MANAGEMENT CONTROLS IN INDUSTRIAL PRODUCTION

Mr. H. Ford Dickie

NOTICE

This lecture has not been edited by the speaker. It has been reproduced directly from the reporter's notes for the students and faculty for reference and study purposes.

No direct quotations are to be made either in written reports or in oral presentations based on this unedited copy.

Reviewed by: Colonel Thomas C. Keach, USAF

Date: 27 January 1960

INDUSTRIAL COLLEGE OF THE ARMED FORCES

WASHINGTON, D. C.

1959-1960

MANAGEMENT CONTROLS IN INDUSTRIAL PRODUCTION

6 January 1960

CONTENTS

	Page
INTRODUCTION--Captain I. F. Fike, USN, Member of the Faculty, ICAF	1
SPEAKER--------Mr. H. Ford Dickie, Manager, Production Control, Manufacturing Services Division, General Electric Company	1
GENERAL DISCUSSION	29

NOTICE

This lecture has not been edited by the speaker. It has been reproduced directly from the reporter's notes for the students and faculty for reference and study purposes.

No direct quotations are to be made either in written reports or in oral presentations based on this unedited copy.

Reviewed by Colonel Thomas C. Keach, USAF, 27 January 1960.

Reporter: Grace R. O'Toole

Publication Number L60-102

INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington 25, D. C.

MANAGEMENT CONTROLS IN INDUSTRIAL PRODUCTION

6 January 1960

CAPTAIN FIKE: Good morning, Gentlemen. The current highly competitive situation in both our domestic market and abroad dictates a most efficient handling of our industrial production in this country.

In recent years technological advances have made possible greatly improved management techniques. Our lecture this morning will outline a system which encompasses several of these modern developments.

We are very fortunate to have with us this morning as our guest lecturer a man, veritably an expert, who has spent almost his entire adult life in this field of study and work. His company, General Electric, has also been a leader in this field of advanced management and production methodology for many years.

It is a great honor for me to present for his second lecture to the College Mr. H. Ford Dickie, Manager, Production Control, Manufacturing Services Division, General Electric Company, who will speak on Management Controls in Industrial Production.

Mr. Dickie.

MR. DICKIE: Thank you, Captain Fike. Gentlemen: I hope my voice holds out today. I might be whispering in the mike before I get

through.

I decided at the last minute that I would start off by telling you the punch line of this discussion before going into the details. We'll have slides when we get into the details, so, even if that isn't interesting, at least it will be restful.

It was just a year ago this very month that the members of my little organization--part of them are pure research people--had the opportunity to make a presentation to the functional officers of General Electric--vice president, manufacturing, engineering, comptroller, and so forth. I thought you would be interested in that demonstration. Briefly, it went like this: We handed to the member of the audience who was sitting in the front row--just as if a group or a dozen of you were gathered around, a small group--a typical General Electric requisition order form, and suggested that he order an instrument. As you might guess, there was considerable prompting as to what he should order. He started out to order a watt meter and, before he got through, as I recall, he ordered a volt meter. He was going to order a single-phase one and they suggested that it be a three-phase one. He said, "Well, I presume we just check 60 cycles," and somebody said, "Hell, no; let's make it 45 cycles and see what they can do with that." So we went on down the line. And, as you have guessed, there was indeed ordered a special instrument that had never been designed before and that had never been produced before.

This hand-written requisition form then was handed to an IBM key-punch operator. The girl punched out a few cards. The few cards then were put into a large-scale digital computer. Incidentally, to be true and factual about this, this was put in with 99 orders, because the reasonable maximum number that this department ever received in a day was 100 orders. So we were in effect giving the computer a full day's orders for that department, which is the instrument department of General Electric, as you may have guessed.

In a few minutes there started to be printed out a number of different things, and we will talk about those a little later. But among other things came out one group of punched cards, and, if the machines were capable, we wouldn't have had to have this human intervention, but they are not set up this way at the present time. But those cards were simply put into a punched card to punched tape converter.

So I hope you won't consider this human intervention. I'd like to consider it not that but inadequacies of the machines today. Tape was produced. Punched tape was handed to our boss as President in Charge of Manufacturing. We walked across the street to the manufacturing laboratory. The punched tape he put in a tape reader, which directed a machine tool. I wouldn't call it a milling machine or a drilling machine or a boring machine. It does a sort of combination of all these things, like a new Milwaukee pneumatics, if any of you are acquainted with them . That machine proceeded to produce the main

frame, which is very complicated. It holds both ends of the armature, has considerable precision, and has about 30 machining operations on it. It also produced the base, which has all of the other components--the chokes, the resistors, and the mounting--for the entire device, as well as leads and what not off the back. It proceeded to produce that piece also, completely automatically.

So, in a matter of minutes, there had been done inside a computer the engineering, the drafting, if there was such--and the question we were talking to the Captain about on the way down was, some insist that of course you need drawings, and my question is: If you have no one operating the machine, who is going to read the drawings?--and if it was still required, the manufacturing engineering, which is the detailed operational planning of how the parts will be made, the quality control standard, the production control schedule, the costing, and, in this case, the operation of the machine, all completely automatically, to produce for the first time a device that has never been designed, never been manufactured, before.

So now, as I said, you know the whole story. But let's go back and look a little at the background. Possibly the greatest challenge to General Electric, and to much of American industry, is finding an answer to the new competition from abroad, an answer that does not destroy the living standards that we have worked so hard to achieve, an answer that does not permit attrition of our industrial strength, which

is so vital to our national security. Yet, how can we compete? Does the answer have to lie in higher tariff walls or sharp import quotas?

During the past four years we have worked intensively on three more positive ways of establishing industrial leadership. The first was innovation. We have to provide the amount of research required to develop new products and to introduce these new products rapidly and efficiently so as to maintain our competitive position. Next we must give prompt and reliable delivery of high-quality products, offering customer-oriented features backed up by dependable, economic field service. But most important, we must reestablish cost leadership. The only logical way to do this is through increased productivity, which means fewer direct and indirect labor hours per unit of product. This increased productivity comes not from sweat-shop techniques but from designing a product with producibility in mind, from best shop layouts, from best methods, from using the most modern factory office equipment, and, particularly, from the thing I want to talk about today--planned, integrated, automated systems.

Recent figures on industrial productivity show how slowly we have improved since World War II. The average increase in productivity per year since 1950 has been approximately 2 percent. In contrast, Germany has increased its productivity by more than 5 percent per year in the same period. Nineteen fifty-eight was the first good omen, when U. S. productivity increased by over 6 percent, this in spite of a

significant reduction in industrial output.

It was an analysis of these data that caused General Electric Services Organization--staff, I think, would be more familiar to you--to attempt the design of an advanced automatic system, one that would be able to respond more efficiently and more economically to incoming customers' orders. This program we named the Integrated Systems Project, or the initials you will see, I.S.P., and certain general objectives were established.

The first one--the new system should be economically practical and technically feasible, and, in a company such as ours, it must be broadly applicable to as many departments as possible.

The system should be multi-functionally integrated and provide a close linkage between the office and the factory.

It should be designed with every attempt at bold innovation in order to break the historically accepted business system patterns. We must blast, not pit.

We hope through research to develop new concepts and tools for use in designing such systems.

We hope to develop new criteria for technically and economically sound approaches to automation that would help us to determine what particular new techniques should be used in specific businesses.

We wanted to provide a foundation for future General Electric progress through research and development.

To pick an initial area for this exploration, we analyzed some of the current weaknesses of industrial systems, which I am sure you will all recognize. Typically, we have very poor manufacturing cycles and inventory turnovers. Delivery cycles are quite long, very long compared with the product costs. This is particularly true of manufacturing cycles in relation to the actual processing time, and the work-in-process inventories are correspondingly excessive. Indirect labor costs are increasing steadily. Many factories even joke about the fact that you can't make a shipment until the paper weighs as much as the product.

A third area is the high redundancy of information used in our factory paper work. For example, on a line of shafts used by a very successful motor manufacturer, it was found that some 300 different drawings, such as the one in this slide, had been prepared over the course of two years to take care of each minor variation in the shaft as it was required. On each of these drawings there were some 60 or 70 fields of information. Of these fields, better than 80 percent were completely fixed. For every shaft, only 20 percent was truly variable. Yet we were making up a new drawing for every shaft. On this typical drawing, the completely redundant information is indicated in red.

With these and other significant problems in mind, we sought the areas of our industrial business systems that would have the greatest impact in these areas of opportunity. We call this heart of the business

process the main line system. Possibly a review of the steps included in this main line system will give you a clearer understanding of the particular scope of our project.

The present main line system starts with the customer's order. They all do. This specifies what the customer wants in functional terms, such as size, color, rating, and other product requirements. The typical order than goes through certain conventional steps which are shown in the left-hand column of this slide.

First it is edited, to eliminate ambiguities and to put the order in the proper, most usable, internal form. Then the order is engineered and drafting prepares the documents that are needed for the factory and others, namely, the blueprints, the bills of material, et cetera. Then, based on this design information, the manufacturing engineers then perform the operational planning, or how to make the product, and what time standards and wage rates should be for the various labor and machine operations.

Then, in a similar manner, the quality-control planning procedures are determined, establishing standards, methods, and frequency of quality analysis. Then, using the existing records and files, cost information is accumulated, compiled, and analyzed. Then production control takes over, to determine when the parts are needed, as well as how many are to be purchased and made. Typically, this includes the functions of customer promising, scheduling, and inventory control.

Finally, instructions, in the form of vouchers, purchase requests, et cetera, along with blueprints and other necessary papers, are transmitted to the factory to direct the manufacture of internally made components, or to purchase from outside for material procurement.

In each of these steps, information is taken from the previous function, typically in the form of written documents, and used to produce the next document or output with the aid of information reference files, shown in the left-hand column, which are, namely, material lists, blueprints, planning cards, quality records, cost card, et cetera, et cetera.

In short, the main line converts the customer's order into a finished product. Substantial amounts of money are involved in this main line system, as you will note in this slide. Normally, 100 percent of the direct labor and 100 percent of the direct material is tied up in the main line system. At least 50 percent of our indirect manufacturing expenses are in this area, 20 percent of our product engineering costs and expense, and 15 percent of our commercial and administrative expenses.

All of our productive raw and work-in-process inventories are in this category, as well as 80 percent of our plant and equipment investment. In total, this area probably accounts for 75 to 80 percent of our product costs, and a similar percent of our investment.

To perform a research and development job on these multi-functional problems, it was necessary to organize a multi-functional team, representing

the various business functions--engineering and accounting, as well as manufacturing. In this particular study marketing and employee relations were not included, simply because the particular system defined did not require their extensive contribution.

It was our belief that an ivory-tower approach would not provide an effective atmosphere for integrating systems' designed work, nor did it aid in selling the new concepts that were developed. What was needed was a real live business, a living laboratory. This selected operation had to be representative of the breadth of business in which General Electric engages, varying from lamp bulbs to large steam turbines and from silicons to guided missiles, and from fractional-powered motors to complex steel-mill controls.

Also, in picking a business, we wished to select one where the existing information was in sufficiently clear form to be readily usable. We looked for a business with a good, clear documentation, one with clean records, since we didn't wish to try automating a mess--which some people have tried to do, incidentally. We sought a well run business where we could concentrate on advanced development, rather than having to devote time to cleaning up existing problems. We also felt that, by tearing out our research in a particular business, the system's team would have its attention focused on specific, clearly defined problems rather than the more vague, imaginary difficulties. In this way the creative contributions were concentrated on the areas most needing

improvement.

After the multi-functional organization was completed, a clear and specific designed program was followed. The first stage was that of data-gathering. This involved getting all the facts concerning present inputs and outputs, volumes of devices, designed variations, manufacturing facilities, historical performance, et cetera. This took us approximately six months and led, obviously, to the second phase.

This was problem analysis. During problem analysis all the information gathered was digested, reviewed, and an effort made to determine clear cause and effects. It took us some time to decide the next point. We wanted to study the relationship between changing external conditions and changing internal performance.

The third phase of the program was that of preliminary system's design. This achieved a first verification of what may be truly called the basic system. This lasted approximately a month, and brought into play the efforts of not just the general system's designer but all specialists in the various areas.

The fourth phase , as you would guess, was that of detailed system's design. This refined the specifications in great detail. It clearly indicated those phases which needed to have their technological feasibility proven and those that had already been clearly demonstrated in previous work.

The fifth phase was that of construction of a prototype to demonstrate

applicability of the new ideas. It was, in the vernacular, a bread-board model. If I don't say that twice, it will be the first thing some one will ask about: How many departments are doing this? What I am talking about today is a bread-board model, the first prototypes people are starting to produce in departments themselves now. So this that I am talking about is not an operating departmental model.

The sixth, and final, phase of any program is that of testing, training, and evaluation. We have been able to test this bread-board model against a wide variety of circumstances and have found it very satisfactory. We have been carrying out our training program objective during the past 12 months, along with initial evaluations of potential savings. We have presented this talk and some detailed explanations, taking a couple of days, to over 2200 General Electric people.

Well, these are quite conventional steps. The important new concept was application of the system's approach to business systems' problems. This kind of technique Rand and similar organizations have devoted to your military system's problems.

With the system's approach, we treated the entire main line system as though it were a black box with only one transaction input, the customer's order, and with only a single basic output, the finished product. All that went on in between was subject to analysis and redesign. The system's approach was intended to design a new main line system. It provided us with an opportunity to completely ignore present techniques,

ignore all the present conventional, organizational, or functional divisions of work, and to concentrate, without inhibitions, on reconceiving the solution.

Incidentally, it took these people months--you've seen some of it here, I am sure--to forget the background--some of them engineers who spent 20 years in engineering--to forget about the function. It isn't what you need; it's what we need to produce that product on the end of the line.

The fundamental concept in carrying out this project was an idea of vertical integration. Integration is currently a byword, of course, but most new work has been concerned with automating common activities. We ask: "What do you hear about that has been automated?" "Oh, we've automated our payroll. We have automated our control of materiel, or inventories, or requisition processing across a total product line, or a whole business." This we have called horizontal integration. However, we are truly convinced that integration should follow lines of information flow. It should cut vertically through all functions in a product line. With this vertical integration, far broader opportunities for profits have become available. Why? By having all of the information processes linked together inside the computer it is quite unnecessary for each function to duplicate the other's files--which we do today under our most efficient systems.

For just one example--cost will no longer have to maintain independent

files of material lists, blueprints, planning records, and time standards for every part and assembly.

This elimination of file redundancy will be felt in many indirect labor activities and will offer opportunities for substantial time and cost reduction. Further, vertical integration of effort also has a major effect on reducing the information and physical processing time. Since all of the decision-making logic to completely process an order is in the computer, it is reasonable to expect overnight data processing. By having dynamic control of the whole physical process, from purchasing through parts-making and assembly, it is possible to reduce significantly the actual make cycle.

This type of control should result in much lower inventories, higher promises kept, and better labor efficiency.

A second principle is the need for discovering a pattern of logic, and this we have done, which formally displays and relates the various decisions that are made in product design, facilities operation, factory scheduling, et cetera. In manufacturing planning, for example, by focusing attention on each variation in method, or elemental time standard, you can spotlight cause-and-effect relationships and thereby make improvements. Organizing the multitude of detail into a clear, easy-to-understand framework shows what design characteristics control the various manufacturing process elements, making clear the simplification and standardization opportunities.

The use of logical decision patterns in a business should reduce direct labor and direct material through the powerful analytical insights they make possible. I could tell you stories all day about the clarity and understanding of the product that engineering has had to gain in order to think clearly enough to put these things down in the logical form that the computer can handle.

What we needed to do was to create bold, advanced, oriented computer techniques, to create a system oriented to the computer rather than what we had been doing, unimaginatively programing the computer to follow the human work pattern. It was certainly not true that computers should be programed to do the work the way the humans have done it in the past, and yet that's the way 99 percent of our computerizing has been done to date. Like the old horseless carriage--what did we do? We took the carriage and sneaked the motor in underneath. Unimaginative. But now I think we're beyond that. We must have the system designed with the computer in mind. Although computers and humans perform many of the same tasks, their relative efficiencies and economical advantages are radically different. To arbitrarily make the computer follow the same routines, the same steps, the same processes as humans is entirely illogical. Rather, the basic system should be reconceived and redirected to obtain maximum performance from the electronic computer equipment.

There is also quite an insight to think about the system/as being

directed solely toward the ultimate user, ignoring all the intermediate functional outputs that have so commonly become identified with our data-processing system. The only purpose of having any operating outputs from a system is to cause someone to take action, to cause a buyer to purchase materials, an operator to make parts. The intermediate transformations, and hence the intermediate outputs, are not essential system's elements but only a reflection of particular data-processing techniques that are currently in use.

The results of this type of work, I think, have been tremendously exciting. As I related at the opening, we can now automatically convert a customer's order into parts of an especially designed product, performing all of the main line system inside the computer. This automatically provides all of the factory's action documents. I mentioned only the tape output a minute ago. It automatically prints out purchase orders; it prints out machine operator instructions, where the machines are still operated by humans--and most of them are--quality instructions for the test and inspection people, punch paper tapes that I did mention, to run automatically controlled machines; it prints out promises to the customer, such as you folks, bills of material, stock order recommendations, withdrawal notices, from warehouse stock or stockrooms, shipping papers, et cetera.

As the result of this project, many new techniques were developed

to help the various General Electric departments design integrated automatic systems. For example, new techniques have been developed for decision analysis; new techniques have been conceived for part and product representation and identification; new ideas have been formulated for computer programing--radically new ways of programing the computer.

All of these concepts, taken together, have changed our viewpoint entirely as to the economic feasibility of installing integrated, automated business systems. We feel there are many benefits from these concepts. In order to clarify them, I should like to describe the nature of each function in the computer and some of the resultant benefits.

Very briefly--a determination of what to build is the key role of engineering. We believe that the requisition engineering activities can now be computed. I said "requisition engineering," incidentally--not the initial design engineering. This isn't designing the new computer; this is designing the motor. It's somewhat different from what we have made before, but it is in the broad realm of motors that we have already designed.

The computer can translate a customer's wants into specific details of the materials, parts, and assemblies needed to satisfy those wants. In addition, this computerized process can avoid the necessity of having to create many of the documents and records with which we have become too familiar. Outstanding savings can be realized in the

preparation of model lists, bills of material, blueprints, et cetera.

Included in the benefits from this engineering advance should be a substantially reduced engineering time and cost, through the elimination of many of the routine steps which humans now take. There should be less drafting expense, through eliminating many of the tasks which drafting has historically performed. A clear, logical statement of the engineering scope of a product line should make it easy to obtain an optimum level of standardization. A properly designed, computerized engineering system will be, contrary to what most people predicted, far easier to change and far more flexible. Too many think it disappeared into the big, black box and they'll never get their hands on it again. But the system we have is far easier to change and far easier to understand.

With knowledge of the product design details, manufacturing engineering is then in a position to do the operation planning and determine the best routing, work methods, and time standards for every part. We have found that much of this work on how to build the product can also be completely taken over by the computer. The possibility of automatically preparing accurate operational descriptions, coupled with correct time standards for every job, certainly has considerable appeal.

Another intriguing area is the communication of the computer with the numerically controlled machine tools. Through the medium of punched

tape which has been automatically produced, three new features should have wide application. First, there will be a single program tape for an automatic machine for the entire day. Second, machine parts are automatically identified. Third, computers are used to automatically generate the machine tool programs. Machine parts can be automatically identified. Parts processed on numerically controlled equipments are sometimes identified in a secondary manual operation. This can be avoided by introducing an identification step in the machine tool program. For example, parts can be identified with shop identification numbers by, say, spotting a shallow blind hole in a coated matrix on the part itself.

Among the other benefits is reduced planning time, since the computer takes over a former manual job. There would also be reduced planning costs, since computers can do this job for less money than humans can. And, probably more important, the best methods, more accurate planning, and consistent time standards should result because of the abilities of the computer to follow the exact instructions that you give it, without failure or error.

In order for quality control to plan for and carry out the evaluation and control of product quality, it must answer these questions: at what point to inspect or test the quality evaluation method, appropriate time standards, the frequency of evaluation, criteria for acceptance or rejection. Here again we found that a computer program could be

prepared which would perform all of these tasks automatically. This would in effect determine how to evaluate the product and its components. Included in the benefits are fewer quality corrections, through having the proper balance between quality failure and quality appraisal costs. There should be fewer complaints, through a careful analysis of customer's needs and production characteristics. There should certainly be lower quality costs, through the integrated planning of quality, along with engineering design and manufacturing operational planning.

Cost accounting offers us another opportunity. The object was to determine planned product costs for quotation work or for cost standards to be used for comparison with actual costs. We find again that cost standards can be automatically developed, and that the computer, properly programed, can also used to establish work-in-process inventory values. Through this cost work, we should be able to obtain better cost analyses far quicker, and by having all the facts at our fingertips when they are needed. It will be far easier to maintain up-to-date costs because of the potential simplicity of storing cost information. It would certainly mean reduced cost-determination expense through the use of the computer to replace human effort.

The next area of production or manufacturing control is particularly intriguing to us. Each of the previous steps in the computer portion of the integrated main line system have dealt with tangible product

characteristics--what to build, from engineering, how to build, from operational planning. In these we could test--this is the point--take the design in the computer build-up and see if we've got something like what the customer ordered. We've tested to see if the computer is right. But, in contrast, in production control, the final element of the computer program, it develops a fourth dimension for determining the time in sequence in which the main line activities take place. Production control is interested in when things happen. It has the responsibility for carrying out the right time, the data processing and the decision-making calculations necessary to support each function. Production control is concerned with the time interrelationships of all the customers' orders. It is responsible for economically satisfying those customer requirements, considering the actual status of the shop.

Manufacturing control provides the scheduled release of the factory action documents--the purchase orders, the punched tape for automatic machine programs, operator instructions to make and assemble parts, quality instructions, shipping papers for delivering the customer's product.

In this integrated system, the computer would daily schedule shop operations, specify operation release dates and due dates, specify specific order quantities, review inventory stock levels, and issue

customer promises. Orders will not be released prematurely.

The integrated main line system will have daily feed-back of completions for shop control. This information will be digested by the computer each night and recognized in the releases to be prepared for the following day. The parts to be started the next day will depend upon the exact status of each of the areas of the shop, whether they are behind schedule or ahead of schedule, what their status is on rush jobs, and related information.

The result is a flexible system, prepared to respond quickly and accurately to changes. Time delays in handling information are avoided and corrective actions can be initiated immediately through the integrated main line system.

Developing manufacturing control rules presents certain special problems. For example, the product performance can be proven in the laboratory. Operating time standards can be checked, say, with a stop-watch. But, how can we pretest a rule for customer promising? General Electric has been instrumental in applying simulation techniques to similar business problems involving many interdependent activities, that change with time.

I would like to ad lib here and say that the people who are now doing this simulation work for us in industry--and, if there is any subject I would rather talk about than this automation one today, it is what simulation is doing for us in our decision-making in industry--who are

doing fabulous work for us--just making improvements that are greater than we've made before in the decision-making area—most all of them, had their experience, their background, their practical education in military simulation. If you folks didn't have to look so closely at economic costs--you had to simulate nuclear warfare; it was pretty hard to go out and test it; so you had to simulate these things--and these folks have learned from this research of yours. Here's one place for sure we in industry bow to you in the military and say we thank you so much for developing a fundamental technique which is proving to be invaluable to us. In our office, in fact, we are spending more money on simulation work at this time than we are on this automation that we are talking about here--although this is very close behind it.

The heart of shop simulation is a computer model which realistically duplicates the behavior of the shop as it processes customers' orders, making allowances for setup and processing times, absenteeism, machine breakdowns, and the like.

The specific computer model developed for the integrated system's project compressed four months of shop experience into a 15-minute computer run. As a result, it was possible to test how well various proposed sets of production control rules would meet due dates and plan cycle times without actually trying them in the shop. In addition, inventory levels, employment stability, and man-machine utilization, could be clearly evaluated and compared, and could be understood. A series

of such tests provided the basis for estimating and selecting the integrated production control rules.

Integrated production control offers several benefits. For example, it seems quite practical to obtain a shorter main line information cycle, actually less than one day. Similarly, electronic computers can be expected to lower our paper-work costs. Shorter cycles in the office and factory, as well as improved scheduling techniques, will permit substantially lower inventories. These improvements should lead to shorter customer promises, much improved service, and potentially higher sales, until the competition catches up.

Of course, the only reason for all this information is to procure parts that are needed on schedule, at optimum cost, and to direct the machines and operators in the factory to transform the raw materials into the right finished parts at the right time. This leads directly to the concept of flexible factory automation.

Too many of us have said, "We put the computer in. It has one program. We have an automated factory. It's inflexible. It's fine if you are going to make Ford V-8 blocks right down the line all day long. That's automation. But, if you want to make different ones, you have to stick to your people." This is not true. In the physical processing system, rather than visualizing automation as a long line of highly specialized machines and transfer devices, as we think of in the automobile business, we believe, for our General Electric types of business, that the

important aspect of this type of automation will be the ability of machines to switch from one task to another at little or no extra cost. The inherent flexibility of the individual machine, or group of machines, will be a determining factor in the effectiveness and usefulness of these automatic systems' concepts.

With numerically controlled machines, such as are now available, the setup cost is generally reduced to practically zero. As those of you who have worked on inventory control problems will quickly recognize, this implies that an economic lot size can be reduced to one. Hence, flexible factory automation permits us to respond to the external customer-oriented requirements and not give such heavy consideration to the internal shop setup, finished stocks, and all this sort of thing.

Through this flexible factory automation, we believe that we will be able to lower direct labor costs per unit through replacing human activity, where desirable, with machine operations. Machine accuracy and setup flexibility will reduce both scrap and rework. Integrated planning and control, with the right tempo, will result in far shorter manufacturing cycles.

The future of integrated systems planning to me is an exciting one. But some of the problems which we face are certainly significant. I'd like to list just a couple of these, and the opportunities will give you some feeling for the scope of our future work.

Decentralization, which we have in General Electric, has many advantages. But one problem is the lack of suitable computer equipment. We used to have the big Schenectady Works, the big Lynn Works. I was just talking to the Captain here. I was at Jonesboro, Arkansas, and Murphreesboro, Tennessee, last week. These are where our plants are now. One problem is the lack of suitable computer equipment in these small areas for such massive data processing tasks. We discussed as one possible solution having a major business locate its plants on the periphery of a wheel whose hub was the plant headquarters. We have wondered about connecting these plants, through wire transmission, or microwave, or what have you, so that the information for decision-making could be fed to the hub for processing and the answers radiated back to the individual plants.

In new plant-location studies we have always given careful analysis to the size of the plant, the amount of labor, the amount of water available, and all this sort of thing--power supplies. However, now indirect labor exceeds direct labor in most of our businesses, and in all of industry. Now that the major improvement opportunities are available in the office or indirect labor end, the data processing part of it, why should not the economic availability of electronic data processing be an essential consideration in plant site location?

Also, we have become aware that, while we have concentrated on reducing our data processing operating costs, we have given inadequate

attention to the start-up and maintenance costs of our installations. Intensive research is required on ways to accelerate the installation of new systems and ways of reducing the cost of maintaining and modifying their programs. You folks in the military I know have talked a lot about this.

This compression of the innovation cycle can be a major factor in our ability to compete effectively in the future. I am sure all of you in the military clearly recognize the importance of reducing innovation time.

It has been our experience that, as the breadth of an application increases, the complexity of conceiving and installing a system grows somewhat like the square or even the cube of the number of functions involved. We must establish tools, techniques, and concepts for coping with this increasing system's complexity to allow our systems designers to get their mental arms around the problem.

As with any new development, there is, at least temporarily, a lack of experience and an acute shortage of competently trained systems designers. These men will have to be developed by the colleges and through on-the-job training courses. This implies the development of a body of knowledge to draw on so that systems design principles and tools can be properly taught. These systems designers must learn to extrapolate wisely from basic, fundamental ideas to develop the best system that should be installed at a given plant.

Returning to a problem mentioned earlier, we have to face up to organizing and educating for such broad system studies. Who, in a business organization, should be responsible for determining the need for such work? If that's the General Manager, who is responsible for carrying it out? Certainly he can't do it. Because of the multi-functional nature of the problem, how can effective cooperation be assured? Who will take the initiative? In General Electric there has been developed over the last 10 years a very clear concept of the work of the Manager and the work of the individual contributor. We have carefully defined the responsibilities of each individual function in the business--engineering, manufacturing, finance, and so forth. In this same way we must now analyze in detail the mortar that holds these bricks together. We must describe the kinds of people and the kinds of responsibilities that are required to constitute the most effective kind of mortar to hold these functions together. It is even conceivable in daily operating areas that the mortar might take over the whole operating responsibility, sort of like having a brick building with mortar in the interstices changing it in effect to a concrete building, which eliminates the individual bricks entirely.

Our evaluation of new systems is generally quite inadequate. I think we must devote substantial research effort to deriving and determining better measurements of business performance.

As you can see on the hotel stationery, I have a new ending. I

thought possibly the most significant thoughts that I could leave with you, rather than what is in the text here, would be a question or so. What are the implications of such a radical advance in industrial automation? Won't the operating functional daily folks, who do the daily job, won't the organizational lines, collapse? Can't manufacturing cyles and innovation times be cut to a fraction of their present unreasonable length? Won't broad bands of technical and clerical employees be displaced? Won't we have to quickly put this highly mechanized system under far greater control than the systems we have had, consisting primarily of humans? To me this means substantial research on new measures, far faster feed-back, and quicker correction. Won't industrial capacity investments be greatly increased? Won't our break-even points be raised? And, lastly, isn't it conceivable that our industrial capacity can be substantially increased?

Thank you.

COLONEL DAVIS: Gentlemen, before we start questions--you may have noticed that we have no visitors today, and the particular nature of this talk makes us request that you do not discuss the contents of it with possible competitors.

Would you like to elaborate on that, Mr. Dickie?

MR. DICKIE: Sure. We are in a competitive economy. I think we have a little jump on some of the boys who feel that's what every

house needs, and a few other things of this sort. Certainly it will leak out or they will figure it out themselves. But I would hate to have you rush home and tell your friends from Westinghouse, "Here's what General Electric is doing."

You know how the system operates. You have your own military secrecy, for exactly the same thing, in competing with some of the boys on the other side of the blue over here, and you are not anxious to have people run out and tell them, either. These things get out, slowly but surely. We work with large computer manufacturers. It's their equipment, in most all cases. They get the idea pretty soon of what we are doing. Things leak, but I am not anxious to go out and drill holes in the dike, at all.

QUESTION: There have been a number of articles lately on machines becoming so intelligent that, the first thing you know, they will be the master and man will be the slave. In fact, it has even been proposed that the only way to keep this from happening is to keep these machines from talking to each other, thereby not allowing them to organize. Some of these things seem to be written in a serious vein. I wonder if you would give us your opinion of articles of this type.

MR. DICKIE: Either they have far more imagination and understanding of the potential of computers than I have or they are wrong. From my point of view, and I think several of the folks in our office are as

competent in the computer area as anyone in the country, or relatively so, this is absolutely not true at all. I think that some of the people who may be displaced and have to find other positions may consider the computer an enemy of mankind.

GENERAL HOUSEMAN: May I bust in here? I think possibly what you are talking about might be a little more definitive, and might be answered more specifically. Some of these articles have brought up the fact that they have finally developed machines which can learn by experience and the machines can translate that experience back into new actions. Isn't that basically what you are talking about? That's the basic difference between an old automated machine and a human being or human intelligence.

MR. DICKIE: Let's put it this way. These humanistic tendencies that the General is speaking about are not inherent in the machine. The machine can do only what it is told. So you tell the machine: "You go back, and if this series of events has occured and this situation has developed, and, if the answer turns out to be larger than this, the next time you come to that decision, instead of taking the right road take the left road, because it will be safer and things will turn out to be less than you have rated as a problem." So these things are nothing more than an automated adding machine, with a memory, but for only what you put in them. They have absolutely no intelligence. They appear to have the intelligence because the people who are programing

these things and doing the kinds of things you are talking about, are probably as brilliant as any people in the country--chess players. The folks in the office are absolutely irate. I think it was the Times, about two months ago, stated that man is still more intelligent than the computer. Some fellow had taught the machine how to play chess. No, Carnegie Tech is working on chess. This was someone else. This was three-dimensional tit, tat, toe. That's exactly what it was. But he said he could still beat it, which showed that man was smarter than the machine. And yet, every step that that machine made was what was programed into it. All they said was, the fellow didn't take time enough to program that machine and show it all the things that actually occurred in the tit, tat, toe game, or they would have ended up probably in a tie.

QUESTION: This system obviously involves a very big capital investment for any particular line of product in proportion to the present investment, and in return you get a lower labor cost, I suppose. In this regard I am concerned over the inability to adapt a really radically new product. I can see where you can design a new transformer to do a new job while you make the transformer. But, let's say you find out how to make transistors and by this system of making radio tubes. There would be a great reluctance to shift over, it seems to me, because it's a big expense, and you have to be darn sure of it. Could you talk about that?

MR. DICKIE: Yes. If you were changing from regular, conventional

electronic tubes over to transistors, the design of these in the computer would be easier, I believe, than it would be under manual systems. The equipment in the factor, indeed, today or tomorrow, is expensive and difficult to change over. We generally haven't changed over a tube plant. We've set up a new plant to build transistors. I think most other people have, too. They are relatively similar devices. I mean there isn't a diversity of sizes. They go down generally roughly the same line. You start a new factory and it's a new process. Today's level of automation makes changing from tubes to transistors expensive.

Let's say we changed over just a conventional electronic tube. The changing of the design of that tube is far easier, changing the basic design, which the engineer still will do, because he he has had to think so very clearly about this design that he can tell it to someone who is stupid, like me, and I can program the stupider computer. He has to think so clearly and lay this out so logically that now it is very simple.

There is one thing that I haven't mentioned that I suspect you might have thought about. That is, when we can cut the manufacturing cycle as much as we do, we also cut the work-in-process inventories a great deal. We can cut our finished goods inventories. You say, "I want a volt meter of such and such." I'll say, "Fine. We'll have it on your dock Monday morning." You say, "O.K." This is what we've had to

tell you before this kind of system was introduced: "Well, let's see. We don't carry that in stock, so it will be about a month." You'd say, "Oh, no. I'm sorry. I have to have that right away." You didn't plan on having it this afternoon, like coffee or something, but Monday would be about right. We would have to take it off the shelf and wrap it and bill it and do the usual paper work. So you would accept it for next Monday. We can now produce it and deliver it to you next Monday. We don't have to carry finished-goods inventories.

So, though our capital requirements under this sort of system are going to be somewhat increased, they won't be increased greatly, because work-in-process inventories will be decreased because these things go through the shop so much faster. Our delivery times will be so much shorter that the finished-goods inventories will be reduced. Also, by convention, the large data-processing equipment manufacturers, IBM, particularly, as you know, primarily lease their equipment. So again, the investment in this equipment is low.

In a couple of cases that we have studied, the total dollars required in this sort of business have not been greatly increased. The reduced inventories pretty well offset it.

But you are right. The factor, equipment, itself, when you change radically from tubes to transistors, certainly means a big expense. You see this in the automobile industry--new bodies, new dies. If they change over to make them of plastic tomorrow, it will take a lot more money.

QUESTION: In the past several weeks we have been hearing a lot about how American industry is pricing itself out of business. I, for one, am delighted to see that General Electric Company has not lost the ingenuity of American business. However, how much is this ingenuity going to be affected by the labor unions, particularly in view of what happened Monday of this week? I am wondering whether the labor unions are going to control your future insofar as automation is concerned.

MR. DICKIE: I am not an employee-relations person, and I would be the poorest one in the world to fill such a job. I'm afraid basically I'm a mechanic at heart. They certainly are an awful drag to us when we are trying to innovate. They certainly cause us all kinds of headaches and problems. I think on the other hand that they keep some of us who maybe don't have adequate humanistic interests basically in our minds from being too ruthless. I am afraid I would introduce something new and throw half of our draftsmen out of work and say, "That's someone else's problem. Let the chips fall where they may." Well, a lot of the draftsmen are organized these days, and I am sure that we will do this thing very carefully over a long period of time.

Certainly it's going to be a real deterrent. On the competition that you speak about, yes. I have suggested--and this has nothing to do with General Electric—on a number of occasions that the study teams that many industries have now--many businesses have them--consider how we meet foreign competition and what we do about it. I have suggested

that the most vocal and thoughtful, if possible, of the union people be put on these study teams. Let them see what one awful tough, knotty problem this is.

On the other hand, in the innovation area, I take courage once in a while. I take trips all the time. I don't know why this one impressed me so. But I did go to Jonesboro and Murphreesboro. Here is a plant where we are competing with foreign motors. These are little--you know--vacuum cleaner motors, fan motors, and things of this sort. Here is a plant laid out to produce 35,000 motors a week. It's producing 62,000 motors a week and they are looking for more space. Why? There are foreign motors all over the market. These are the cheap and dirty little ones, if you know what I mean. But here's a motor that you just about recognize as a motor, if you are born and raised in the business. This, again, please don't take to the Westinghouse boys. They'll be able to buy these on the market pretty soon. It will be quite a revelation for them.

I hope most of you can picture a motor. It's a stack of punchings for the stator, a stack of punchings on a shaft for the rotor, end shields to hold the bearings, a wrapper around that stator, and the end shields are machined to fit on so that you get precise alinement of that rotor inside the stator. There are steps on the shaft so that you can press it into the punchings. Obviously it can't be big on both ends or you can't get the punchings in the middle. Usually you have a step so that the

punchings push up against it. I don't know how well I can describe this and short-cut it in a minute or two.

Oh, yes, and all the windings are put in the stator. You have all sorts of, let's call it, paper of the press-board type insulation in there. They make their punchings and then they ceramic-coat the sides of those punchings. The temperature limits that you previously had were based upon this paper starting to char and losing its insulation qualities. You've seen the old motor smoke when you did something wrong or when it did something wrong. This is no longer the case. At the present time the copper starts to run. This is its problem. Really. Of course, before long the bearings get too hot, but this takes time. You overload it right at the time, and the copper starts to deform and sag. This is a pretty nice temperature to be able to operate in.

So, number one, the paper insulation is all gone and we have a new ceramic insulation which is sort of, let's say, painted on. Actually, it's a very fancy extrusion process. You put it up through there. This also cements the punchings together. We used to take these punchings and rivet them together. When you rivet them in a couple places they tend to buckle on either side. So then we welded them down the side, and this in effect smears the punchings together and your core loss goes up. So now we have these punchings all insulated with a very high-temperature insulation which takes up a very small amount of space.

So we've got a smaller device--less iron. Then we put our windings

in on a machine that goes about four times as fast as the fastest machine we had before. Then, before, the windings were always taped by hand to hold them in place. Now they are automatically held and go through a new resin dip. When you get through you could drive nails with the windings. It's all set up perfectly solid. The breakdown between turns has been practically nothing, because you have not only the insulation on the wire but all this other stuff by capillary attractions going in to fill all these little spaces.

Instead of having this wrapper that is machined on to the end and an end shield fitted precisely to it to hold an air gap of say five or ten thousandths, the end shield is not a machined casting or a die casting; it's made on a punch press--just chug, chug, chug, chug, chug. These are end shields. The end shield, then, has about ten thousandths' clearance. It's dropped on this stator. It's located in a very expensive fixture. Then some of this new molecular cement is put in around it. When you get through, you actually distort and tear the metal, tear it apart. But it is located properly and cemented together. There's no machining. There's no wrapper on the stator at all.

We had a problem, you know, getting the shaft right, if it was too tight when we pressed it into the rotor and tended to distort the punchings. We now have one that's run continuously through a centerless grinder, so it in fact has bearing surfaces the full length of it. And we drop it in. It's a thousandth or a half a thousandth too small for

the punching hole in the rotor. We cement that in also.

We end up with a motor, now, that is being most favorably considered by a number of vacuum cleaner manufacturers. We thought we never could compete with them, because they always bought cheap motors. We are selling these motors to the folks who sell the fans in the drug stores, who have up to now been buying foreign motors.

So my point is, if we can be ingenious enough, and if we can keep a step ahead of the other folks, I think we've got a good fighting chance. Now, in some areas we have used our ingenuity and we are not meeting foreign competition--the transistor radio business. I don't know what the answer is. There are some short-range answers, sure. Take our designs and our specifications, and let them produce them, and bring them over here and sell them through GE outlets. We save our marketing group, but we put the folks in the factory out of work, and, when the folks in the factory are out of work in our factory, they are apt to be in other factories, so who's going to buy the transistor radios? So it's a short-range solution. I don't know what the long-range solution is. But certainly, the continuous, bitter fight in inflationary trends--shorter working hours, featherbedding, and limitation of output, and resistance to automation and mechanization--does make it difficult to do this kind of thing.

QUESTION: Going back to your computer, you indicated that there was a certain amount of flexibility as to what it could do. In your initial

example you were able to change from volt meter to watt meter. It seems to me, with all the steps you have indicated it does, and all of its many and varied outputs, that you must be experimenting with something that is a cross between the biggest accounting machines and the biggest computing machines you can buy on the market today. Could you expand on just how complicated your computer system is as compared to the flexibility of outputs in terms of what it can and cannot do?

MR. DICKIE: We spent far more time working on the method for programing the computer than it took to do the programing for this whole job. We have a completely new method of handling the data in the computer. This experiment--for those of you who know computers--was done on an IBM 702 which is about 8 years old. It is not a large memory machine; it is not a high-speed machine. We expect before this month is over that we will be able to do this sort of thing on a 650, and we hope to be able to do it, for small businesses, on a 305, which is just a rare use. My budget schedule calls for the end of March.

General Houseman brought up the same question, that we must be using Stretch or one of the big computers that you folks in the armed services are using. This is not the case. We are delighted to have a bigger computer. It's faster and makes our problem easier and we can do more business. But we do not have file reference. If you read between the lines in the speech, we do not take the way humans do jobs and

mechanize them. We were using an example out in the hall here. If you were looking down the long hall, which is very attractive, and if you had a civil-engineering job to do, you'd say, "Now, quick get me my trigonometric tables and store them, because I'll be darned if I am going back and figure these things up over again." So, as humans we would say, "We're going to put this in the computer, so we'll store all of our trigonometric functions. Get the book, get the program, and put them all on the table. They take up a lot of room. Put them in memory." There's a nice long formula, you remember, for deriving these various functions. You can store a half-dozen of these formulas. Then you go back and say, "I want the sign or the co-sign for such an angle." It rattles through a formula this long (indicating). As a human being you'd say, "Oh, no. If I have to do it it will take me half a day. I'll probably have the wrong answer and I'll have to do it 2 or 3 times to get the same answer twice. Even then it may not be right. Of course I'll look it up." You can look it up in 15 seconds or half a minute, or something. Say it takes you 15 seconds. The computer maybe can look it up in 2 or 3 seconds--a ratio of less than 10 to 1. It can look it up quicker than you can. When you calculate, it takes seconds for calculation. The computer does tens of thousands of calculations a second.

On that chart I showed, we do not store all of these answers. We store the basic formulas or basic decisions; the foundation for these decisions is what is stored. So we take account of the fact that the

computer can work out tens of thousands of calculations a second. It goes back to the fundamentals and recalculates them.

Think what this means in changes. Assume we wanted to make the shafts on these motors we were talking about a quarter of an inch longer. Today we've got thousands of engineering specifications and thousands of drawings that are as of now out of date. Better than that--during the war we ran out of a lot of stuff, as you know--nickel, chromium, and so forth. We'd go back and all of these things would have to be changed. We just said to everybody, "Please remember--no more chromium-plated stuff." This isn't true today. If we want to make these shafts a quarter of an inch longer—or a quarter of an inch shorter, now, to save steel--everything is out of date? Oh, no. We go back to the formula for determining shaft length. It's all in terms of customer specifications—in no other terms. It's based on the horsepower, the frequency, the speed, temperature rises, and so forth. Those are the only elements, other than constants and factors, in the formula for shaft length. Maybe on the end before we had something or other; now we just put minus .250. All shaft lengths are now decreased by a quarter of an inch. Everything is up to date again.

QUESTION: Sir, do you foresee, and are you concerned about, the eventual possible loss of skills and technology as a result of all this automation? Well, really, automation is what I am getting at.

MR. DICKIE: I don't want to sound frettish, but I am worried about

skills, but the skills I am worried about are the inadequacy of our skills to do this sort of thing. In other words, we have said that engineering is done in the computer. Yes, the engineering--and I was an engineer when I started out as a student--the wet-thumb kind of engineering is out. Let me see--this is a 50 cycle, 3-phase job. Get around to the right technique, a big turntable and 4 engineers. There, boy, I got the 50 cycle. Oh, no, it's 2 horsepower. Now, let's see-- a 30-degree temperature rise. Oh, yes, I've got it. And so you work, and pretty soon you know what the wire size is. Now I've got to go to the winding table to find out how many turns. That's another set of books. Everybody has worked them out. I don't want to work them out. Somebody worked them out before, so I'd use what he did and do it over again.

That's out. But the fellow who designed the new motor that I was just talking about up here a while ago, boy, we need more of them. It's the same thing here. The fellow who does the everyday, routine ordering job, the routine production-scheduling job, he's out. But the master, who goes back and plans the manufacturing planning and detailed scheduling of that shop where we are running 60,000 a week in a 35,000 shop--you'd never believe it, but in Jonesboro, Arkansas, we've got two Ph.D.'s in mathematics working to do the simulation of that shop so that we know about Thursday of this week precisely how things are going to go through that shop next week. They've never known this before.

This is why that place is just running so slick and at pretty nearly twice its capacity.

The routinized jobs can be dropped out. But the people with the skills for master-planning this thing are so precious they are hard to find. So we are really raising the job requirements.

STUDENT: Isn't there a certain feed-back of the experienced people in the shops under the present system--the masters, the foremen, and so on? There's a certain amount of feed-back to the innovators. There's a cross-feed there that aids these Ph. D.'s and mathematicians to come up with a better process. This is what I'm thinking of. Are we going to lose that ingredient, that feed-back?

MR. DICKIE: No, I don't think we are going to lose the thoughtful folks at all. I think we are going to make them more thoughtful, give them more time for real planning. In other words, we'll take the bright young engineer who is spending his time doing wet-thumb designing today. Maybe we'll get rid of half of these folks. The bright half, though, we'll put over and say, "Let's see if we can't work out a new motor that will beat these Japs all hollow." They'll say, "Oh, good. I can get rid of this wet-thumb designing and go to work on working out a new, better motor. I'm a new young fellow. I'm uninhibited. I've got a bunch of ideas. Let me try it and see if I can't mould this whole thing all in one operation, or something. Wind it with aluminum foil; the heck with wire. Let's see what we can do."

It will release these people for innovation, for improvements, rather than doing the routinized kind of work over and over. I think we'll be ahead. I think it is going to require better and more thoughtful people. Just as when we have mechanized the shop, folks with lower I.Q.'s and things of that sort have found themselves in difficulty adjusting to these new and better ways of doing things. This is a very real problem, for sure.

I met before the International Board of Directors of the Y.W.C.A. to discuss automation in New York City. Incidentally, you can tell how well you are doing when you speak to the ladies. They stop knitting and tatting when they are really interested. When they are not interested they just knit. Every darn one of them had some handiwork with her. They come, and they are all colors and sizes and shapes, and they knit and tat and hemstitch, or what ever they are doing. And when they are really interested they put it down and then pretty soon they are back at it again. Their point was this: The really highly skilled secretary or the gal who could run computers, or something, doesn't come to them for help, except rarely. She just comes in, gets a couple names, and has a job. But the poor girl who had trouble struggling through the fifth grade, or something, comes in and says, "Gee, what can you find for me in the way of a job?" They say, "Well, normally, you could go in a factory and put one wheel on the kiddy car, and do this and be very happy. But, gee, they've automated that job now. I wonder what we

can find for you." So we are causing people who are in this area real problems.

I don't have any answer for them, either.

COLONEL DAVIS: Mr. Dickie, you have given us a mighty good insight into a very important aspect of our industrial economy. On behalf of the Commandant, thank you very much.

MR. DICKIE: You're a wonderful audience. Thank you.