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AUTOMATIC CONTROL TECHNIQUES IN INDUSTRY

10 February 1953

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GENERAL GREELEY: I believe that if you asked the American industrialists and businessmen what they wanted most from our economy, the answer would be unlimited markets, the means to produce more things better and cheaper, and freedom to bring these things about in the best way they know how.

These desires are strong and insistent. It is important to our country that they remain so, because the constant effort to attain them accounts to a very large degree for our strength and our leading position in this uneasy world.

Markets, production techniques, free enterprise are really parts of a concept. One is not more important than another. Rather they are mutually supporting.

Today our attention will be centered on production techniques. Our speaker will tell us something about mass production but, more important, he will discuss the science of mass production of the future. It has been called automation; cybernetics. What is it? I doubt that very many of us here know.

Dr. Wiener, a leading world authority on automatic control techniques, is here today to tell us about it. It is a great pleasure, Dr. Wiener, to present you to this college and to welcome you to this platform.

DR. WIENER: Sir, I thank you. I am going to depart rather widely from the plan that I had written out in advance. I am going to concentrate at the beginning on how I came to be interested in this field, because it will tell a good deal about the nature of it.

During the war I was working on antiaircraft predictors, and before the war I had been in touch with Dr. Bush on various sorts of computing machines. At that time it became clear that the analogue computing machines, which was most exciting before the war, was coming to the end of its resources--perhaps not the absolute end. It was clear that the devices (we called them analogue devices--in which we set up a problem like the one we wanted to solve but could be hitched together by a sort of super set of mechano-parts) were an inadequate approach to some problems; also, the old-fashioned sort of desk computing machine in which we deal with mathematics by working with numbers and not quantities was going to have a great deal of importance in the future.

But it also became clear that the type of desk machine we had thought of for years--it depended on gear teeth, on accurate machining, on working on the scale of ten--had become pretty primitive already. We began to see the following things: That gear teeth were simply a way of making a choice among ten possibilities; that when we added two numbers we combined their digits in such a way as to get new digits from them--or when we multiplied two numbers. In doing this we were doing too complicated a job. There was no reason for making a choice among ten numbers when we could make a choice between two, and the easiest way of making a choice between two quantities was the electric circuit which could be on or off.

The arithmetic in which we chose between two things instead of between ten things already existed. It became clear that by exploiting the much greater rapidity of electronic and electrical devices through competition with mechanical devices we could take great steps in computing machines. That is actually the type of fast computing machines you are hearing so much about nowadays.

Why use these extremely expensive and elaborate machines for doing the work? What advantage do they have? I want to say right at the beginning that we ourselves are computing machines; that the elements of our nervous system are switching devices, not purely electrical, but for all that choice devices; that the individual nerve fiber can exist in two states--either firing or nonfiring. Indeed nerve fibers are put together in such a way that if certain of them fire, others will fire. They are extremely closely analogous to these computing machines that are being made.

Why don't we do arithmetic in our heads? Why don't we use our brain as a computing machine? Why do we use an electronic computing machine? What advantages has it? I will tell you some advantages it does not have. No computing machine begins to approach the human brain in complexity. Let me say that the individual choice-making unit in the human brain is probably something like one hundred thousand times less in volume than the best machine we hope to make. It means that to get the same degree of complexity you have to have something one hundred thousand times as big.

So computing machines are not chosen instead of doing things in one's head; they are far less effective. They are chosen for one good reason: They are enormously faster in making the individual choices than the nervous system is. The nervous system is not too slow a mechanism; but compared with the computing machine it is very slow.

Now, if we are using our computing machines because of their speed instead of doing things in our heads, one thing is clear--we have to use that speed; and that means that we cannot in our high-speed computing machines delay the machine by putting in data by hand and removing it

by hand. If you have a complicated machine made by a succession of parts, (a) of one speed and (b) of another speed, the speed of the total machine is much nearer the slowest speed. The result is that the moment the high-speed computing machine came in, it proved to be necessary that its programming--that the way in which data were taken up by the machine, combined, and used by the machine--would have to be at the same high speed as the rest of the machine. The machine developed two phases: (1) a phase for handling numbers and (2) a phase in which it handled programming, and in which it tested what operation should come after what, by a certain taping, at extremely high speed.

I am bringing this in to say that the moment this thing came to pass the automatic factory was essentially here; because, if you can accomplish the task of high-speed programming by automatic machinery for computing, you can also accomplish the task of high-speed programming of one operation after another for running a factory. The problems are very similar. The techniques for solving them are very much the same. Even identical numbers can be used in one and in the other.

That's the reason that immediately after the Second World War, when high-speed computing machines were coming in, it became equally apparent to me that the automatic factory was around the corner. This is a very common thing in invention. Inventions do not go by straight paths. The idea we have that we set ourselves a problem today and solve it and are content with it, and that this is the way inventions are made, is a false picture of the thing in many cases. In many cases inventions are made in a fog long before we have the means to cary them out. When we find we have the means to carry them out, we find we have made a lot of incidental inventions that we haven't realized we were making.

I would class the automatic factory as an incidental invention already implicit in the high-speed computing machine. Let me give two examples of inventions which depended on other inventions for their main idea: Television was discussed in a book which I read as early as the beginning of the century when I was a child. At that time the photoelectric cell, did not exist and the nearest equivalent to it, the selenium cell was so beastly slow it could not keep up with the needs of the apparatus. When that was invented, a whole lot of knowledge that already existed came to be useful for television.

Similarly, the idea of an automatic factory probably could have existed long before the hign-speed computing machine; but the moment the techniques of the high-speed computing machine, depending on the vacuum tube, were properly developed, then the automatic factory was bound to come.

Now, I want to point out the situation in which knowing this fact left me. With the automatic factory coming, it was clear to me that this would be a second industrial revolution and it had the makings in it of a social revolution; mainly, because the typical repetitive job of factory labor, the sort of thing that could be covered by the work Taylor and Gilbreth did,

the scheduling of one movement after another, could be transferred to the scheduling of one operation of a machine after another. Then a very large sector of our labor front becomes untenable.

What we shall have done is to make a slave machine which is at our command. It will make no commands of its own; it will replace ordinary factory labor for a large part of its work. Now, we may say this is not the moral connotation of the slave. That is true, so long as we don't make it so; but there is this thing: Any labor which competes on an even basis with slave labor must accept the terms of slave labor.

In other words, there is the making in this of great unemployment; there is the making in this of possible economic disaster--as well as the possible making of great good, of great expansion of production.

I tried to get organized labor interested in it at the time but was not successful. Later I have been successful in getting people like Walter Reuther interested in it, and at the same time I have been successful in such talks as I gave at the Society of Mechanical Engineers early in December in getting the management people interested in it, and I think they see very closely eye to eye as to the problems--namely, we cannot continue to value the laborer for what he can earn at a pure, simple, repetitive task in competition with the machine and make it so he can't earn anything, and then expect to get out of it without headaches. It means that we must reconsider very seriously what we are going to value human beings for. Obviously we can't value them for a job that we deprive them of the privilege of doing.

Well, the first thing I want to say is that since we have come to the base idea of the automatic factory, the automatic factory has come in. It has not come all over the field, not as a general way of replacing assembly lines, although it is beginning to come there; but particularly in continuous process engineering, and in such places as the chemical industry. A related field which has already come to it is the oil cracking industry. Such places are dangerous; you want as few people around as possible. Besides general repair and cleaning up jobs, the jobs of these people are to read gages and turn on valves of heaters on the strength of reading those gages.

But there is no reason at all why the gage reading could not be done automatically and why the gages cannot be used to turn on the various valves and other parts according to previously arranged schedules. Not only can that be done but it is being done.

Here I want to bring in, in connection with the automatic factory and in connection with the computing machine, the idea of feedback. Since I am talking to a military group, I am going to present feedback in military terms. Feedback is the engineers' word for reconnaissance; for not only

occasional reconnaissance, but for a process of continual reconnaissance, on the basis of which the action is adjusted or changed. In the good old days of military doctrine before the First World War, your Army marched with a point and with all advance guard, and so on. These were there for feeling-out, and were meant to be driven in by the enemy, to show what the enemy was trying to do, so that we could come to grips with him. On the basis of this continual information we were able to act intelligently.

Now notice that this is not confined to military strategy. When we drive a car we drive it by a continual reconnaissance. When we hold the wheel, we do not drive according to a pattern. Say we are going through a right angle; we shall turn the wheel so many degrees and after such and such a time turn it back. Try that and you will be in trouble with the pavement and with a policeman before you know it. What we do if we find ourselves going to the pavement is turn into the middle of the street; if we find ourselves trying to cross the line in the middle of the street, we go back toward the pavement. In other words, we correct errors as they occur. Error itself is fed back into the machine as a correction.

I lift this piece of paper. What sort of commands do I give through my muscles? I can tell you this much--there is not an anatomist alive who could do that by specifying which muscles he would ask to act and in what order. That is not the way we do it. You want to pick the paper up; you move in such a way as to reduce the amount by which you have still to move in picking up the paper. That is a negative feedback, but negative feedbacks are quite as possible to make mechanically as they are to make humanly or militarily; and you can control machine work by negative feedback.

If a certain batch of material is getting too hot, you turn off the heater. You can make the thermometer itself work a relay that turns off the heater. By the way, the body is full of processes of that sort which we call hemostats to keep our temperature as it should be. Our chemical internal environment can go wrong and we have disease. It ought to be familiar to you that such machines can have diseases, too.

To show you how the feedbacks move in another field: There is in my house an old-fashioned thermostat for regulating the heat. The architects used bad judgment in putting it in the living room, which has a fireplace. Whenever we light a fire in the fireplace, we cool the house; it turns off the thermostat. This will illustrate the behavior of a negative feedback process.

By the way, I want to point out that under military circumstances, a field where reconnaissance is most essential in the cases, where there is no feedback, we are likely to find ourselves in dangerous and difficult situations. That is where the weakness of the Sunday punch is. I think the classical case is the gas in the First World War as used by the Germans. Because the whole action depended on the surprise element, the only sort of reconnaissance that was possible was the imaginative medium of what it

might be. After reconnaissance became possible, the effect of the weapon was much less, and part of its inability to produce victory in the war was due to the fact that its use wasn't tied in with any practicable feedback process.

Without going into detail, I want to point out that the atomic bomb type of weapon shares those disadvantages. If, for example, you get to the point of poisoning the whole air, you will know it too late to do anything about it. One-shot weapons don't combine well with reconnaissance and are exceedingly dangerous for everybody. They are guns which kick almost as much with the butts as they do with the bullet. They require extremely intelligent and careful use.

Well, to go back then to the automatic factory, if it is coming in, it depends on feedback processes. At present we are not using these instruments to anything like their real possible extent. I want to point out the possibility of what you can call a second order feedback which is being considered very seriously by people like Grey Walter and W. R. Ashby in England, and which may in 5 or 10 years come into the industrial field. The ordinary feedback of a machine makes it search for quantities that represent the difference between its performance and the desired performance. It affects the numerical data. But it is thought possible to build a machine in which the difference between policies and desired policies is also subject to a feedback--in other words, machines which can learn and can modify their behavior according to the success or failure of their policies. Indeed they learn at a very low level compared with the mind, but still they learn.

Ashby has been studying the possibility that a machine may in that way absorb more information from the outside by learning processes than has been put into the machine in its actual construction. The machine itself is not only given instructions but is coupled with the outer world; and while very few machines as yet made do learn more than is put in at the beginning, there is no contradiction in supposing that future machines are possible.

I want to go directly to the point of how all of this may affect us in another war. If we are faced with another full-size world war, there will be two things I think are obvious as maximum needs. We will need the biggest enlisted force we have ever had and we will need the biggest production we have ever had; and these two pull in opposite directions. We will need more material and more men. To get more men we will have to withdraw men from making material. Therefore, the automatic factory for the assembly line as well as for the chemical plant will be very high in the order of priorities for the next war. You know better the way it will be than I do. I have no information, secret or otherwise, here. I am talking from my common sense. I cannot conceive another war coming without automatization. I hate the word "automation." Automatization will be one of the chief demands of the next war, as radar was in the last war.

You know how fast radar was developed from its beginnings to an ordinary tool in two years and to a dominating tool in three or four years. It was developed by turning a massive body of men on it. You can't successfully turn a massive body of men on a problem where the main ideas have not already been laid out; but the main ideas have been laid out on automatization. There are men you need for this work and many will be found among the men who were trained in radar in the last war. The same need or forced development that created radar in the last war in my opinion would work; I am giving you a guess, not an estimate. We should see in two years a very substantial development of automatization, and in four years a large amount of actual equipment and a large use of it in our industry.

Now, suppose this is the case. You know how hard it is to attend to anything but essentials in time of war--by essentials I mean the essentials of the fighting. You know reforms don't get made in the midst of the fighting; they have to wait, unless they are carefully anticipated in advance. You know also how easy it would be, if the know-how is there, and a large surplus of apparatus is there, for people to go in for a quickie world war, by taking certain sectors of industry and turning them automatic, with a large production, quite irrespective of the general effect on the life of the country. When that happens, there will be a lot of men coming home for jobs that will not exist. That is a situation with disastrous possibilities.

I therefore say most emphatically that, in considering the automatic factory and its introduction in time of war, it is important for you to pay attention to the disorganization it can make socially and to take measures to provide for things in advance--at least to know what measures you will want to recommend when the time comes. Otherwise the thing is explosive and dangerous. I believe that a great deal of good could come from the automatic factory. I think we can have greater leisure than we ever had. I think we can get rid of some of the most disagreeable sorts of slavery that have existed, which is slavery of a dull, repetitive job.

I am not worried about the consequences of the automatic factory; but in any engineering change there are two types of phenomena that occur: (1) steady state phenomena, when the thing is running and (2) transients, when you are getting it to run. Those of you who are engineers will know that transients can wreck a system quite as thoroughly as steady state changes can. If you try to switch in a badly designed electrical system, while it might run perfectly if you ever get it to run, you may keep blowing your circuit breakers every time getting it to start, of if you don't blow your circuit breakers, you may burn it out.

Do you know the story of the Quebec bridge that sank into the St. Lawrence? What happened? If the bridge had ever been finally erected, it would have stayed erect; but less care was taken in studying the transient strains of erection than in studying the steady state strains of the bridge as erected.

The automatic factory is going to introduce serious social disturbances. The time to consider those is now when we have peace. It may be a shaky peace--but is peace--when people are able, as you people are here to come and think of things of that sort. We must avoid making the machine not only our servant but our god. We must avoid the psychology which says that because the machine does certain tasks more efficiently than we do we are all for the machine and against man.

You won't see that, but there is a strong temptation for the gadgeteer to overworship his gadget. It is ridiculous, but it exists. We must find some way of cushioning the change to the automatic factory if it should come suddenly. I am not worried if it comes slowly, but if it comes suddenly, under war pressure, we must find some way of cushioning it so as to avoid what is most serious and catastrophic.

I haven't given you directions how to make the automatic factory. I haven't made one in my life. All I claim in connection with this is what I see in the existence of high-speed switching apparatus. I see not only that it would lead to rapid computation, but that the programming would be an essential part of that computation. I see that high-speed programming would immediately spurt up beyond the computing machine and the automatic factory, and there are people who judge that I have been right.

I don't say, "Damn the automatic factory." I say that it is a powerful agent in changing society and that every powerful drug is a powerful poison if it is used with ill advice.

I thank you.

COLONEL KLEFF: Professor Wiener is going to take on your questions.

QUESTION: I have seen, in trying to figure out how these computing machines work, where you give instructions on a tape and the amounts given would be to go to position 100 and pick the number up and add it to the position at 103, or compare it, and so on. It seems to me you have so much instruction on the tape it would be easier to put the problem on a calculating machine. Can you explain how that is done?

DR. WIENER: I think I can. In the first place, take the work of Taylor or Gilbreth, it amounts to the very same thing as wielding a tape. They say slide and shift--you take it to this position, move it to that position, and so on (indicating). A whole lot of work done in a factory could be done by the Taylor-Gilbreth method. If it can be done that way, things can be written out on a tape and given to the machine.

If you once cover a job by motion analysis, then you have already essentially taped it. All you need is a slight modification of that technique to get a job the machine can do. The whole problem of motion analysis was already converged toward the automatic machine.

COMMENT: It is not so much the question where you have a repetitive process or where you are working out some complicated problem as where it is a one-shot affair. How can you tell that machine what to do so it will work out the equation?

DR. WIENER: The whole importance of this is alternates. You don't know in advance what contingencies you will get, but you give some information, such as, if such and such a thing comes up, go over to tape number 5 and work from that point on; if such and such a thing comes up, go to tape number 3 and work from that point on. In that way you essentially assemble a complicated system of instructions by using different numbers, different tapes, as they come up. It is not simply a one-way reading; you have contingencies provided for. You don't simply say, "Do this; then do this; then do this." You have whole sequences of contingencies provided for. When you consider the combinations of these pieces, they are so much richer than the single tape it amounts to having tapes a thousand or a million times as big. In other words, when you take a large number of things, the number of combinations goes up much more rapidly than the number of things. So I think that is the way you arrive at it.

QUESTION: You spoke of programming. I wonder if you would comment on the application of this programming idea to the problem of the Department of Defense, where we are trying to relate 3.7 million men to bases, operations, dollars, and things.

DR. WIENER: Well, what I really would like to say there is that the various concepts of programming, of organization, of information are not confined to the machine; neither are they confined to the machine and the individual man. The same sort of problems come up in handling human organizations. It is precisely because of the parallelism of these problems, however, that you do get programming problems there. However, your programming may be done by hand--typed by a secretary--rather than on the machine.

I found it necessary to invent a word for the whole group of theories that fit together, "cybernetics,"--for the problem of control in the animal, man, the machine, and also in society. I calculated details on it. I don't know--I myself am not a good programmer. But the problems of laying out lines of orders, lines of authority is a large scale parallel of the computing machine or the control machine problem, and the general theory, the theory of measuring information, the fact that an order, that a command, is related to information--these things are equally true in those systems as in the purely mechanical systems. That is why I had to coin the word "cybernetics," which I took from the Greek word meaning the art of the steersman.

You are quite right; the whole question of programming in bases can have a lot of light thrown on it from the similar programming of machines.

QUESTION: Professor, you have made a very good case for being concerned over the rapid automatization of factories, but don't you think actually that we are almost in that state of revolution right now?

DR. WIENER: We are; and the thing that makes me feel less blue about it is that at such meetings as I attended in New York early in December when I talked before the Mechanical Engineers, I found that the administration people, the management people, are beginning to be aware of the dangers. These are dangers which exist, but which are somewhat less if you know they exist. The important thing is to realize that because we are in this revolution, our time to think out a policy is not unlimited. I don't claim that we cannot think out a policy. I never said that. I say we have not much time to think out a policy.

QUESTION: Sir, the history of our industrial progress has indicated that, as we have mechanized, rather than throwing men out of work, we have opened up numerous jobs which have put people to work on jobs. Why are we going to change the formula by going into automatic factories?

DR. WIENER: I said I am not worried about the steady state--I am worried about the transients. I am not worried that it cannot be done. I am worried that the final placing of people in industry is certainly something which will not occur at the right time to take care of the boys coming back for jobs. I may say this much. If you are going to go without anything to eat for one month, the fact that you are going to get ample food afterwards is not interesting. That is, provided the machine emergency is transient. If it is not, we couldn't handle them anyhow.

QUESTION: Dr. Wiener, would you care to go on a little further with this thing and, looking into the future, tell us what kind of environment and social order you think we might eventually fulfill when this thing has clicked?

DR. WIENER: I think there will have to be much dependence for jobs for the average man on farming and smaller distributing, which are places where automatization is not so suitable--although I will not say it will never come in farming. Your farming instruments are essentially instruments that have to observe; your weeding instruments must tell a weed from a useful plant, and so on. I think that is quite remote.

The other thing, I think, is that for the remaining industrial jobs there will have to be a grading up. Most of the new jobs will be maintenance jobs and repair jobs, which come very close to the edge of being junior engineering jobs. That is what the remaining crew in the automatic factory will be doing. Those can be graded up--they will have to be graded up.

The next thing is--I found this very interesting at the meeting in New York that people were realizing it--a greater evaluation of what people

can do in their leisure and of the value of leisure. Curiously enough, I found the hardheaded management people talking of what sounded to me like straight William Morris in that connection. In any case, the value of leisure and the use of leisure in a way that would be socially, if not individually, productive is an important thing in the future.

QUESTION: Professor, you have indicated that you fear perhaps this automatization might proceed so rapidly that it might be compared to a stroke of lightning in an electrical storm. Have you any indications you can point to on the rate of automatization during the last two or three years, or four or five years, that it is accelerating?

DR. WIENER: It is accelerating. But I am not talking about that. I am talking about what it will be when the realization has been made that it is a very necessary thing for war, in which case it would be completely changed. As to the matter of speed, the Atomic Energy Commission ought to be quite aware that it makes a great deal of difference whether there is a nuclear action occurring with the speed of an ordinary reactor, or that of an atomic bomb. I say that even if the cumulative reaction may dissipate itself after a while, your danger is in your transient. What makes the transient so dangerous is that the speed is increasing and can increase considerably more under straight economic pressure. Next, in case of a full-size war, the situation is entirely out of the economic field; the need for maximum production and at the same time for maximum manpower in the Army would push the thing, without any economic use for it under ordinary circumstances at all.

QUESTION: Doctor, has there been any application of these techniques to improving our prediction of the weather?

DR. WIENER: There have been new techniques on weather prediction. The use of automatic machines has been greatly increasing. I know that is Johnnie van Newmann's job. He has been working on that. I don't know the detail of it. There are very good men on it. There ought to be very good results. I am a little skeptical as to how far one can go on really good long-time predictions on weather with the very incomplete net of stations, compared with the extreme complexity of the air. I would not be surprised if a good deal of improvement could be made without reaching the very high degree of improvement that some people in the general public expect. But I don't want to say that dogmatically. I am interested in some techniques of my own that I think could be used; and I am convinced that in a meteorological prediction the contrast made between dynamic methods, statistical methods, and synoptic methods is wrong; that the methods finally used will make full use of the known dynamics of the air for determining what the important data are; but will nevertheless not be so complete we will not have to treat the remaining data statistically.

Furthermore, if there is a dynamics, the statistics will have to show it. In other words, I have a feeling--and I think we are probably over

the hump in that already--that the original quarrels and rivalries between the dynamic and the statistical schools represent for both of them very partial views of the thing. That is the nearest I can get to it. In both methods, statistical and dynamic, I am sure the computing machine will play a large role.

COLONEL BARNES: Professor, I am trying to visualize what one of these factories is going to look like after its face is lifted. I can't help but think that the processes that were formerly necessary will still be necessary; but, instead of a man standing in front of a machine, there will be a battery of panels with little blinking eyes, and once in a while they are going to go wrong.

DR. WIENER: They are, most certainly.

COLONEL BARNES: I am trying to visualize what kind of scientist or workman there will be, and where we are going to get him, to put him in the place of the fellow who used to stand in front of the machine.

DR. WIENER: You military people have had remarkable success in making remarkable electronics people out of ordinary soldiers and sailors. If the military can do it, it can be done in industry too. As a matter of fact, the people to do this job will come from the people you have trained in the Army and the Navy.

Now, the other thing is that I have seen one of these machines, the automatic lathe, and that records on tape the successive motions to be made. It is really not a lathe; it is a milling machine. It has turned out to be an excellent machine for what you might call semimass production, where you don't have the great mass of production to justify the specially made stamping machine or milling machine for the particular job, and where you must do the job better than you can by having it done by an individual worker. The tapes are easier to handle; they are more flexible; easier to keep up to date.

The next thing I want to say is that in good semiautomatization you do not try to duplicate the exact sequence of operations done by hand. It almost never is good technique in introducing a new engineering modality to imitate the old. Without going into detail, I want to give a historical item that is very interesting. When the electric motors came in, in the 1870's and 1880's, what is it that the factory did with them first? They replaced the original steam engine source of power by a big electric motor worked by the power company, which was the wrong way of doing things. What we do now is, we put individual, small motors in each machine, to get the flexibility that way. The point is, the introduction of electricity was first taken as simply a way of buying power from the power company, using the small millwright techniques. Now; so, the old millwright technique is no longer proper and the individual motor is the proper technique. This is given as a lesson.

When you introduce a new medium in industry, the first idea is to use it exactly as the modality you have replaced. That is almost never the right way in the long run. You must always devise your technique, not according to what has been best in the past, but according to what your machine will do best.

QUESTION: Professor, it appears to me that we have an atomic safety device field in the atomic safety program. It has been pointed out that the production line end product war machine is not a suitable line to satisfy peacetime economy. Won't that cost the Government a lot?

DR. WIENER: It will if we finally come to the catastrophe. The point is the production line, if producing war machines with new techniques, still may not be an equally satisfactory production line for the devices of peace. It may be better than what we have had until we find the production line for the devices of peace. In other words, if it is the best thing we have, and it is better than anything else, the fact that it still will be replaced later on won't prevent the immediate crisis.

COMMENT: Is there an analogy to the cutting edge in the factory? My understanding of the military machine is that the men actually in combat are a very small proportion of the total. Isn't it true in factories that direct labor has to be multiplied by 200 or 300 percent of overhead? Aren't your fears pretty much confined only to the direct labor problem?

DR. WIENER: I wouldn't say so. I think there's a limitation--that what you say is true, but not complete. If I were to automatize a factory, I would do much more than affect the over-all labor. In other words, the proper place for doing your cost accounting, for doing a whole lot of record work, is by devices attached directly to the working machinery. The business machine end of the thing is as much a part of the factory machine as the machine actually making the wheels go around.

QUESTION: What effect would the cost of tooling up to this kind of production have on the speed?

DR. WIENER: As you know, when things are done for a war, everyone thinks if it is done for a war it must be on an emergency basis; and it becomes essentially cost plus. If similiar measures are taken because our national survival depends on a production that can be obtained only that way, the effect of the cost would be very little. In the long run, cost might be a very important factor. But as you know, the people who use government equipment after the war get it for a fraction of its cost. That is the history of the past. So the impact of the restriction of cost would not be immediate.

I have every reason to believe that the automatic computing machine and the automatic control machine are getting and are going to get smaller and smaller and cheaper and cheaper for the same functions. Originally one

was talking in terms of millions and hundreds of thousands of dollars. Obviously those are down to tens of thousands now.

In other words, the expense of the automatic brain of a factory is not determined by developing the level of expense for a single model. The real expense, and where the really difficult work has to be done, is where you go over to automatic hands. I can't give prices. I don't know them; but I think after a certain state you will find that all prices here go explosively downhill.

If, for example, the transistors, which are showing a lot of bugs now, come through as reliable, reputable elements in circuits, where you don't have to look for the precision point, all expenses will go down explosively, because the elements are much steadier in the long run and will be cheaper than vacuum tubes; and the bulk will be cut down, the heating will be cut down, the amount of switching wastage will be cut down, the auxiliary apparatus will be cut down; and prices may go downhill explosively.

QUESTION: In connection with automatization, we have so many million people in agriculture, so many million in the services, industries, transportation.

DR. WIENER: And the service industries are still not being automatized.

QUESTION: We have certain industries ideally situated in mass production to adopt this system. In terms of immediate war, in enlarging the armed services, in releasing labor to increase the Army, Navy, and Air Force, roughly, how many people are we talking about?

DR. WIENER: I don't know. I give a guess that we are talking about something like 10 million people; I might say 25 million. We are not talking about 150 million. We are talking about some of the most critical sectors of industry. It certainly is not a total thing, nor anywhere near total.

As to the question of automatic machinery in agriculture, I don't think it is near and I don't think it is expected. An agricultural machine for picking cotton must essentially be able to discriminate between cotton and waste. For that it needs sense organs. It needs feedback in the way that any industrial machine does. The difficulty is to get a machine you can carry around behind a tractor that won't be jolted to pieces and be light enough to carry. It is a long job. I don't see it immediately. I do see it coming ultimately, particularly if the lighter and steadier machines and less brittle machines come in.

QUESTION: So far as the absorption of a greater number of these people in agriculture is concerned, are we not already at a point where agriculture is having great difficulty in employing all the people who

would like to be in that line of work already. The number of people employed on farms is going down already. We are already producing more than we can eat in this country.

DR. WIENER: In other words, it would mean something like subsistence farming. I don't say susbistence farming is impossible. It would mean an evaluation of the individual and what he earns no longer as a competitor to individuals but as an individual. Part of the bad name subsistence farming gets is not socially inevitable.

QUESTION: Won't chemistry come in and attack agriculture? From a chemical view, you mentioned cotton. Why do we need cotton? You mentioned foodstuffs. How about something artificially created?

DR. WIENER: I say that is possible in textiles. It is coming in. I have never seen anything that has all the qualities of wool; although the movie "The Man in the White Suit" was technically an accurate job and is being used at MIT in our textile courses.

The bottleneck in synthetic foodstuffs is the engineering need for synthetizing not so much the sugars as the amino acids. It may come. There are ways of doing it, which go through living organisms. Synthetic foodstuffs are in the future, but rather more remote than the automatic factory.

QUESTION: Is this revolution in cybernetics taking place in other parts of the world?

DR. WIENER: It is, definitely.

QUESTION: Will you comment on that, sir?

DR. WIENER: Yes, in the first place, the French have just as much interest in this as we have. The English have as much, too. Mr. Bronowski of the English Coal Board has lectured on the science--he and his group are interested in it. I will tell you something that has come to my notice recently. The mathematics which I used for my prediction theory during the war I thought I had started all by myself. I found that some very similar and closely related work had been done by a Russian named Kolmogoroff just before that. I have never been in touch with Kolmogoroff, but I have run into his work all the time. He and I have been chasing each other in the matter of ideas for 30 years. He is an extremely good mathematician.

By the way, as to the publication of my work, I want to say that my government document was released and published through MIT, and with the Government's permission. Through a friend of mine who reviews books for the mathematical reviews, I saw a Russian book on essentially the same theory; this book was to be used in connection with the automatic factory,

and was based on Kolmogoroff's study even more than on my study. This Russian book gave credit to my work--my published work, for that is all the Russians have seen.

The point I want to make is, I have been called all sorts of things in the Russian press periodically, such as a cigar smoking slave of the industrialists, or something of the sort; but in the scientific job, though they gave a lot of credit to their own man, a good deal of which was deserved, they still gave me credit, gave reference to my work. That means they are working on it. This has come to me through legitimate channels of knowledge.

I have also heard rumors that they are working on the automatic factory in Russia.

Leaving Russia aside, I think the more important repercussions we get are from places like China and India; namely, it may be possible to go through this second industrial revolution of decision without going through the first industrial revolution of energy, of power, in such a way that less damage will be done to existing social structures, say village structures and so on, than has been found in countries which have had to learn these things the hard way.

That is a common experience: that it is not only the first country to industrialize, but the last, which has the advantage. As we have seen many times, the first country to industrialize often has the burden of primitive methods and the capitalization of primitive methods, which may interfere with it.

I am thinking of English railroads. They have too small loading gages. To reconstruct the British technical system by modern criteria would be out of the question. Therefore, the newer country to come in, in some respects has the advantage.

I turn to South America. It is avoiding the railroad era entirely by going to the airplane era. I don't regard it as ridiculous to suppose there will be places in the world where the second revolution of the automatic factory occurs before or simultaneously with the first revolution of industrial power.

QUESTION: Professor, I am bothered by what you have just said now. In talking about automatization in India, China, and places like that, essentially, it seems to me, it is a problem of capital versus labor costs. Where countries have the cost of labor so low in comparison with capital, how can it pay them to go into extreme capitalization?

DR. WIENER: It may be because of the tremendous social degradation that occurs with the standard type of industrialization in places like

India. Bombay, I am told, is as bad as Lancashire was. There may be social ends to achieve which demand industrialization, but the large scale shed factory is not the ideal mode of work, and under certain social conditions it can be disastrous. I am not saying that this is always the case. I am saying there can be motives other than the immediate economic motive operating there, and that the introduction of factory life on a broken down village system can be catastrophic. I am suggesting this; I am not saying it will come. I am suggesting that we may not expect that the automic factory will always be introduced from the same motives in all the places.

COLONEL KLEFF: Professor, you were talking to me this morning about the interest of your subject in France. I think the students would be interested in hearing about it.

DR. WIENER: I don't need to tell you that cybernetics has some importance on the technique of controlled missiles. Now in France there is a very close cybernetics group which has its meetings at the École Militaire in Paris. The people in it are largely general staff officers who are working on controlled missiles. One of the very interesting members who is not from the services is Father Dubarle, a Dominican Friar, who is closely associated with it. Other people who are very much interested in this sort of thing are the communications people, the telegraph and telephone people.

In the Netherlands the Phillips people are interested in this. There is a good deal of interest on the part of psychologists and psychiatrists, both on the continent and in England, as well as here. Now, as the analogy between the brain and the computing machine bears on the structure and functions of the nervous system, I would say the cybernetic interest is pretty general.

There is a meeting on this subject taking place in England this summer. I won't be able to go over, but a good many of them are coming to various meetings of physiologists in Canada and electroencephalographers in Boston. I expect to see them this summer.

I know in Mexico I did some of my first work with Dr. Rosenbleuth. He is Chief of the Laboratories at the Instituto Nacional de Cardiologia. There is a good deal of interest in the subject in Latin America. I also found a good deal of interest in the subject in Spain. There is a Journal of Cybernetics in Spain. I was there for one series of talks. I found the atmosphere too restricted; I won't go again. But the people as individuals were very interested in my field.

COLONEL KLEFF: Professor Wiener has agreed to stay over this afternoon. Those of us in Areas 35 and 36 will have a seminary in Room 275. Others who do not have seminars but who will be interested may attend. Professor, on behalf of all of us, I thank you for a most interesting lecture.

(18 Mar 1953--750)S/sgh