to be recognized as a profession, and we began to educate for it seriously, management was identified with the process of problem-solving, most notably in the writings of Herbert Simon. The case study method was developed at Harvard to develop skills in problem-solving. Later, training in scientific problem-solving began to push the case method aside a bit.

Two very startling things have occurred during the past few years as a result of the new view of the world. The first is the recognition that "problems" do not exist. Then, you say, what the hell does exist? What does this mean?

William James, the great American psychologist (brother of Henry James, the great American novelist) had observed at the end of the 19th century that people don't start a day's work with problems. He said what a person is confronted with at the beginning of the day is something he called a "great big buzzing confusion".

Now that's not a very good term, so his principal student, John Dewey, the great American philosopher, changed the term and, characteristically, made it incomprehensible. He called it "an indeterminate situation".

To simplify things, I am going to invent my own technical term for this thing because it is a little shorter, however obscure. I am going to call this thing a "*mess*". Then we say that what reality consists of is "messes", not "problems".

Now what is a problem? Let's take a mess for a moment, which is what you are confronted with in the morning when you come to work, and let's analyze it. Remember what analysis is – to take something apart. So, if we take a mess and we start to break it up into its components, what do we find that those parts are? The parts are problems. Therefore, a problem is a an abstraction obtained by analyzing a mess.

Then what is a mess? That's the significant thing – a mess is a system of problems.

The significance of this is that the traditional way of managing is to take a mess and to break it up into problems and solve each problem separately, with the assumption that the mess is solved if we solve each part of it. But remember Systems Principle #1: if you break a system into parts and make every part behave as effectively as possible, the whole will generally not behave as effectively as possible. Therefore, the solution to a mess does ***not*** consist of the sum of the solutions to the problems that make it up. And that is absolutely fundamental.

This has implications for the whole way that management approaches messes. These implications are basic and we have recognized them implicitly and unconsciously, but have not yet faced them consciously. If you look at the literature of management over the last ten years, you will discover a fundamental shift occurring. We don't talk about problem-solving anymore; we talk today about something called "planning" instead.

Planning is the effort to deal with the mess as a "system of problems". It is the attempt to solve a set of problems as interdependent and interactive. The only difficulty is that we don't know how to do it very well., and so problem #1 of the Systems Age is that we must develop improved capabilities for dealing with sets of interacting problems as sets.

We know today that, if you take a city and isolate a function like transportation, housing, health, or narcotics, and develop a program to improve that particular phase of the activity, the city as a whole will not improve. We have expended 25 years of effort to take the city apart and solve its problems in pieces, and one thing we now know is that the sum of the solutions of these pieces has not solved the problem of the city.

The same thing is true of a corporation. If you break a corporation up into marketing, production, research and development, engineering, finance, public relations, etc., and attempt to solve corporate problems by solving the parts and putting them together, you will not succeed. It can't be done.

We have to learn how to solve these problems as interactive sets and we have only begun to develop the necessary technology for doing so. We will succeed only when we give up on Machine Age thinking and political thinking. That is Problem #1 of the Systems Age.

Issue 2: Systems that Learn

Problem #2: Even if problems exists, solutions don't . At least if they do exist, they don't last very long and that is the critical point. The assumption of the Machine Age is that the world is essentially stable. Therefore, if you have a problem, you go to work and solve it, then you leave it and go onto another problem. One of the great shocks that the operations researcher and the management scientist ran into was that they'd go into a corporation, take on a big problem, come up with a brilliant solution, apply it, and there would be noticeable improvement. Then they would go off to solve another problem.

Two years later, they come back to see how the old solution is doing, and find out that it has disappeared. And for a damn good reason. For if the old solution were still there, the company would probably go bankrupt. Why?

Let's look at the assumption that used to be made and represent it as follows: suppose we drew a graph on which we plot time across the bottom and the quality of the solution down the

side. Now if you get a perfect solution to a problem, we called it the optimum. Everybody wanted the optimum solution.

But what actually happens is that, if you got an optimum solution, the system that had the problem and its environment changed, so that this solution deteriorated over time. It started to get worse and worse. It simply was not being modified to take changing conditions into account. We finally began to realize that it would be a hell of a lot better to start with a less perfect solution that stayed constant, or preferably to get a solution that would ***improve*** as the situation changed.

So attention was turned from looking for the best solution at a moment in time to developing *processes* – not solutions – but processes which would assure the maintenance or improvement of solutions over time. And that involves two fundamental properties of mental work: the properties of *learning* and *adaptation*.

- To learn is to improve effectiveness under constant conditions – as in "to learn from experience". By repetition, you become better under unchanging conditions.
- To adapt is to maintain or improve effectiveness under changing conditions

Therefore, the second fundamental problem of the Systems Age has become: how do we design systems which will learn and adapt, not how do we design systems which will find short-term optimal solutions. Because if that is all that we can do, they won't stay optimal very long.

This has a fundamental impact on management. Because management itself is a system. It is a sub-system which is responsible to control the larger system of which it is a part. We can show that, for management to succeed, it must be a sub-system which can learn and adapt effectively. Why? Well, that is what Alvin Toffler's book *Future Shock* is all about.

Toffler points out what is apparent to most of us, that the rate of change has been increasing so that, for example, if I consider the greatest speed at which I could travel when I was a child – about 75 miles an hour – and compare it to the speed at which I can travel today, that change is greater than the change in the speed of travel in all of history that preceded us. Furthermore, the same thing will be true for our children.

This fact – that the time between changes decreases and the magnitude of change increases – has an important consequence. It denies one of the basic aphorisms or our culture. Experience is *not* the best teacher, it is not even a good teacher. It is too slow, too imprecise and too ambiguous. We must substitute another way of learning for experience, a way which is faster and more precise, and we have one. It is called *experimentation*. We have to design systems that learn and adapt through experiment, because experimentation is faster, more precise and less ambiguous. We have to design systems which are managed experimentally, as opposed to experientially. That is Problem #2.

Issue 3: Organization and Purpose

Problem #3: the corporation, like all systems, was looked at for many years as though it were a machine, and a machine had two fundamental properties. First, it has no purposes of its own; it

is an instrument which is used to serve the purposes of someone else. The hammer is an instrument which serves the carpenter's purposes; it has no purposes of its own.

As long as we looked at a corporation as a machine, the first basic question was: whose instrument is it? The Machine Age answer was clearly that it is the instrument of the owners, the people who own the stock or who own the company outright. And the function of the company was to provide these investors with a return on their investment.

That Machine Age concept of a corporation has another significant aspect – if the machine has no purposes, neither do its parts. Therefore, we took the parts of the corporation – the managers, laborers, staff and everybody else – and treated them as though they were parts of a machine, as though they too were purposeless.

You may say, "My God, we knew that people had purposes, even back in the early days of the Industrial Revolution." Right, we did know, But our concept of the employment contract was that when you, as an individual, agreed to go to work for a corporation, in return for money received, you agreed to withdraw the relevance of your personal purposes from the consideration of the corporation. You agreed to act as though you were a part of the machine and to let it treat you as such. That was part of the employment contract. It didn't have to give a damn about your interests. That was part of what you were being paid for.

That point of view was a successful one, as long as two conditions were satisfied. The first was the existence of economic scarcity – it was hard to find a job, and those were the only conditions under which you *could* work. The second condition was that most workers were relatively uneducated.

In the period from 1875, when the First Industrial Revolution began, through the next half-century, both these conditions were reversed. We became an affluent nation with welfare provisions, so that very few people had to worry about outright starvation, and we educated even the workers. The consequence was that the productivity of labor began to flatten off after fifty years and by World War II had started to drop. The output per dollar spent on labor (not per dollar spent on capital) began to come down. Something had obviously begun to happen to labor.

At that point we began to revise our concept of an organization, because biology was the emerging science. We devised a new equation: organization is equal to organism. An organism is different from a machine in that it has a purpose of its own, but its parts don't. Its parts have functions, but no purposes.

When we looked at an organization as an organism, it was quite natural that we saw as its principal purpose a biological purpose – survival. The fundamental purpose of a corporation is to survive, and the means for that survival are making a profit and a return on investment.

Under the new concept, the corporation has a life of its own. It became a legal individual, but the new concept had no effect on the corporation's perception of the purposes of its parts. That didn't occur until World War II when another new equation emerged: organization is equal to organization.

What then is an organization? It is a unique kind of system. It is a system which has a purpose of its own; which consists of parts that have purposes of their own; and is itself part of a larger

system which has purposes of its own. Thus a corporation has purposes; it has parts with purposes; and it is part of an economy or society which has purposes.

We are now being forced to think of it as such, because there is a worldwide revolution going on called the ”revolution for participatory democracy”, in which the parts of systems are insisting on the right to participate in decisions which affect the behavior of the parts. It is the emergence of a concept of dignity and self-fulfillment on the part of the purposeful elements of systems. The race problem, women's lib, the youth movement, the Catholic movement in Ireland, are all manifestations of people insisting on their right to participate.

For five years, we have been working with a self-development group in a large black ghetto in Philadelphia, which has an extremely informative motto – “Plan or be Planned For”. It says it is better to plan ineffectively for yourself than be effectively planned for by someone else

There is a new value system that arises out of acknowledging the purposefulness of the elements, and it gives rise to Problem #3: the humanization problem

That problem is simply: “how can an organization effectively serve the purposes of its parts and in so doing serve its own purposes more effectively?” Any corporation can serve its employees and go out of business in the process. That is no problem. The problem of contemporary managers of corporations and society is how to serve the purposes of the employees or citizens and still have the corporation or society thrive. We don't know how to do that yet. And if we don't learn, our corporations may very well not survive.

Issue 4: Organizations and Their Environment

Problem #4 – the last – is the converse of #3. Just as a system consist of elements which have purposes, it is itself an element of a larger system that has a purpose, the system called “society”. We have come to recognize two wonderful things: what this system does affects society, and vice versa. The corporation has an impact on its environment, and the environment has an impact on the corporation – and these two aspects are interrelated.

In the past we believed that a corporation was sufficiently decoupled from its environment that it was not the corporation's concern how it affected the environment. We have now come to recognize that what you do to the environment affects what it does to you. We have recognized that through two principal social movements, one called ecology and the other called consumerism. These are demands by your environment that you take into account the effect of what you are doing to it.

The fourth problem, therefore, is the environmentalization problem: how can an organization effectively serve the larger system of which it is a part and, in so doing, better serve its own purposes? Again, it is easy to serve the environment if you are willing to go bankrupt. The problem arises when you try to do it while maintaining corporate viability.

In conclusion

There you have the four problems. What I am arguing today is that all the apparent problems that management confronts are manifestations of these four or some combination of them.

- First, how do you deal with sets of problems interactively, not independently?

- Second, how do you design organizations which will learn and adapt more effectively, under conditions of increasingly rapid change?
- Third, how do you manage organizations so as to better serve the purposes of their parts and, in so doing, serve the organization more effectively?
- Fourth, how do you better manage so as to serve the purposes of the society of which the organization is a part and, in so doing, better serve the purposes of the organization?

Selected comments from the Q&A period

Question: To what degree do you feel that industrial managers know that this new world of yours is going on?

Answer: It varies tremendously, just as it does among academics. I recently spent a little time thinking about how to classify organizations with respect to their attitudes toward this concept of the future, and I've settled on four attitudes. Let me give you their names first. It took me a long time to get a good set of names which satisfied my poetic requirements. The first group I will call "inactive", the second group "reactive", the third group "inactive", and the fourth group "interactive".

Let me describe those four attitudes and you can decide which you have. The Inactivist believes that this is already the best possible world, like Lagnetts, Candide and Voltaire. Therefore, my intervention can only make it worse. So his motto is "Don't rock the boat, let things alone, let nature take its course. Ultimately what appears to be a difficulty will smooth out." So the principal function of inactivist management is to keep people's hands off.

Now the fact is that when a culture is moving up to an accelerated rate of development, that is a very good policy. The most recent example of it, I think, would have been Eisenhower's administration, which was essentially an inactivist administration – do nothing, and if the times are right you will thrive, and if they are wrong you will die.

The Reactivist is a person who believes that while this isn't the best possible world, it is satisfactory. He is willing to settle for it as it is, and doesn't want to change it. It could be improves, but it's good enough. Therefore, his posture toward the future is "Don't do anything unless you have to."

So he reacts to problems when they reach crisis stage but no sooner, because he believes that if you let most problems mature they will fade away. They will solve themselves. It is only when there is no alternative that you take action and when you do, you analyze the situation to find out what has happened to make this situation different from what it used to be. Then you take out what is new and go back to a previous state.

Therefore, the reactivist is always trying to return to a previous state that didn't have the current cause of difficulty. For example, f you get too much pollution in the city, you say "What is the principal cause" If you decide it's automobiles – get rid of automobiles. That is the reactivist's solution.

Too much solid waste? Get rid of one-way containers. The solution is always remove, eliminate, repress – go back to the previous state.

The third type, the Preactivist, is a guy who believes that the future presents both problems and opportunities and whether we develop or go back depends on how well we can forecast what is going to happen and how well we take advantage of it.

Unlike the Reactivist, who believes that you only direct your effort at curing problems, the Preactivist believes that you try to do two things: You ***prevent*** a problem; you attempt to predict what is going to happen, and hen avoid having to face it. You ***predict*** opportunities and exploit them by acting early. So he does intervene in the future, but he intervenes preactively in a sense that he does not believe that you can control the future – what you ***can*** control is the effect the future will have on you.

You can't control the economy or the political situation or the environment, but you can control its effect on you by taking action early to avoid problems and exploit opportunities. So he is the first one of these four that does anything that you would recognize significantly as planning.

The motto of the Reactivist is "Wait and see". The motto of the Preactivist is "Predict and prepare". And the motto of the Interactivist is "Make it happen".

The interactivist believes that most of what will happen in the future depends on what we do between now and then, and not on what has happened before. Therefore, his fundamental posture is that you must decide what kind of a future you want, and then you must do everything in your power to bring it about; that you do not merely anticipate the problems and opportunities, but create them. He is an interventionist in the future.

Now these are four different attitudes. The dominant one in US industry today is reactivist. There are very few inactive corporations. There are, however, many inactive institutions, the best example of which is the American university. Its predominant policy is "Do nothing, and if you wait long enough things will go away." Unfortunately, the students won't.

The more technologically advanced companies, especially since World War II, have begun to move towards preactive policies. To cite a few examples, Xerox and IBM would be instances of companies which have moved from reactive to preactive management. We have only a few instances of corporations that have taken interactive postures, but hey are increasing every day.

Question: How about some examples of interactive activity?

Answer: Let's say a company looks at the problem of urban congestion, and the way it would be affected by it, both with respect to its product and its people getting to work. Should it relocate outside the center, in the suburbs ?

It started out by saying "What is the nature of this problem?" It is primarily a problem that arises from the increased use of the automobile. So it sat down and asked the following question: "Suppose population in the United States continues to grow as is forecast by the Census Bureau, and the number of automobiles per capita continues to increase as it has since World War II." Then it asks "How many streets and highways are we going to have to build in cites to maintain the 1960 level of congestion for the predicted growth in the use of automobiles?" The answer turned out to be 55,00 miles of new streets and highways.

Then the question "How much will that cost?" Using conservative estimates, the costs of building those streets and highways turned out to be $18.9 billion a year until 1985.Now the largest amount the United States has ever spent on streets and highways is $1.4 billion a year. This is more than 12 times that amount, so that is not likely.

Furthermore, if the government did do that, 115% of the surface of the city would be covered by streets and highways. Therefore the company knows that the current system must go through a fundamental change – it is inevitable. *What* change it must go through is not obvious, however.

So the company says "What are the business opportunities that this is going to create?"

By analyzing the alternative of getting out of *that* hole it designed a whole new business to go into, which would be profitable to the corporation and help solve a fundamental social problem. That is interactive thinking.

Question: Do you think history is irrelevant?

Answer: No, of course not. You always have a great deal to learn from history, but you cannot just extrapolate the past into the future, because such extrapolation always assumes a mechanistic concept of the universe. We were talking at breakfast this morning about *The Limits to Growth*, and the whole work of Jay Forrester at MIT. People were saying "what is wrong with it, if anything?" Those of you who have read it can see that it is a mechanistic view of the universe. It projects a view of the universe 100 years from now, based on extrapolations from the past.

Now here is an interesting thing: the only way you can predict the future accurately is if the laws which will hold in the future are identical with those which have held in the past. Now if those laws actually hold, then you can't do anything about the future. That's an interesting paradox.

In the mechanistic view of the world, the only conditions under which you can predict accurately are conditions under which you can't do anything it. So what the hell good does it do to predict?

On the other hand, If you can do something about the future, who cares about predicting/? What you are concerned with is what you can make of it, not what it is going to be. If there us any one major preoccupation of management which is dictated by Machine Age thinking, it is the conviction that "If we only had good forecasts we could manage effectively."

And the answer to that is that if you had good forecasts, you couldn't mange effectively.

Question: What effect does the systems approach *have* ***on the concepts of centralization and decentralization?***

Answer: The issue of centralization and decentralization becomes irrelevant in this Systems Age. It is a Machine Age concept. It no longer is a problem, although it is hard to show why this is so. Let me try with an example. Fundamental to our culture is the distinction between science and humanities. The big problem, as CP. Snow puts it, is how do you get these two things back together again. The answer is, they were never apart.

There is a big difference between how we conceptualize things and how they are. You can talk about the head and tail of a coin as though they were separate things. You can *look* at them separately, but *try* to separate them. We confuse our way of talking about things with the thing itself. Now, humanities and science are exactly like that; they are the head and tail of a coin. What is "science"? Science is the search for similarities among things that area apparently different. What is "humanities"? IT is a search for differences among things that are apparently similar.

Now you cannot do wither without the other. Why? Given a problem, there are two things you must know. One is "How is the problem similar to previous problems I've experienced, so I can use what I've learned before?" Right? But if that is all I did, I would not solve the problem. Why? Because every situation is unique.

I must also know what is different about this situation from any that preceded it, so I know what I have to learn before I can solve this problem. There are two aspects and solutions to every problem. What I have already learned that is relevant – that is science's contribution. What do I yet have to learn – that is the contribution of the humanities. Without both, you can't solve the problem. They are simply two aspects of the same thing that are inseparable.

If you start to look at centralization and decentralization – you find exactly the same thing. In every system there is both centralization and decentralization. Every time you centralize something more, you will decentralize something else. The question is not to centralize or decentralize., but what do you move up and down? So it is not a question of centralization. It is a question of what decision is made where.

I realize that isn't a complete answer. I'm just trying to indicate the tone of an answer because decentralization is so completely embedded in our thinking that it is very difficult to dispel it. You have to actually sit down and demonstrate that in every instance of so-called decentralization, you have been centralizing like hell at the same time, and vice versa. The only difference between centralization and decentralization is whether you are looking at the head or the tail of the coin.

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