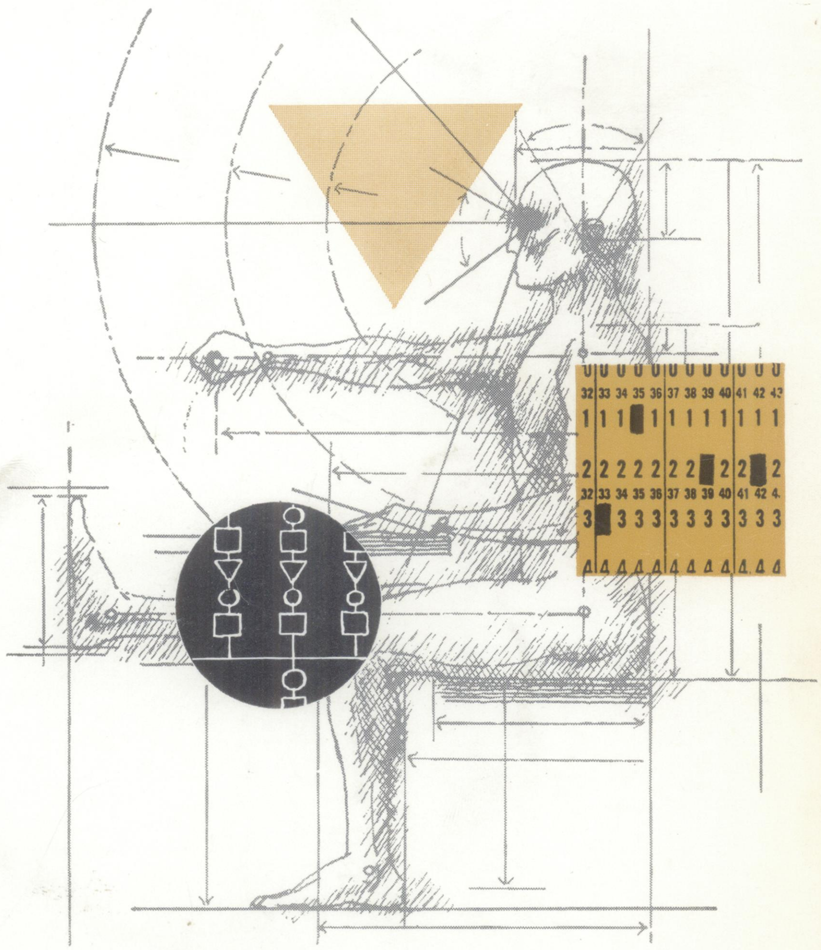
PROCEEDINGS

FIFTEENTH ANNUAL INDUSTRIAL ENGINEERING INSTITUTE



UNIVERSITY OF CALIFORNIA

BERKELEY and LOS ANGELES February 1 and 2, 1963

PROCEEDINGS

FIFTEENTH ANNUAL

INDUSTRIAL ENGINEERING INSTITUTE

Presented by

UNIVERSITY OF CALIFORNIA

THE COLLEGES OF ENGINEERING
THE SCHOOLS OF BUSINESS ADMINISTRATION
THE INSTITUTES OF INDUSTRIAL RELATIONS
UNIVERSITY EXTENSION

At Berkeley and Los Angeles
February 1 and 2, 1963

In Cooperation with

AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS
Los Angeles, Peninsula, Sacramento, San Gabriel, Orange County and San Francisco-Oakland Chapters

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FIFTEENTH ANNUAL
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FOREWORD

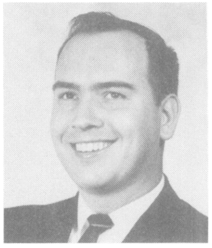
Thomas H. Hazlett
General Chairman
15th Annual Industrial Engineering Institute

The Proceedings of the Fifteenth Annual Industrial Engineering Institute contain the papers of the ten speakers who appeared on both campuses, as well as the welcoming remarks by Chancellor Strong at Berkeley. This year's group of speakers were especially outstanding, which may be verified by those who attended the Institute or by reviewing their respective presentations reproduced in these proceedings. A great deal of appreciation is extended to these men, in particular those who experienced some difficulty in order to appear at the scheduled times in Berkeley and Los Angeles for their presentations.

An endeavor was made to improve some of the organizational and operational aspects of the Institute this year. Only individuals who were considered to be of equal interest to both campuses and therefore might appear in both Berkeley and Los Angeles were extended invitations to participate, thus limiting the total number of speakers to ten. The final announcements for Berkeley and Los Angeles were combined into a single publication, which facilitated printing and mailing efforts.

The subject of the papers presented this year, as in the past, were largely determined from the summarization of the interest questionnaires completed by those who attended the Fourteenth Industrial Engineering Institute. Once the general subjects were identified, the most capable individuals in each area were located.

Any credit for the success of this Institute must be shared with many individuals from both the Berkeley and Los Angeles areas. Personnel from University Extension in particular made the task of general chairman rather enjoyable by continuing to provide excellent support from the first initial planning stages through to the actual publication and mailing of these Proceedings.



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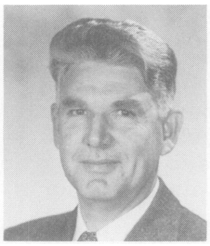

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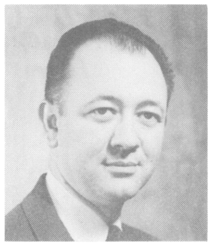

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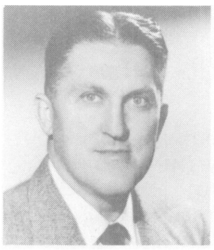

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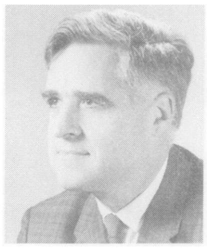

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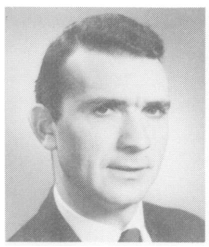

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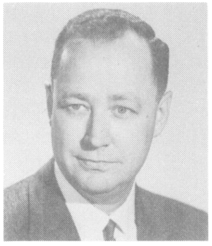

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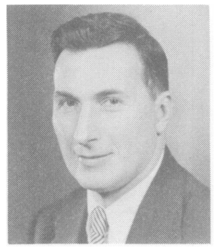

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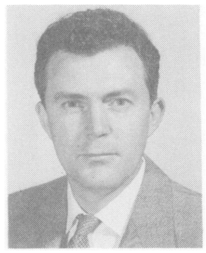

John R. Whinnery

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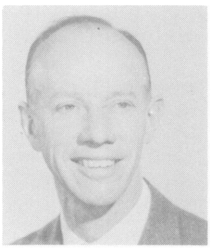

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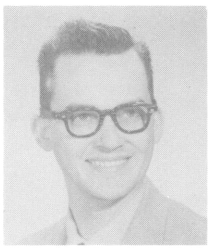

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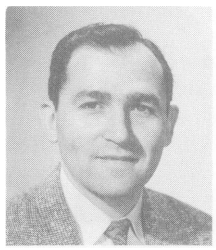

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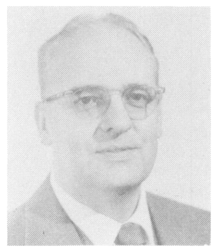

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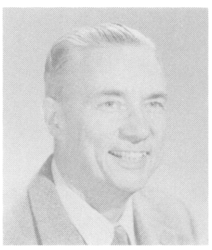

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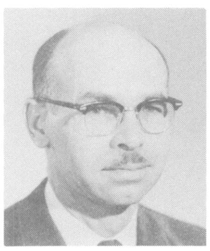

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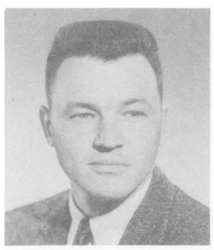

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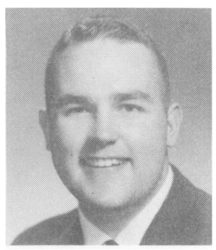

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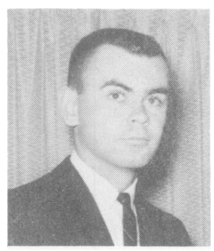
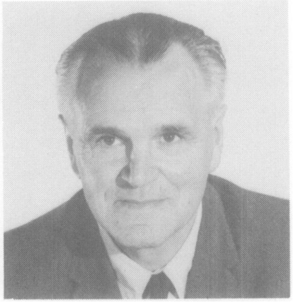
(Student)



Steven Pinney
(Student)



WELCOMING REMARKS
BERKELEY

Edward W. Strong
Chancellor
University of California
Berkeley, California

Last year you were welcomed to the 14th Annual Industrial Engineering Institute by Dean Whinnery. Speaking both as an official representative of the University and as an engineer, Dean Whinnery could perform both a ritualistic and a useful function. The ritualistic function, the one that I am now performing, is that of the host welcoming the guest, and you are indeed welcome.

The University is glad to have the opportunity of participating in meetings of this kind and of doing all that we can do to have these meetings be pleasant and profitable to you who attend them. Of this you were assured by Dean Whinnery when he spoke to you last year, of this I assure you today.

But beyond that, Dean Whinnery in speaking to you last year in his welcoming address, spoke about the challange of the European Common Market and of the need and the importance of improving through Industrial Engineering the productivity and efficiency of our industrial plants. He made clear that we consider it to be our responsibility in the University to train skilled personnel needed to meet the demands for their services in industry.

Finally Dean Whinnery also spoke about this Institute as a means of exchanging ideas. Were this a meeting of philosophers, I as a philosopher might try to be useful instead of just being ritualistic by venturing some remarks about ideas and their exchange, but should I do so, I would be talking shop. But to talk shop with you would be to talk Industrial Engineering, operations research, management problems and the like. I confess that we have some management problems in the University, and I do talk about these problems with other academic administrators. But you are not here today as academic administrators. I think that the problems that we encounter, the management problems in the University, are not totally unlike the problems you encounter in your firms and businesses and industries and yet they are not the same.

The exchange of ideas that is useful relates to the time, the place, and the context. Considering the time, the place, and the context the most useful thing I can do here and now is to get out of your way and to let you get down to the business of exchanging pertinent ideas. But I cannot refrain from a closing observation.

Were the power of man limited just to his physical equipment, he would still be an animal struggling to feed himself. Equipped with ideas, man has devised the tools and controls that have increased his powers, until today these powers are far beyond anything dreamed of at the beginning of the Industrial Revolution. The problems of managing these powers to ensure results that are desired and desireable, are indeed large and formidable problems. I think it is well that you are met to discuss them.

Again it is a pleasure to welcome you. . . I wish you a pleasurable and profitable meeting.

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THE ANATOMY OF AN AUTOMATION PROJECT

H. H. Arnold
Department Chief
Manufacturing Development Organization
Western Electric Company
Winston-Salem, North Carolina

INTRODUCTION

This paper will present a description of a project originated to provide fully automated manufacturing facilities for an electronic component - the deposited carbon resistor. A description of the product and of the consideration leading to automation will be followed by a brief description of the resulting production line. We will then consider in some detail the actions necessary for implementing the project from its inception through its production trials.

PRODUCT DESCRIPTION

The deposited carbon resistor is basically a comparatively simple piece of apparatus. It consists of a thin film of crystalline carbon coated on a short ceramic rod. Metallic terminations are placed in direct contact with the carbon film, end caps pressed over these terminations with leads attached, a helical groove cut in the carbon film so as to raise its value to a precise final resistance, and finally an environment-resistant covering placed over the entire unit. These components are used in large numbers in all electronic systems. As the complexity of these systems has increased during recent years, the number of resistors used has proportionally increased so that now some electronic systems utilize resistors in quantities measured in the millions. This large-scale usage has demanded higher and higher reliability for these components and was one of the primary factors leading to the development of the automated production line to be described here.

The production line is 110-feet long and consists of eleven machines - eight operating and three inspection. Maximum production rate of the system is approximately 1200 resistors per hour in power sizes of 1/4, 1/2, 1 and 2 watt. The process begins with the deposition of crystalline carbon on a purchased ceramic core. The core then moves progressively through inspection, termination, capping, helixing to value, second inspection, encapsulation in a protective casing, marking, leak inspection, final inspection, and packaging.

Heart of the automated production system is a Librascope LGP-30 digital computer which provides on-line control of the entire line. Western Electric engineers modified it, adding input and output circuits so that it could control the programming, setup, and feedback control of individual machines in the system. Basically, the computer performs in three areas: Production control, quality control, and setup control.

<u>Production Control</u> - A month's requirements for resistors can be fed into the computer at random by means of a keyboard or punched tape. The computer sorts out the separate orders, groups the resistors according to the four basic power sizes, accumulates resistance values of each power size into an orderly production sequence, and schedules the sequence in which the various power sizes and resistance values will be processed.

<u>Quality Control</u> - Using methods of statistical quality control, the computer analyzes control data accumulated at the three inspection stations in the line and applies statistical tests to determine if a deviation trend is developing. No control action takes place while this analysis indicates a normal statistical distribution around a desired nominal. When a trend away from accepted manufacturing tolerances develops, the computer uses stored data to calculate new setup information for the appropriate station.

<u>Setup Control</u> - In addition to feedback control functions, the computer provides initial setup of wattage size at eight machines and setup of resistance values at six machines.

Time sharing of the input equipment and of portions of the output equipment helps to conserve apparatus in the computer system. The computer output is stored in transistorized registers and setups such as wattage size, gas flow, and core speed require binary registers for each machine. Those machines requiring decimal setup - helizing machine, marking machine, and two inspection storage bridges - share a single binary coded decimal register. The input unit is an analog-to-digital converter. Although it is time shared between the individual input stations, the 140,000 bit-per-second speed at which it sweeps data into the computer precludes any delay in the manufacturing operation.

Computer control of the automated system first occurs at the coating furnace at the beginning of the line where ceramic cores are coated with crystalline carbon to form a resistance element. Three parameters govern the value of the resistance coating: The speed of the core through the coating zone, the pyrolysis temperature, and the flow of methane gas. The computer controls these parameters by means of a data feedback loop from the first inspection station which immediately follows the coating furnace in the line. At this station the coated core passes between four probes using the Kelvin bridge principle. Analog voltage proportional to resistance is digitized and fed to the computer memory drums where it is stored and sampled on a statistical quality control basis against programmed requirements, also stored on the memory drums. The computer calculates the data, and, if a correction is necessary, the computer actuates solenoid operated digital flow valves on the furnace to control the gas flow in the coating zone.

After inspection (and rejection if necessary) the coated cores are blown through pneumatic tubes to the terminating machine where a gold contact is sputtered over each end of a core. During the sputtering operation, each core is held in a mask which prevents the center of the core from being coated. Since there are four different sizes of cores used in the system, the computer is used to program the proper mask size when the machine switches over to different core sizes.

The next machine in the system is a capping machine where gold-plated brass caps with wire leads are pressed on each end of a core. The capping machine uses two different capping assembly heads to apply one of three different cap assemblies for each of the four resistor wattage sizes. The computer controls both the switching of the assembly heads and the changing of the cap sizes.

The components are then transported to a helixing machine which cuts a helical groove into the carbon film of the core to obtain the desired resistance. A computer-controlled bridge monitors the cutting operation as it is accomplished by rotating a chucked resistor against a diamond-impregnated wheel. The control servos of the bridge balance when the desired resistance is reached, disengaging the lathe bridge. The helix lathe bridge is slightly biased to compensate for machine inertia and for resistance change caused by heat generated in grinding. This data is programmed and stored in the computer memory drum. The computer also is connected into a servo that controls the speed and pitch used for proper spiralling.

The feedback control and self-correction of the helix lathe bridge is based on a statistical quality control analysis of values when the resistors are inspected at the second inspection station, immediately following the helixing machine. A Wheatstone bridge, set to the desired nominal resistance value of each resistor lot by the computer, precisely measure the resistance of each resistor. Off-balance voltage is digitized and fed back to the computer, which then computes the desired correction and corrects the helixing machine setting.

The resistor next feeds into an encapsulating machine where a precured epoxy is fitted over the core and two partially cured epoxy pellets are inserted over each lead wire. After heating, curing, and cooling the encapsulated resistor is transported through a leak detection machine which detects small holes or cracks in the shell. Acceptable resistors are conveyed to a computer-controlled marking machine where the wattage, resistance value, production lot number, and date are stamped on the encapsulated resistor. Servo drives, controlled by the computer, can set any of 45 different code numbers with over a million and a half permutations of code and resistance value combinations. When the line switches over to a different size core, or different resistance value being processed, the computer automatically resets the marking wheels to the correct value.

After marking the resistor passes through a third inspection station which checks the resistance value and feeds the data back to the computer. The information is used by the computer to compensate for shifts in resistance value caused by the heat of encapsulation. Corrected changes are then transmitted to the second inspection station and used to reset the computer-controlled bridge for the helixing machine.

Final station on the line is the packing machine where groups of resistors are inserted into foamed polystyrene blocks. This packaging method is a function of customer demand. The machine is controlled by the computer in that servos are actuated to control the stroke settings for the platen and anvil when the system is switched into processing different core sizes of resistors.

IMPLEMENTING THE AUTOMATION PROJECT

In originating and managing a project leading to a fully integrated facility of the type described here, it has proved desirable to consider the complete system as an entity rather than as individual process machines, although the latter approach is by far easier from the standpoint of the planning engineer. Because of the inter-relation between product design and individual machine decisions, the system concept becomes quite important. Each machine in the system can, of course, be designed individually, produced and proven in as an individual unit; but for the over-all automated facility to work satisfactorily, central coordination must be established to keep all machines compatible with the over-all concept.

ANALYSIS OF ECONOMIC CONSIDERATIONS

The first step to be considered in a program of this type is perhaps the analysis of need for such a system and justification of the necessary expenditures of engineering and effort and money. The economic factors are of major importance. The criteria by which such expenditures are justified will vary, of course, from company to company. It has been reported that required payoffs within a one-year, within a two-year, or within a five-year period are used by various companies. Other companies consider a long-term payoff with a high required rate of return on investments.

These calculations in general are quite straightforward and are based on savings in labor, improvements in yield, or improvements in material usage. With the advent of complex electronics systems, however, still another criterion enters the picture. While also relating to economic factors it is much less readily calculable, yet of perhaps equal or greater importance. This is the necessity for inherent reliability or consistent quality which can be achieved perhaps only through fully automated production. This latter consideration was the most influential in justifying the particular project being described. Here the absolute necessity for improved component reliability in itself would have justified the project, even if direct cost consideration had been unfavorable. It follows then that for a project to be successfully initiated, sufficiently sound justification must be provided to warrant the expenditures involved.

TECHNOLOGICAL CONSIDERATIONS

The next phase of analysis has to do with the technological considerations surrounding the project. Two prime criteria exist. One is that the product line is sufficiently stable so that a reasonable degree of assurance is present that the project can be completed and payoff realized before a change in the state of the art obsoletes the particular product to which the production line is tailored. The second criterion is that the product is sufficiently well understood from an engineering standpoint that a knowledge of its process variables at each critical stage of manufacture is either already available or can be reasonably obtained. In the particular project under discussion, these criteria were satisfied because of a considerable backlog of resistor manufacturing experience by manual and partially mechanized means. It is extremely important, however, that careful consideration be given to these factors since a technological change in product or an uncertainty as to how to control a process variable could rapidly change the anticipated savings to losses. A third technical consideration in tying together an automated facility is the feasibility of obtaining mechanical cycle times for each operation which are reasonably equal. Greatly different cycle times in consecutive operations would either create bottlenecks or make necessary multiple paths at individual stations which might greatly complicate the control problem. The electrical and electronic feasibility of the automation process also needs to come under consideration. In order to control a given variable it is obviously necessary to measure the resultant of this variable. If measurement techniques for the critical characteristics of the product are not already available, the feasibility of providing these new measurement techniques must be considered. Finally, the extent and nature of the control system and related data processing system must be determined and its feasibility established.

PRODUCT-PROCESS-FACILITY INTER-RELATION

The inter-relation of the product, the process and the facility to be provided must be emphasized. Most products which we have explored with an eye toward automation have been found to require considerable change in order to adapt them to most efficient automated production. A close relationship thus exists between the product engineering, the process determination, and the machine and control system design in order that decisions made in one area can reflect consideration of the entire system rather than relating to the individual aspect alone.

An example of this inter-relation was the choice of a resistor termination in the case under discussion. The previous method of termination utilized a silver flake paint with an organic binder. This material required a sixteen-hour curing cycle, quite incompatible with the concept of in-line computer control. The choice of a sputtered termination in order to reduce the time of application thus determined the machine design, and changed the resistor design to this degree. At the same time the resistor design involving no organic coating on the carbon required the use of a metal not subject to electolytic migration, so that gold was chosen for the termination material. This in turn required changes in machine design to permit the use of gold, a metal having a slower inherent sputtering rate than silver. This interplay between all phases of the project planning presents a continuing challenge to the system coordinator.

Once the feasibility of the project has been determined from the standpoint of economic justification and technical considerations, we have found it highly desirable to establish detailed scheduling of all steps of the project with realistic objectives so that each individual task can be properly followed and additional effort applied where necessary. We are faced with the necessity of determining from the standpoint of budgeting and programming when a facility is realistically likely to be in service. By the same token we feel it highly desirable to establish tight objectives so as to challenge the personnel assigned to the task to optimum performance. This has led us then to a system somewhat similar to the "Pert" (1) approach. We establish engineering objectives for each phase of the development and prove-in of the system. At the same time we establish a more pessimistic schedule which we consider the outside permissible times for each step of the operation to be completed; thus our development and production personnel work toward a more optimistic objective whereas our production commitments and funding provide for the more realistic schedule. The various bench marks that are established for the operation may be listed as follows:

1. Research and Feasibility Study

This phase of the program is basically an engineering study to determine the economic factors, the reliability factors and the technical feasibility of the proposed project.

2. Proposal

The preparation of a proposal in whatever detail is necessary to satisfy the responsible levels of management of the desirability of the project in question.

3. Funding

A period of time is normally necessary in all but the smallest organizations between the time a proposal is submitted and a decision reached and funds made available. This will, of course, vary with the urgencies of the project as well as with the individual company.

4. Prototype Development

In many cases where new ground is being broken it is advisable to build a prototype machine. This facility may or may not prove useful in the final system design but it may be essential in order to determine the best method of performing a given operation or in some cases to find a practical method for its accomplishment. The individual areas where this activity will be required must be identified and time allowed for its accomplishment.

5. Design

The mechanical and electrical design may be started immediately on some phases of the program, but will necessarily be delayed in areas where prototype development is called for. Thus a staggered set of time intervals will be determined for the design phase of the project based on the necessity for and the length of prototype development activity.

6. Facility Procurement

Upon the completion of design, orders can be issued for facility procurement, either on one's own model building shops or on outside vendors. We have utilized several different approaches for the procurement of facilities. These include procurement of complete machines from outside vendors, purchase of machine parts from outside vendors with assembly and prove-in by our own personnel, and complete manufacture of the machine within our own organization. Each of these approaches is feasible, depending on the time available and the degree of liaison required between engineering and design personnel and the machine builder.

7. Debugging

This might well be considered the most variable item in the development program. It consists of taking individual machines and/or control systems through the required cycles and making the necessary changes to meet the system design objectives. It is at this stage where perhaps the highest engineering development skills are required and where close relations must exist between the system coordinator, the product design engineers and the mechanical and electrical development engineering personnel. Changes in one area may very well cause unanticipated effects in others so that a continual interchange of information is desirable.

8. Final Installation

The final installation of individual facilities in the integrated system is again generally staggered in time depending on the completion dates, both scheduled and actual, of the previous tasks. This is generally a rather closely predictable interval and constitutes preparation for the next phase.

9. System Prove-in

The prove-in of the entire facility can be started only when all the individual segments are installed. However, prove-in of sections of the facility is highly desirable since it minimizes the complexity of the problems which develop concurrently. Whenever two or three machines can be tied together these machines can be operated for purposes of determining weak points in the system planning or in the continuous performance capability of individual machines. In order to show up machine reliability short-comings, long periods of trial operation are necessary; thus it is highly desirable if requirements exist for product of the types the machines can manufacture so that their output can partially offset the cost of these trial operations.

10. Production Trials

After the entire system has been proven on limited scale production, production trials can begin. This is the phase of the operation where the shop personnel who will finally have cognizance of the machinery receive their training and pick up the continuing operating duties from the development personnel. During this periods, increasing efficiency in operation is expected leading to the final objective.

11. Production Turnover

This is the point in time when the original objectives are met, but does not signal the end of development activity. Continuous improvements in the facility may continue as long as improved yields and "up time" warrant the cost of development.

Not every manufacturing operation can be economically automated at this time. It seems likely that it would be many years before a major portion of our manufacture will be automated in the true sense of the word. It does appear certain, however, that the trend is in this direction and that each year will see an increasing number of automated production lines and integrated production, control, and manufacturing systems under computer control. The system outlined here is, we believe, a typical one in that it contains all the essential elements of the larger and more sophisticated versions we will see in years to come.

1. "Pert" is a production control plan utilized successfully by the Navy and others on several large-scale R and D projects.

PERT – SOME APPLICATIONS AS A DYNAMIC TOOL

Oscar Barry
Vice President
C-A-P-C-O-M
Oakland, California

I shall start by saying that I do not fully understand what is currently meant by PERT; I think that PERT means something slightly different to each person. PERT started in life five years ago by meaning something quite precise and its rapid evolution has changed some of its concepts but it looks as if the word PERT will survive as the generic term for all the various techniques of doing the same job. PERT uses a network diagram to represent the discrete activities that constitute a project and the interrelation of these activities. Basically, PERT is event oriented and CPM is activity oriented, but the differences are being phased out.

Now to recap the basic concepts of the systems, we will take a few minutes to go through a sample problem and use attached diagrams 1 through 6 to explain the solution.

I am a plant engineer; the Production Superintendent is having trouble with his existing batch paper pulper and has approval to install a new one with an automatic feed and will get delivery in two weeks. My boss, the plant manager, tells me to look into it and get a proposal on his desk. Let us examine part of the problem of the new installation – to prepare the base to pour concrete as a foundation for the pulper.

I will divide this project down into eight jobs or activities and I will list them as shown on chart #1.

- 1.2 - Remove existing ground floor slab and excavate.
- 1.3 - Fabricate and deliver reinforcing steel.
- 1.4 - Fabricate and deliver imbedded mechanical items.
- 2.3 - Form pits and sumps in base.
- 2.4 - Set chairs for imbedded mechanical items.
- 2.5 - Set imbedded conduit.
- 3.5 - Set and wire reinforcing steel.
- 4.5 - Set imbedded mechanical items.

I will then arrange these jobs which together comprise the entire project in the sequence of the execution. If I represent each job by a line I can generate the network diagram shown on chart #2. I then estimate the length of time it takes to do each job and may calculate the length of time for the entire project. My calculation process gives me the information indicated also on chart #2.

I then can go to my boss with my proposal and I am happy because,

1. I know the duration of the project is 11 days.
2. I know the priority jobs.
3. I know what each trade must be doing each day to the end of the project.
4. I know my latitude or float on non-priority jobs.

But the boss says, "I want the project done in a week."

I say, "But this will cost money and in any case I do not know if I can complete this project in 7 days."

"How much will it cost and prove to me that you cannot do this in 7 days."

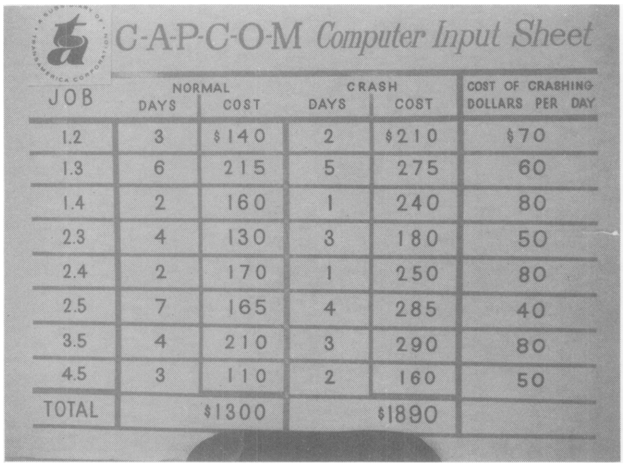
So I carry on my study still further. I make more estimates and get all the information shown on chart #1.

I have been fortunate enough to have a friend who has developed an excellent computer program and to avoid the leg work of tedious calculation, I use a computer to derive the answers shown on chart #6. This is valid because 90% of the "think" goes into establishing the network or my sequence of activities; the computer just assists me in doing the repetitive arithmetic fast.

The process of the arithmetic is indicated on chart 3 through 5. As shown on chart #3 the object is to reduce the overall duration by one day. We examine all the activities on the Critical Path and shorten by a day the activity which will cost the least money, i.e. activity 2-3 @ $50 per day. The duration of the project is now 10 days and the premium cost of this one day reduction is $50. In addition, activities 1-3 and 2-5 have become critical, but at no additional premium.

The next phase is to reduce the project duration to nine days. We again examine the Critical Paths - we now have three and the least premium for the required compression is by reducing the duration of activities 1-2 and 3-5 at a cost of $150; we also find we can relax activity 2-3 by one day and save $50. The net cost of the time reduction to 9 days from 10 days is $100 - this is shown on chart #4.

The final stage is shown on chart #5. The



C-A-P-C-O-M Computer Input Sheet

JOB	NORMAL DAYS	NORMAL COST	CRASH DAYS	CRASH COST	COST OF CRASHING DOLLARS PER DAY
1.2	3	$140	2	$210	$70
1.3	6	215	5	275	60
1.4	2	160	1	240	80
2.3	4	130	3	180	50
2.4	2	170	1	250	80
2.5	7	165	4	285	40
3.5	4	210	3	290	80
4.5	3	110	2	160	50
TOTAL		$1300		$1890	

Chart #1

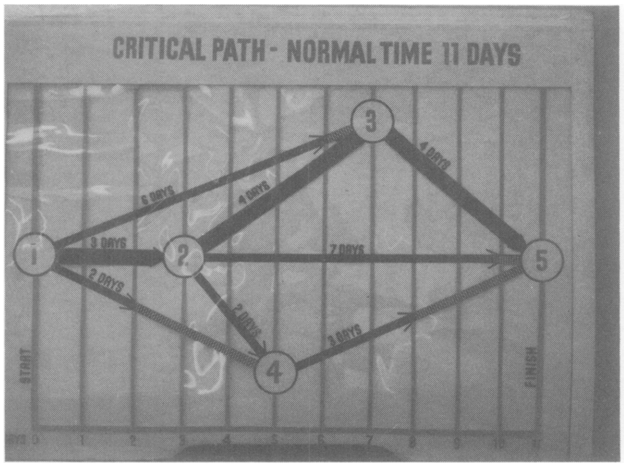


Chart #2

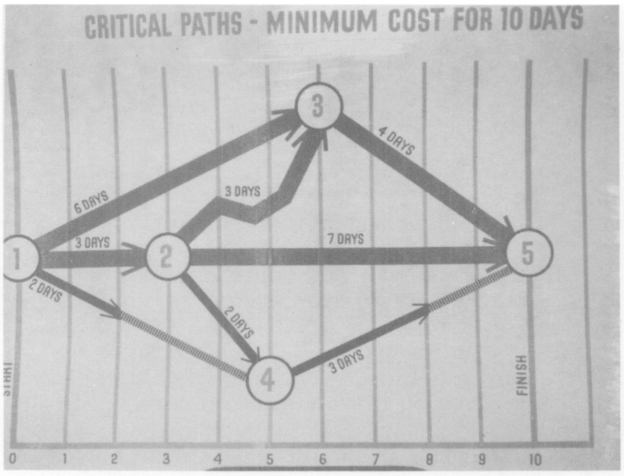


Chart #3

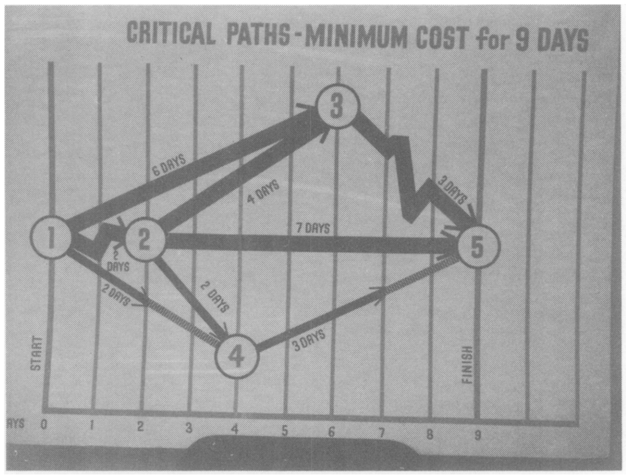


Chart #4

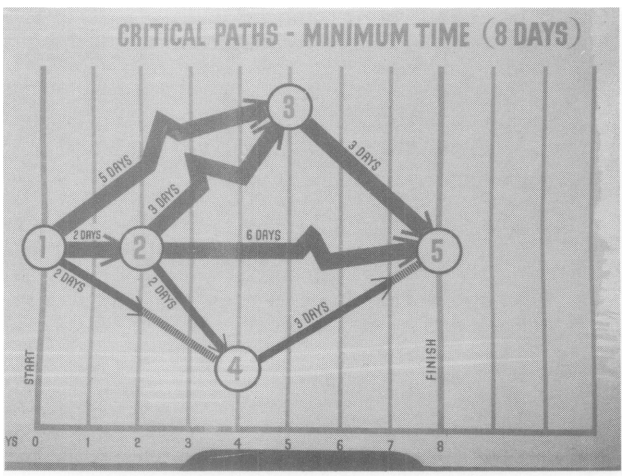
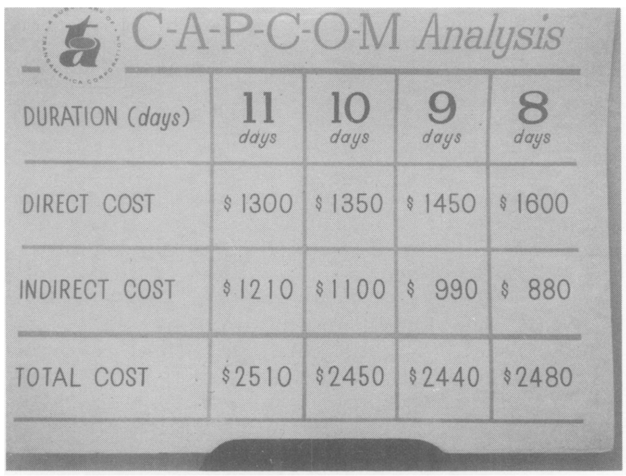


Chart #5



C-A-P-C-O-M Analysis

DURATION (days)	11 days	10 days	9 days	8 days
DIRECT COST	$1300	$1350	$1450	$1600
INDIRECT COST	$1210	$1100	$ 990	$ 880
TOTAL COST	$2510	$2450	$2440	$2480

Chart #6

project is reduced to the minimum duration of 8 days. Minimum because each of the activities on at least one critical path have been "crashed". The paths are 1-2, 2-3 & 3-5 and 1-3 & 3-5. The premium for this compression is $150.

The results of the direct costs are entered on chart #6. To the direct costs are added, the optimum duration time based on cost factors only, is 9 days.

Now both the plant engineer and the plant manager are happy and each is speaking a common language.

To leave our example and get into actual field techniques and application we find basically that if a project team knows what it is doing, PERT can be a great tool or, "it tends to make good firms better rather than bad firms less bad."

I will describe in some detail one method which has proved this to be true. When we get to the field application we find many of the objections to the system are normal human problems and must be solved as such. For example, the system to be effective, requires a complete showing of the hand and if there is a feeling that a PERT network will only be used as a big stick to remind the estimater of bad estimates then his projection will tend to be a little less than honest. Therefore, a very clear understanding of the uses to which the system will be put must be understood at all levels of management.

The results from PERT are only as good as the information fed into it – this we will call input – how do we get this information and from whom?

We have found that the best person to get this input is the person who has the direct responsibility for executing the project. The information is got by satisfying the following question for every job or activity in the project.

"Before I can start this subject activity, what activities must be just completed?"

This establishes the job listing and the job sequence. In practice the field superintendent must have a clear concept of his methods of execution, otherwise the interrogations can be a long and tedious learning process. It is emphasized that one of the difficulties and subleties of the interrogation is to be able to express in terms of activities, the benefits of 40 or 50 years of experience, and unless the activity sequence and subsequent network reflects proven "seat of the pants" judgments it is not making the full use of available experience.

From the completed interrogation sheets a network diagram is prepared. This catches any discrepancies in the activity sequence and also provides a numbering sequence which can be used for computer input.

Then the interrogation is continued to extract the estimated time taken for each activity. Some changes are made in the sequencing at this stage as the opportunity to review the entire project is present. The refining of the network has already begun. This information is also obtained from the field superintendent.

From the information we now have, we can calculate the duration time of the project and indicate the critical path. This we now do.

The computation may be done manually or by computer. The computer does a two-fold function. It executes the calculations and it gives us an output in a form best suited to the needs of the field.

The calculations are not very advanced mathematically, but are voluminous and provide for each activity the following information:

Earliest Start Time
Earliest Finish Time
Latest Start Time
Latest Finish Time
Total Float
Free Float
Independent Float

This information is useful to the scheduler but it has very little sympathy of the foreman or superintendent who wants to know:

1. What job do I start this morning based on the information I have already given you? or
2. If I do the particular job I want to do this morning, what effect is this going to have on my completion date?

We, therefore, should present the output of our calculations in such a way as to satisfy the needs of at least three functions:

1. The scheduler needs his information in such a way that he can prepare a realistic schedule. He wants to know the amount and nature of the float assigned to each activity and he wants to be able to refer quickly from the network diagram to the activities. He then gets a print-out called an "activity listing" and this listing is sorted so that we can always find a specific event or node number.

2. The field is not too interested in the network diagram or in "complicated mathematics" as such. The field wants to know what it does today or this week but usually from the reverse position expressed as, "if I cannot do this activity today, what is my position on the schedule?" To provide the field with an output to flag this condition the following output format has been developed:

   Earliest Start
   Earliest Finish

Semi-critical Start
Semi-critical Finish
Actual Start
Actual Finish
Critical Start
Critical Finish

This information is sorted by Semi-critical Start so that for any given day, or week, if the activities have been started by their Semi-critical Start times, then the field knows that there need be no change in the overall schedule to complete the project within the scheduled time.

When the Semi-critical dates are exceeded, the scheduling department must be informed so that a revised schedule can be completed. Management may have many such reports on all the current projects.

This is done by listing the critical activities on each project in ascending order of float up to say twenty days. If the report interval is bi-weekly, this indicates that if every current activity listed on this report is being satisfactorily worked on, then the project will meet schedule as any activity not listed has the power to delay the project.

Now that we have proven techniques to apply the PERT system to a non R & D project, how do we know that PERT has any financial advantages over the existing method? After all, management expects a project to be completed in a given time and past experience has shown that these estimates can be met. Unless PERT can beat these schedules, while it may make life easier for some of the field personnel, it does nothing for management and profits.

Experience in applying PERT shows that a fixed procedure has to be followed in order to derive the full advantages of the system. I shall describe the sequences we feel necessary to achieve this result:

1. Derive the initial printout as described by interrogation for sequence, prepare the network, interrogate for time, and calculate the results. The moment of truth at this stage normally shows a completion time in excess of that prepared by conventional methods. The first printout permits at least 90% of the activities comprising the project to be discarded as they have no effect on the overall duration time. The remaining activities then receive the individual attention of the project team, with this concentrated effort we proceed with the next step.

2. The next step is to review the printout with the originator and normally we find some errors in sequencing and, on second thought, some of the duration times of the activities are a little pessimistic. Revised input is then prepared and the subsequent printout will normally show a scheduled completion time at a little less than the target date derived by conventional methods. At this stage, PERT has done little for management - at least management feels so.

3. The final steps, and the payoff for the system, is to review, in great detail, those activities that are at or near the critical path, and determine whether a day can be saved from an activity here and a slight sequence change effected there. The technique of certain construction procedures is re-analyzed and small time savings usually result. The input is then changed and the final printout generated to show a completion date normally ten to twenty percent less than our target completion date. This is a realistic date but has the habit of making all associated with the project a little dubious of its realization. For want of a better word, we shall say "tight" completion date. This makes management happy - real happy. As a 10% - 20% saving has been realized in overhead at no premium, it is now necessary to make reasonably sure that this "tight" completion date can be met! It is mandatory that our PERT schedule be updated at regular and close intervals. On a large project it is usually a great advantage to update at least bi-weekly.

To achieve updating, the field is asked to do three things:

1. Enter the Actual Start and completion times of each activity listed in the Construction Schedule, that are current on the Semi-critical column.
2. Advise of any anticipated sequence changes that are contemplated in the future.
3. Review the Critical Activity listing in detail and enter any anticipated duration changes from that shown on the schedule.

This is the dynamic part of the PERT tool. The "best opinion" of a supervisor is better now than it was two weeks ago, particularly as his thoughts have been channelled into the ten percent or less of activities that are listed on the Critical Activity listing.

When this information has been provided by the field, it is possible to determine by normal inspection whether the duration time for the project is affected. If the completion time is in excess of our "tight" completion date, then we go back to the field and find out what means are necessary to overcome the delay - other sequences changes and/or acceleration of certain activities. If we find, and this sometimes happens, that our "tight" completion time can and has been improved upon, then this is reflected in the report and becomes the new completion date.

With the updated information the input is again changed and the printout is made current and provides the construction schedule for the remainder of the project. A note here: If the Semi-critical Start time has never been exceeded during the execution of the project, no updating is necessary. The only thing then in question is whether the original schedule was too long in the first case.

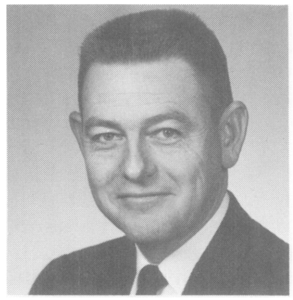
1. <u>Occidental Center - Los Angeles</u>

The PERT system was applied to this Center when the steel for the first phase of construction had been topped out. At this stage there was a major change of scope where it was decided to erect the tower phase immediately. It was decided by the owners to integrate the mechanical services. A PERT network was established and the completion time established at 200 working days. The Critical Path passed through the erection of two 20" water lines between the chillers in the sub-basement and the cooling towers on the roof. The reinforced concrete supporting structure was the prime delay in the completion of this phase. The contractor indicated that acceleration of this reinforced concrete structure would be possible at a premium of $20,000.00. A network diagram was prepared in great detail for this phase of the structure and a schedule printout prepared. The first week of overtime amounted to about $500.00. The second week of overtime amounted to $250.00 and from that date no overtime was necessary on this repetitive type work. Because of the very clear definition of the problem involved and the realization on the part of the work force of exactly what was expected of them, they met the target successfully at no premium after the first two weeks. In this phase of the operation, the original schedule of ten days per cycle was reduced to four by the application of PERT. The savings were approximately as follows: 20% in time for the entire project and 60% in time for this change of activities directly bringing about the overall saving.

2. <u>Office Building</u>

A contractor submitted a bid for an office building and quoted a very attractive completion date. He received the job and discovered that the completion date was unrealistic because of inter-relation between concrete and steel in the erection of the structure. This would add a further three months to the completion of the project. PERT was applied to see whether it would be possible to bring back the schedule to the quoted completion time. On the initial phase it was found by intensive study that two months could be picked up. The schedule was so set up hoping to reduce the project duration by the further month as a project progressed. The first updating showed that this schedule was, in fact, being bettered and there were two phases where the sequence could be changed to reflect the saving of the month required. The revised schedule showed a completion time in accordance with the original bid. The contractor is convinced that he would not have been able to realize this 25% saving in time unless he used PERT.

ARE INDUSTRIAL ENGINEERS TAKING A BROAD ENOUGH VIEW?



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The title of this talk is a question. Furthermore, it is a question I do not intend to answer directly. What I infer is that industrial engineers are not generally taking a broad enough view. If they are not, the question then becomes, "How can industrial engineers take a broader view?" and "Why should they do so?"

As a dutiful industrial engineer, I should answer the "why" question first. It has seemed to me that industrial engineers tend to get smothered in their growing body of techniques and perhaps lose sight of the ends to which these techniques should be directed. If there is any one theme which has persisted throughout the history of industrial engineering it is the theme of improving Organization Performance. These words, "Organizational Performance" have not been widely used to describe this central tendency of industrial engineering but they do describe the focal point of all industrial engineering activities, past, present and future. In trying to provide a "why," I submit that a sharpening of the focus on this large objective requires us to take a broader look at all of the factors which affect it. It requires us to examine our kit of tools in light of how they enable us to help our organizations improve their performance. If you will, it requires a broadening of prospective.

There are a number of dimensions along which breadth of industrial engineering practice could be discussed. I should like to emphasize two dimensions which I shall call the "Systems Dimension" and the "Human Dimension."

I. The Systems Dimension

So much has been said and there are so many points of view about systems and the systems' approach, that a little groundwork is required here. It seems that there has been one characteristic of traditional industrial engineering practice. Our approach for many years assumed that we should concentrate on unit operations. Despite admonitions such as "look at the preceding and suceeding operation" we have by and large tended to optimize Organizational Performance piece by piece. It was implicity assumed that if each individual operation in an organization (or system) was brought to some peak of efficiency, then the sum of this was surely equal to optimal Organizational Performance. The Systems' concept teaches that the sum of optimal parts is not necessarily equal to an optimal whole. Interactions between units or sub-systems and environmental variables can affect the performance of a system. The effects of this are only obvious when we grasp the system as a total system.

Take a not too hypothetical example characterized by many situations in our own plant and which has as its central theme the problem of allocation. Our example deals with a production system which has many products flowing through a multi-channel machine complex. For a given production period, product requirements may be expressed in pieces, footage, etc. and machine capacities generally in hours. The system dictates that the product requirements be produced within the constraints of machine capacities. Known information includes production rates and costs for all combinations of products and machines. As a further complication, technological improvements have resulted in higher production rates and lower costs for newer machines.

Traditionally, when faced with a problem of this magnitude, we attempted to examine each machine individually and assign the most least cost products to that machine. When all products were assigned, products were then shifted from their least cost machine into less desirable machines in order to avoid exceeding the total available capacity on any machine. Thus, by optimizing the assignment of each machine in the system, we were concluding that the total system was treated in an optimal fashion. In other words, the sum of the parts is equal to the whole. In our example, because each machine was assigned optimally, we concluded that the system itself was optimal.

Let us digress for a bit and consider essentially what we are attempting to accomplish. First, we must decide which products to assign to the many machines. Secondly, the assignment must be made in some optimal fashion so that we minimize the total cost of operating the system. In our favor, however, is the fact that this decision will be made under certainty for all is known about the problem; costs, production rates, requirements and capacity restrictions. In spite of this knowledge, decisions are still being made in a sub-optimal fashion. Today, the bulk of formal theory in economics and management science embraces decision-making under certainty. Several of the matematical tools used are the calculus, which deals with finding maxima and minima of functions, and linear programming, which deals with optimizing multi-variable problems.

Linear Programming has enabled us to assess the total system of products and machines, take into account the many inter-relationships of production rates and costs and arrive at a machine loading program that is within the specified restrictions and is optimal for the total system. Problems involving a large number of products and machines rapidly tax the capacities of the most modern computers; however, an efficient algorithm called the "Generalized Transportation Problem" (ref. SHARE NO. HD IB ML1) is capable of solving problems with as many as 300 products and 18 machines.

A fundamental advantage of using a model such as this is that it forces one to quantify the variables that are used in the process of arriving at a decision. Such intangibles as "better quality" or "this product runs better on this machine" are generally assessed using "managerial wisdom." The model, however, requires these "judgement" factors to be specified in economic terms.

The linear programming approach has proven useful not only as a control in assigning products on a weekly basis, but for long range planning of machine requirements such as:

1. Determining where to place development effort to overcome technological restrictions which limit the capability of products to be produced on certain machines.

2. Determining the economics of adding additional capacity which is generally more efficient than present equipment.

3. Determining the best allocation of products for special situations such as extended periods of machine downtime for maintenance or design changes.

This is just one example of work done in the Systems Dimension. Actually, the technology in this area has developed rapidly and can have significant influence on our goal of improving Organization Performance.

II. The Human Dimension

For the Human Dimension, I'd like to cover two areas; Work Physiology and Organizational Behavior. Both these areas, involving the life sciences, have been almost completely ignored by industrial engineers; however, some important beginnings have been made. Let's take Work Physiology, first.

A. Work Physiology

In the year 1903, Frederick W. Taylor in his book Shop Management stated, "One of the most difficult pieces of work which must be faced by the man who is to set the daily tasks is to decide just how hard it is wise for him to make the task." (end of quote) This, then, at the time of Taylor was a decision under conditions of uncertainty and not a measurement. And, judging by the labor disputes which arise over this question, we seem to be no nearer the point of being definitive about this question than was Taylor. In a labor dispute this past summer which idled 77,000 workers for 18 days, it was finally arbitrated, not measured, that "the operators on the jobs involved were putting forth normal and satisfactory working effort."

What is work effort? Is there an objective way of measuring this effort? Effort can be defined as an exertion of power or energy and this can be measured and quantified. Energy cannot be measured by measuring time, but it can be measured by measuring such physiological phenomena as heart rate, oxygen comsumption and respiratory volume. The industrial engineer has implied consideration of these physiological phenomena in his concern with fatigue allowances and rest pauses, but even these allowances have generally been based upon time criterion rather than physiological measurements. Today the engineer has available to him, thru his own and other disciplines, the knowledge and capability necessary for making quantitative determinations of many of these factors involved in studying man at work.

In the future, to successfully fulfill our role of studying man at work and to integrate him into the organizational system, we need to know the real demands which are being placed upon people. In a sense, we need to know their tolerance to physical and psychological loading. While as engineers, we wouldn't think of regularly exceeding the design capacity of a production machine, neither should we exceed the design capacity of the human operator. Knowing this design capacity has definite humanitarian and economic value.

The optimum work situation is when the work capacities of an individual are compatible to the work demands of the job. If we underload the individual, the situation is obviously inefficient and costly. Although it is less obvious, the reverse is also very costly. The resolution of grievances over work rate, working conditions, and the costs of on-plant medical care, as well as compensation, do not come cheaply.

While I have earlier singled out the area of effort determination, I don't wish to imply that this is the only area in which knowledge of human capacities and capabilities is needed. Some other work situations in which such knowledge is needed are; tasks involving maintenance of a performance level during monitoring and vigilance tasks, frequent decision-making associated with rapid paced operations, and the integration of an aging industrial population into an increasingly complex and rapid paced industrial enviornment. To define and approach these problems requires an understanding and application of physiological knowledge which traditionally is foreign to industrial engineers. If they are to be solved, we must seek the assistance of other professions and disciplines. No one discipline is sufficient within itself to bring to bear all of the effort that is needed. This, then, dictates the need for the team approach.

Our work physiology studies at Kodak Park, which started about five years ago, developed from a common need of the Medical Department and the Industrial Engineering Division to better understand the physiological limitations and capabilities of people. The understanding of common problems that has developed between these two divisions, in itself, almost justifies the effort which has been expended on these studies. The real reward, of course, is in our growing ability to evaluate and quantify situations which heretofore, from a job design standpoint, had to remain unknown.

Initially, our investigations were confined solely to the "effort" or "energy expenditures" aspect of work. This was natural for several reasons, namely:

1. High effort is more obvious to the observer of the industrial scene and, therefore, demands more attention.

2. While it is fractionated and scattered, much work has been done and reported by other investigators relative to "energy expenditure", which is a measure of effort.

3. Instrumentation has been developed such that it is now practical to measure this variable of "energy expenditure" on the industrial scene.

Energy expenditure is measured by the indirect calorimetry method; that is, respiration and oxygen consumption are the variables which are measured and converted to energy. Combined with heart rate, these represent the physiological responses which we feel are necessary for accurately assessing high effort industrial jobs.

Physiological measurements in conjunction with time study now provide us with an insight into industrial job design problems which is not obtainable in any other way. Using criterion relative to energy expenditure, we can now assess jobs prior to the installation of a new work standard or job design. We are in a better position to determine in terms of time and energy what the job requires, the frequency of rest breaks, the necessity of providing auxiliary labor saving equipment or the need for re-engineering the job completely. In situations where the manufacturing process is not amenable to change, then the same physiological measurements help us to select persons with the physical capacity demanded by the process. Most pre-employment medical examinations do not completely provide this information.

This new approach to designing industrial jobs has been successfully employed in many types of jobs ranging from the handling of containers in a darkroom cold storage area to the loading of box cars. A most rewarding use of it involved the pre-evaluation of a proposed piece of production equipment. The work physiology studies indicated that additional materials handling equipment was necessary if we were to obtain the anticipated increased production. The nature of this materials handling equipment was such that installation at a later time would have caused an extensive shutdown with the resultant loss of production.

With the measurement of and utilization of energy expenditure as a factor in job design, we feel we are just beginning our work physiology studies. Energy expenditure is just one facet of the problem. Other physiological phenomena of people may be studied so that we can integrate them into job systems which take advantage of their capabilities and do not aggravate their limitations. The result will be mutually beneficial to the individual and the company. The second part of our Human Dimension is Organizational Behavior.

B. Organizational Behavior

I am using this term to refer to the behavior of people in an organizational or industrial setting. As an area of knowledge, among other things, it refers to the reasons why people work or don't work, decide or don't decide to perform so as to achieve the objectives of their organizations. If the concept of "Organizational Behavior" seems remote from industrial engineering to you, let me say that an incentive system, or any control system for that matter, is primarily designed to direct and influence the behavior of people towards organizational goals. As industrial engineers we are, it seems, in the business of designing systems to influence, direct and control human behavior, but we've never quite faced up to it in these very words.

The famous Western Electric Hawthorne studies of thirty years ago marked the beginning of organized research into Organization Behavior. Since that time, studies in industry plus general behavioral research have yielded information which promises utility to industry.

I think I can summarize the results of this research this way. Let's assume that a behavioral scientist was summarizing the case - a behavioral scientist who was familiar with research findings and, most important, really knew what industrial engineers did. I believe he might say something like this:

> "You industrial engineers profess, in effect, a theory of management - a theory of how to organize men, machines, and materials so as to get the best results. The part of this theory which deals with men assumes that the performance of people will be best under situations where they are told exactly what to do and how to do it, and are rewarded with money in proportion to performance.
>
> "Your way of doing business rests on certain behavioral assumptions. Generally, you don't even recognize that these behavioral assumptions are assumptions - you take them for

granted and rarely, if ever, examine them.

"To put it another way, you are hip-deep in designing systems for influencing behavior and you make almost no use of the collective scientific information about the behavior of man. The assumptions which support your practice are not all wrong; they are just not complete nor up to date. You need, first, to realize that you are deeply involved in influencing people's work attitudes, second, that you do this based upon certain assumptions, and third, that there is a good deal of information available which would alter and improve these assumptions.

"Instead of assuming, as it seems most industrial engineers have, that people have an inherent dislike of work, and that they must be directed and controlled as closely as possible, you might assume that under the proper conditions, they will actually find personal satisfaction in working towards your objectives."

He would conclude his case by directing your attention to the research which has been done in this field. Unfortunately, he would avoid prescribing how you could "engineer" this situation but would indicate that this is your problem.

If there is any substance to his case, it seems that this is a fundamental dimension along which industrial engineers can broaden their views.

In the short time left, I can only outline the manner in which we at Kodak Park are trying to answer this challenge. In the first place, we have acquainted ourselves with the research which bears on the problem. We have tried to integrate this to the best of our ability and reduce it to the probable effect it may have on our practice. The following specifics are indicated:

1. Job Design

Instead of simply designing operations from the point of view of the optimum technical system, we think there are gains to be made in considering the nature of the jobs which people will do. The usual industrial engineering criteria for job design stress extremes of task specialization. The consequences tend to be meaningless jobs. That is, jobs in which the individual has difficulty seeing the relationship of his function to a larger whole. A version of what has been called Job Enlargement is called for. This is not just a matter of adding functions to a job, but adding a set of functions which will comprise a set of activities leading to accomplishment of a visible objective. The activities making up a job should be examined to see if there has been a tendency to remove the thinking functions and specialize them in other persons. Taken as a whole, we should endeavor to design jobs such that people have a maximum of control of the variables which lead to end objectives.

2. Goal Orientation - Information Systems

A natural consequence of the over-division of labor has been to focus the attention of individuals on very minute goals such as pieces per hour. We believe that industrial engineers should re-examine their approach to the goal setting function which is, after all, what time study has led to all these years. People, it seems, do not behave on the job as isolated individuals. Many jobs are parts of a system and depend for success upon a high degree of interdependency of people. We are examining the structuring of goals to see what beneficial effect there is in providing the individual a perception of his contribution to system goals. This takes the form of specifying job goals in terms of end-results and also in terms of the contribution of job level goals to system goals. Individuals are kept informed of system objectives, current progress of the system and any contemplated changes in objectives. In effect, they are kept "in the know" about objectives and progress of the unit as well as their own job goals. In effect, we are trying to enlarge the focus of the individual relative to end objectives. By giving his more control through Job Design and overall goal orientation, we think his performance and personal satisfaction will both increase.

III. Compensation or Incentive Systems

For many years, industrial engineering activity has been closely identified with incentives. The classical incentive approach stresses the closest possible relationship between pay and rate-of-output performance. As any of you who have administered an incentive system know, you have to take the bitter with the better. There are a number of practical problems or dysfunctions associated with incentives. I shall not stress these, but will try to describe the more fundamental problems.

If we are to believe the results of behavioral research, people work for the satisfaction of a number of human needs. Only some of these can be satisfied by money.

The most serious indictment of classical incentives is that they have pre-occupied us with money to such an extent that we have largely overlooked other considerations. Such things as achievement, responsibility, recognition and work, itself, are satisfactions and sources of motivation in themselves. Our problem, here, is to retain some monetary incentive, some pay/performance relationship, but not to do it in such a manner that it is seen as the be-all and end-all of motivation. We believe that closer attention to Job Design and Goal Orientation, previously mentioned, is one way of providing a basis for satisfaction in the job.

There is nothing in motivational research to indicate that relating rewards such as pay to performance is unsound. How this is done seems to be most important, however. We think that money should be looked upon as an after-the-fact reinforcement, not the primary initial motivator of good performance. In contrast to classical wage incentives, which stress close, short term, hour by hour correlation of pay and performance, the shift from "motivator" to "reinforcement" may be brought about by extending the time over which pay and performance are related. In addition, by utilizing longer time periods, performance considerations like quality, versatility and dependability can be considered in terms of pay.

We may close by reviewing the official definition of Industrial Engineering as it appears on the AIIE Journal:

> "Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of men, materials and equipment; drawing upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems."

If we are to believe this definition as a statement of what industrial engineers do, then we must assume that in our practice we do, indeed, draw upon knowledge from the social sciences. If anything, industrial engineering has distinguished itself by almost completely ignoring the social or life sciences. If we are to be designers of integrated systems of "men, materials and equipment," and if the design activity is to be based upon specialized scientific knowledge, then we had better equip ourselves to do so, particularly in the social or life sciences.

SIMULATION STUDY OF AN AUTOMATED MATERIAL HANDLING SYSTEM

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In each of the last three institutes there has been a paper presented on some phase of simulation studies. In the papers which have been presented previously the concept of a simulation model as an approximation to a real situation has been developed. To develop a model which successfully simulates a real situation requires:

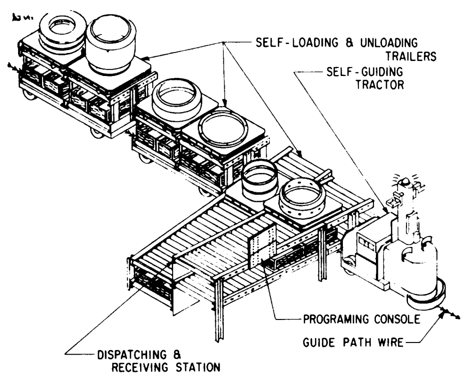
1. A technical knowledge of the industrial system to be simulated.
2. Formulation of the system into a block diagram, in which mathematical definition is given to the subsystems and interrelationships.
3. Translate the block diagram into a computer program.

Of the previous two examples of simulation models which have been presented, one involved a fork-lift truck system in which there were random calls for service and random service times. The other was a good deal more complicated in that it described a manufacturing activity in which the productive output of a system, having a fixed sequence of operations, was evaluated for various product mix inputs taking into consideration stochastic delays and breakdowns which might occur. This paper is concerned with the simulation of a proposed automated materials handling system for the Alameda Naval Air Station, Overhaul and Repair Department.

The main mission of the Overhaul and Repair Department of the Naval Air Station is the direct support of the striking forces of the U. S. Navy air arm by the rework of aircraft, guided missiles, target drones, pneumatics, engines, accessories and components. This includes disassembly, cleaning, examining, repairing, modification, modernization, assembly, test, inspection, preservation, and packaging. To accomplish this mission, the Air Station Overhaul and Repair Department is staffed with 6,300 civilians and 100 military personnel.

The proposed materials handling system is for the Overhaul and Repair Department Building in which engines are disassembled, inspected and routed to various process shops for repair, modification, and other operations. At present, reciprocating engines, reaction and turbo prop engines are being processed. Normally, 10 days are required to completely disassemble an engine and send the parts through the processing shops. This activity requires 175,000 square feet of office and shop space and involves approximately 550 personnel.

The proposed materials handling system would replace 5 electric fork-lift trucks and 860 linear feet of overhead trolley conveyer, as well as eliminate the need for 14,500 fork-lift operator man-hours per year. In the present system, the fork-lift trucks use a 3 ft. x 3 ft. wood pallet for transporting the engine parts and the overhead conveyer transports parts in an 18 in. x 27 in. basket. The proposed tractor-trailer handling system will have 11 dispatching and receiving stations. The tractor is self-guided by following a magnetic field surrounding a guide path wire imbedded in the floor along a specified route. The tractor senses the location of the wire and controls its own front wheels. In the event that something remains in the path of the tractor, its radar scanning equipment will sense the object and actuate the tractor's stopping mechanism. Each of the 11 automated dispatching and receiving stations will have both an unloading and a loading conveyer. Pallet loads will be placed on the station's top level loading conveyer by production dispatchers using existing portable hydraulic lifts, and basket loads will be placed on the bottom level loading conveyer. Production dispatchers will program pallet and basket station destinations by selecting the proper button on the load destination programming console. The dispatching capacity of a station, in terms of the number of pallets and baskets, will vary from station to station, depending upon the load requirements of that particular station.



AUTOMATED MATERIAL HANDLING SYSTEM

Figure 1

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It is proposed that the tractor pull either 3 or 4 self-loading and unloading trailers, as indicated in Figure 1. Each trailer will be double-decked with 2 pallet compartments on the upper deck and 4 basket compartments on the lower deck. In the figure shown, we have a simultaneous loading and unloading of pallets as well as the loading of a basket on the trailer.

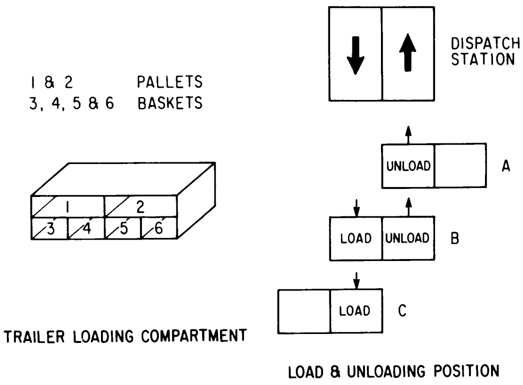


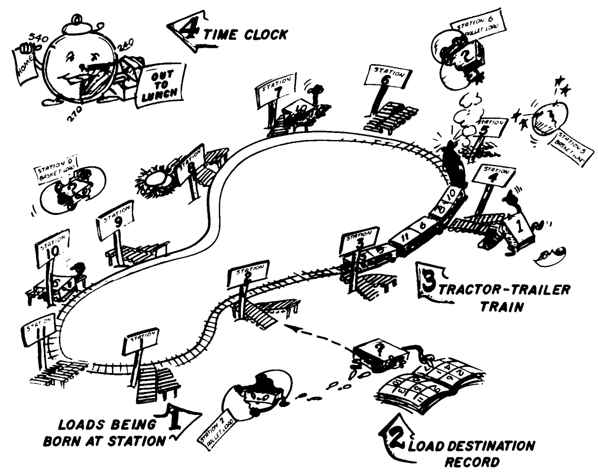
Figure 2

In Figure 2, we have indicated the loading and unloading positions the trailer may assume at the dispatching station and also have shown the trailer loading compartments for pallets and baskets. In Position A, the trailer may perform an unloading transaction. In Position B, the trailer may simultaneously unload to the dispatching station and receive a load from the dispatching station. In Position C, the trailer may perform only the transaction of receiving a load. The tractor-trailer train will operate at a maximum speed of $3\frac{1}{2}$ miles per hour and will only stop at a station in the event that either a loading or unloading transaction is required.

Up to this point, we have briefly considered the nature of the overhaul and repair operation at the Alameda Naval Air Station, the equipment that is presently being used for materials handling, and the equipment that is proposed for materials handling.

At the time it was decided that a simulation model be undertaken, it was found that the data available with respect to the system characteristics were not in a form suitable for a simulation analysis - a somewhat typical situation. In general, the system requirements with respect to the number of loads generated and the transfer of these loads were known. These data, which were collected by the production engineering group over a 10-day period, were analyzed and re-evaluated so that they could be used for formulating a simulation model. In order to formulate the simulation model, it was necessary to describe the transfer of loads from one department to another. Since the amount and depth of overhaul and repair for a given type of engine varies, the sequence of operations and the transfer of material could best be described by a probability transfer matrix. If a load destination chart is assembled indicating the number of loads transferred from a given station to each of the remaining stations, it is possible to calculate the probability of transfer based on the number or frequency of occurrences.

In addition, the study period revealed that on the average 750 basket and 375 pallet loads were generated daily in the system as a whole. In analyzing the arrival distribution of loads to each dispatching station, it was found that the hypothesis of a Poisson arrival distribution was acceptable. In terms of the simulation model, there was no significant difference in the number of loads generated in the morning as compared with the number of loads generated in the afternoon. The data obtained by the production group revealed that in some instances loads required as much as 3 to 4 hours for transfer. It was decided that the transfer of loads on the average should be within one hour.



TRACTOR-TRAILER SIMULATION MODEL ELEMENTS
Figure 3

Let's now consider the simulation model and its essential elements. The simulation model can be best described by considering four main elements of which we have already mentioned three: 1) the arrival or generation of load at the dispatching station; 2) the probability transfer matrix or load destination; 3) the tractor-trailer train system. All of the transactions or elements which describe the simulation of a tractor-trailer system are related to the fourth element, namely, clock or time.

Element number one, the generation of loads, is determined by a Monte Carlo technique whereby the interarrival time of loads at the dispatching station is calculated by the use of a random number generator from the Poisson arrival distribution. Element number two, the load destination, also involves a Monte Carlo technique whereby a random number generator is used in conjunction with the probability transfer matrix to determine the destination of a load. This is illustrated in the figure by the blindfolded or random manner in which the load destination is being selected. In considering the tractor-trailer system, element number three, the figure illustrates loads being transported as well as loads at various stations waiting to be picked up for transfer to their respective destinations. In the simulation model, all three of these elements are related to the clock, the fourth element.

Loads are generated for 240 minutes in the morning and also for 240 minutes in the afternoon. No loads are considered to be generated during the noon period from 240 to 270 minutes. The tractor-trailer train operates 540 minutes each day. Consequently, it performs loading and unloading operations during the noon period and for 30 minutes following the end of the shift.

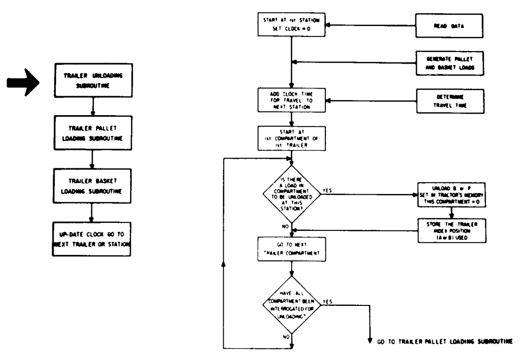
The simulation model block diagram is presented in Figures 4, 5 and 6:

Fig. 4. Trailer unloading subroutine which considers the travel time between stations and the trailer unloading transaction time.

Fig. 5. Trailer pallet loading subroutine involves the pallet loading transaction time and the pallet load destination.

Trailer basket loading subroutine which is similar to the pallet loading subroutine in that the loading transaction time and the destination of the baskets are determined.

Fig. 6 Up-date the clock and go to the next trailer or station. In this portion of the block diagram the loading and unloading transaction time is added to the clock time. In the event that there are loading or unloading transactions to be performed on the remaining trailers at this station, an iterative procedure is followed until all transactions of loading and unloading have been completed. The tractor-trailer train may then proceed to the next station.

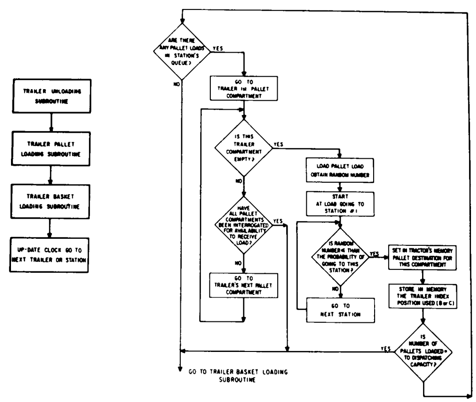


TRAILER UNLOADING SUBROUTINE

Figure 4

The block diagram, Figure 4, begins by reading in of data, such as; tractor speed, the number of trailers in the train, individual station dispatching capacity for pallets and baskets, probability transfer matrix, distance between stations, and the constants pertaining to the rate of generation of loads at each station.

The simulation program begins at the first station with the clock set at zero. The travel time to the next station is determined and added to the clock time. During this elapsed time it is determined whether pallet or basket loads have been generated. The tractor interrogates its memory system to determine if there are any loads in the first compartment of the first trailer to be unloaded at this station. If there is a load in a compartment to be unloaded, the basket or pallet is unloaded and the fact that this compartment is empty is set in the tractor's memory along with the index position so that subsequently the transaction time can be calculated. The next compartment of the first trailer is interrogated to determine

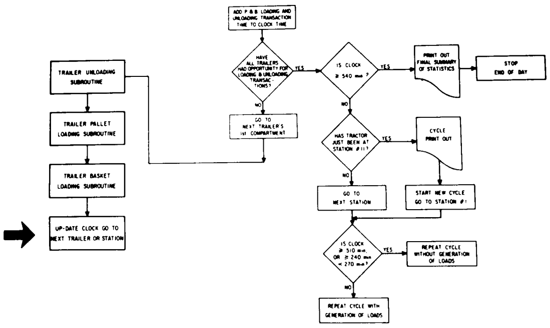


TRAILER PALLET LOADING SUBROUTINE

Figure 5

if a load is to be unloaded at this station. When all of the compartments in the first trailer have been interrogated or unloaded, then the pallet loading, Figure 5, subroutine is considered. If there are any pallet loads at the station to be loaded on the trailer, the tractor is interrogated to determine if the first pallet compartment of the first trailer is empty. If this is the case, the pallet is loaded on the trailer and a random number is generated for the purpose of determining the pallet destination using the following procedure: A random number value is compared with the probability of the pallet going to Station No. 1. If the random number value is equal to or less than the transfer probability of going to the first station, the pallet load is designated for Station 1. If the random number value is greater than the transfer probability of going to the first station, it is compared with going to the cumulative transfer probability of Stations 1, 2, 3, 4, etc., until the transfer probability is equal to or greater than the random number. The station at which the cumulative transfer probability is equal to or greater than the random number becomes the pallet load station destination and is set in the tractor's memory. As in the previous routine, the index position used is set in the tractor's memory. If the number of pallets loaded is equal to the dispatching capacity of the station, the loading of baskets is then considered. In a similar manner, the tractor is interrogated and baskets are loaded on the first trailer. The designation of the basket load destination is determined by the same procedure that was used for assigning the pallet load destinations.

Up to this point in the block diagram, all of the required loading and unloading transactions have been performed on the first trailer of the tractor-trailer system. As indicated in

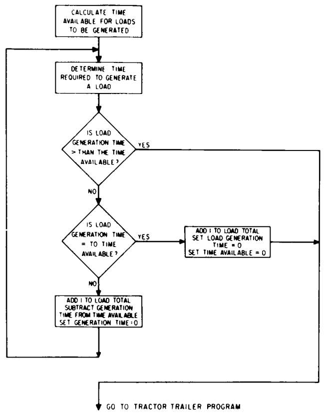


UP-DATE CLOCK GO TO NEXT TRAILER OR STATION

Figure 6

Figure 6, the total transaction time for the first trailer is calculated and added to the clock time. Since we have only considered the transactions which have taken place at the first trailer, the program proceeds to the next trailer and its first compartment and back to the first block diagram for the trailer unloading subroutine until all of the transactions for the trailers in the tractor-trailer system have been completed at this station. If the clock time is greater than 540 minutes the final summary of statistics is printed and the day's run is completed. If the clock time is less than 540 minutes, the tractor proceeds to the next station until it has reached Station 11 at which time a cycle print-out is made and a new cycle is started. If the clock time is equal to or greater than 510 minutes, the whole routine is repeated without the generation of loads. Likewise, if the clock time is equal to or greater than 240 minutes or less than 270 minutes, namely, the noon period, the cycle is repeated without the generation of loads. If the clock indicates it is not in any of these intervals, the cycle is repeated with generation of loads.

Let us now consider in more detail the subroutine for generation of loads referred to in the first block diagram and shown in Figure 7. In this routine, it is necessary to calculate two times; the time available for loads to be generated, and the time required



SUBROUTINE FOR GENERATION OF LOADS

Figure 7

to generate a load, which also could be expressed as the interarrival time of loads. If the load generation time is not greater than or equal to the time available, the load is recorded as arrived and the time required to generate this load is subtracted from the time available. This generation time is initialized to zero and the time required to generate the next load is determined. The generation of loads is repeated until the interarrival time is greater than the remaining time available. At this point the program returns to the tractor-trailer main program because we have generated all the loads in the time available. The last load generated will have to be evaluated at the next cycle with respect to the time available. The foregoing idealized block diagrams translated into computer language required approximately 450 FORTRAN Statements and involved 10 subroutines.

Let us examine the underlying reasons for approaching the solution of this materials handling problem by means of a simulation analysis which by now should be somewhat evident. Initially the system was approximated in a deterministic manner based on certain assumptions with respect to the loading and unloading time and the required number of loads to be transferred using a tractor-trailer system operating at a speed of $3\frac{1}{2}$ miles per hour. However, in such a deterministic approach, it was not possible to evaluate the stochastic nature of the materials handling requirements and the occurrence of simultaneous loading and unloading transactions. Although the dispatching capacity at each station is a function of its load generation rate, any deterministic calculation would not reveal the kinds of interaction which could occur. For example, a high loading capacity at a given station could result in using all of the available spaces on the trailer system and prevent subsequent stations from utilizing their dispatching capacity with attendant increase in the size of the queues and waiting time for the following stations. The simulation approach does not require a predetermination or guesstimate of the occupancy level of the trailer for an average cycle, in view of the fact that the randomness of load arrivals together with the destination of loads is an integral mathematical defined part of the model. Briefly then, by means of such a model an insight could be obtained of the stochastic interactions which might occur in a materials handling system of this type. Certainly, a most significant reason for considering a simulation model is the ease and facility with which design parameters can be investigated. By means of the simulation model and a computer program, it is possible to evaluate a given set of design parameters with $1\frac{1}{2}$ minutes of computer time for a 5-day period of materials handling operation.

```
AUTOMATED TRACTOR TRAILER TRAIN SIMULATION RUN    1 DATE 12  2400

INPUT DATA
    SPEED   308.0 FT PER MIN
    NUMBER OF TRAILERS      3
    INITIAL INDEX TIME 0.15 MIN
    TIME ADDITIONAL INDEX 0.17 MIN

LOADING DOCTRINE
    PALLETS  2  1  1  2  1  1  1  1  1  1  2
    BASKETS  3  2  2  3  3  2  6  1  1  1  3

DISTANCE BETWEEN STATIONS
  80.   85.  125.  170.   85.  115.  110.  120.  130.  135.   65. FEET

PROBABILITY TRANSFER MATRIX
    PALLETS
0.      0.13200 0.18100 0.11600 0.06900 0.06600 0.09900 0.      0.07100 0.18100 0.08500
0.06300 0.      0.23300 0.06300 0.13300 0.30800 0.03900 0.06000 0.08600 0.00700 0.00800
0.11500 0.18100 0.      0.11500 0.02700 0.17000 0.29700 0.      0.      0.02700 0.06800
0.05900 0.16300 0.14000 0.      0.14000 0.29000 0.03900 0.02600 0.03300 0.00900 0.10100
0.16000 0.40500 0.01700 0.07400 0.      0.09100 0.05200 0.08600 0.07200 0.02000 0.02300
0.09200 0.26900 0.05400 0.02900 0.43000 0.      0.08700 0.02700 0.      0.00300 0.00900
0.25100 0.08700 0.02600 0.01000 0.33600 0.15500 0.      0.00600 0.      0.03300 0.09600
0.63600 0.36400 0.      0.      0.      0.      0.      0.      0.      0.      0.
0.13600 0.13600 0.13600 0.18200 0.36500 0.04500 0.      0.      0.      0.      0.
0.02000 0.60800 0.      0.      0.      0.      0.17600 0.02000 0.17600 0.      0.
0.01800 0.24200 0.00900 0.12500 0.33500 0.07300 0.08400 0.00700 0.04100 0.06600 0.
    BASKETS
0.      0.11400 0.11800 0.00800 0.05100 0.01100 0.34600 0.00300 0.00500 0.11400 0.23000
0.01600 0.      0.02400 0.04000 0.15000 0.20500 0.17600 0.01400 0.21800 0.09400 0.06300
0.00500 0.078[illegible]  0.      0.08100 0.01400 0.10000 0.64900 0.      0.      0.02700 0.04600
0.074[illegible] 0.[illegible]  0.10600 0.      0.05600 0.06200 0.15800 0.10700 0.17300 0.04500 0.10200
0.01000 0.362[illegible] 0.04000 0.04700 0.      0.18500 0.09800 0.09000 0.11400 0.01700 0.03700
0.04700 0.52300 0.05900 0.05100 0.07800 0.      0.18500 0.05100 0.      0.00500 0.00100
0.01100 0.04000 0.00100 0.00700 0.79900 0.09400 0.      0.02800 0.      0.00700 0.01300
0.      0.99900 0.      0.      0.      0.      0.      0.      0.      0.      0.00100
0.      0.19400 0.03200 0.      0.58000 0.19400 0.      0.      0.      0.      0.
0.02400 0.09400 0.11800 0.42000 0.05700 0.01700 0.22100 0.03400 0.01500 0.      0.
0.02100 0.19200 0.07100 0.00800 0.18700 0.15900 0.15500 0.01000 0.07200 0.12500 0.
```

Figure 8

The input data of a typical run for the simulation computer model is shown in Figure 8. The input sheet shows the probability transfer matrix for both the pallets and the baskets, the distance between stations, and the loading doctrine or dispatching capacity of each station for pallets and baskets. In addition, there is indicated the trailer speed of 308 feet per minute; the number of trailers, in this particular case, 3; the initial index time, .15 mins., that is the time it takes the tractor-trailer train to position for the first transaction at a station; and the time for additional index, .17 mins., which is the average time required to make a loading or unloading transaction. If you will recall, reference was made to a cycle print-out on the fourth block diagram of the simulation model.

```
CYCLES COMPLETED    21.
CLOCK TIME 238.44

PALLETS GENERATED   3.   0.   1.   2.   0.   1.   1.   0.   0.   0.   2.
BASKETS GENERATED   0.   1.   2.   1.   2.   1.   6.   0.   0.   1.   5.

PALLETS UNLOADED    1.   4.   1.   1.   2.   1.   0.   0.   0.   0.   2.
BASKETS UNLOADED    0.   3.   1.   0.   7.   0.   5.   2.   0.   0.   0.

PALLETS   LOADED    1.   0.   1.   2.   1.   1.   1.   0.   0.   0.   2.
BASKETS   LOADED    0.   1.   2.   1.   3.   1.   6.   0.   0.   1.   3.

PALLETS WAITING     5.   0.   0.   5.   7.   0.   2.   0.   0.   0.   0.
BASKETS WAITING     6.   0.   2.   6.   2.   0.  10.   0.   0.   1.   6.
TRAILER NO.  1  COMPARTMENT STATUS     2.   5.   4.   7.   5.   2.
TRAILER NO.  2  COMPARTMENT STATUS     4.   0.   6.   2.   5.   5.
TRAILER NO.  3  COMPARTMENT STATUS     0.   0.   5.   5.   6.   9.
```

Figure 9

Figure 9 shows such a print-out of the 21st cycle for the data input previously mentioned. This cycle was completed at a clock time of 238.44 minutes, just a little over a minute before the noon period when generation of loads will be terminated. The print-out shows for each station the number of pallets and baskets generated, unloaded, loaded, and waiting. In addition, the trailer compartment status is indicated at the time the tractor-trailer left Station No. 11. Referring to Trailer No. 1 compartment status and reading from left to right, there is a pallet in the first compartment for Station No. 2, a pallet in the second compartment for Station No. 5, a basket in compartment no. 3 for Station 4, a basket in compartment no. 4 for Station No. 7, a basket in compartment no. 5 for Station 5, and a basket in compartment no. 6 for Station No. 2. It is interesting to note that for this cycle 12 pallets were unloaded and 9 pallets were loaded. This can be explained in that at the start of this cycle there were 6 pallet loads on the tractor-trailer train which were unloaded in cycle 21. Of the 9 pallets which were loaded in cycle 21, 6 were unloaded, accounting then for the total of 12 pallets unloaded and leaving on the tractor-trailer train 3 pallets as shown by the compartment status. If we were to look at the transactions which occur at a given station, cycle by cycle, we could plot data for a day's run such as shown in Figure 10.

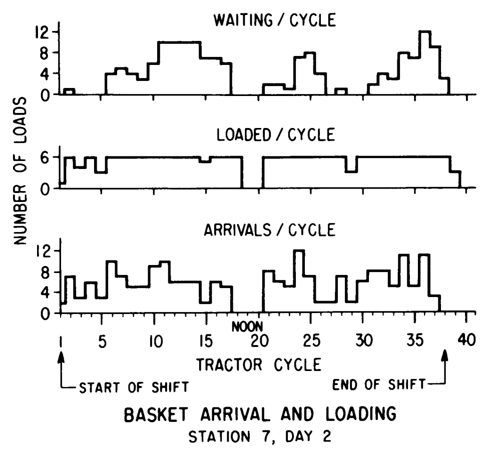


Figure 10

This figure shows, for Station 7, the basket arrivals, trailer loadings, and the status of the queue, cycle by cycle. The queue reaches a maximum of 10 in the morning and a maximum of 12 in the afternoon. The tractor-trailer was able to reduce the queue to zero during the noon period in one cycle. The graph clearly shows that there were very few cycles in which the station was not dispatching to its capacity of 6 loads per cycle. The arrival graph indicates a maximum number of 10 in the morning and 12 in the afternoon as well as no generation during the noon period.

SUMMARY OF STATISTICS RUN NUMBER 1

STATION NO. I=	1	2	3	4	5	6	7	8	9	10	11
MAX NO. OF PALLETS UNLOADED	2.00	5.00	2.00	2.00	3.00	3.00	3.00	2.00	2.00	2.00	2.00
MAX NO. OF BASKETS UNLOADED	3.00	5.00	3.00	2.00	8.00	5.00	5.00	2.00	3.00	2.00	3.00
AVE NO. OF PALLETS UNLOADED	0.44	1.72	0.72	0.44	1.10	0.94	0.54	0.20	0.28	0.40	0.26
AVE NO. OF BASKETS UNLOADED	0.23	1.28	0.76	0.70	4.38	1.24	2.50	0.56	0.62	0.66	[illegible]
MAX NO. OF PALLETS GENERATED	5.00	3.00	2.00	4.00	4.00	3.00	3.00	1.00	1.00	3.00	5.00
MAX NO. OF BASKETS GENERATED	9.00	4.00	4.00	6.00	5.00	4.00	10.00	0.	1.00	3.00	5.00
AVE NO. OF PALLETS GENERATED	1.38	0.60	0.38	1.30	0.98	0.58	0.62	0.04	0.02	0.24	1.00
AVE NO. OF BASKETS GENERATED	1.44	0.76	1.24	1.38	1.86	1.06	4.36	0.	0.16	0.74	1.70
MAX NO. OF PALLETS WAITING	6.00	3.00	3.00	8.00	10.00	4.00	3.00	1.00	1.00	3.00	5.00
MAX NO. OF BASKETS WAITING	15.00	4.00	4.00	10.00	6.00	4.00	22.00	0.	1.00	6.00	4.00
AVE NO. OF PALLETS WAITING	3.18	0.90	0.60	2.42	4.34	0.90	1.16	0.04	0.02	0.34	1.78
AVE NO. OF BASKETS WAITING	5.16	0.94	1.78	2.86	2.18	1.28	7.86	0.	0.18	2.00	[illegible]

Figure 11

The summary of statistics print-out for a day's run shown in Figure 11 lists information pertaining to the activity at each station.

In the next three figures, results will be presented for four different sets of design

	STATION / RUN	1	2	3	4	5	6	7	8	9	10	11
MAXIMUM BASKET QUEUE	1	10	4	9	10	7	5	15	0	1	3	7
	2	28	4	12	13	8	5	19	0	1	4	11
	13	8	4	7	8	9	6	19	0	1	5	7
	14	11	4	6	9	7	5	14	0	1	4	7
MAXIMUM PALLET QUEUE	1	8	4	3	6	5	5	3	1	1	2	5
	2	12	5	4	9	6	7	4	1	1	3	5
	13	9	9	3	11	10	8	3	1	1	2	5
	14	8	7	3	7	7	7	2	1	1	2	4

RUN	NO. TRAILERS	INITIAL INDEX TIME MIN.	STATION LOADING CAPACITY	1	2	3	4	5	6	7	8	9	10	11
1	4	0.25	B	6	4	2	6	4	4	8	2	2	2	4
2	3	0.25	P	3	2	1	3	2	2	4	1	1	1	2
13	4	0.25	B	3	2	2	3	3	2	6	1	1	1	3
14	3	0.10	P	2	1	1	2	1	1	1	1	1	1	2

Figure 12

parameters. In these runs, two sets of loading doctrines were used, one set for Runs No. 1 and 2, and the other for Runs 13 and 14. For example, looking at bottom of Figure 12 for Station 1, Runs 1 and 2 had a station loading capacity of 6 baskets, and for Runs 13 and 14, Station 1 had a basket loading capacity of 3. It should be noted that for Runs 1 and 2, the total load dispatching capacity for all stations was 66 loads per cycle, 44 baskets and 22 pallets. Runs 13 and 14 had a total station load dispatching capacity of 41 loads per cycle, 27 baskets and 14 pallets. Each of the runs represents 5 days of operation.

Let us first examine the maximum basket queues for the various stations and runs. It appears that the most significant differences occurred at Station No. 1. Run No. 2, Station 1, with a dispatching capacity of 6 baskets, had a queue size which far exceeded the size of the queue at the same station for Run No. 14 in which Station 1 had a dispatching capacity of 3 baskets. This indicates that in this instance the initial index time is far more sensitive in the reduction of queue size than the station loading capacity. The maximum pallet queue situation at Station No. 1 behaved in a somewhat similar fashion as the baskets.

	STATION / RUN	1	2	3	4	5	6	7	8	9	10	11
AVE. NO. BASKETS WAITING/CYCLE	1	3.09	0.98	3.15	2.32	2.57	1.37	6.00	0.01	0.10	0.80	2.30
	2	11.83	1.12	4.41	4.25	2.73	1.49	8.26	0.02	0.11	0.90	3.70
	13	2.71	1.28	2.77	2.48	3.93	2.20	8.15	0.01	0.10	1.56	2.73
	14	3.50	0.95	2.06	2.37	2.37	1.43	5.28	0.01	0.08	1.06	2.03
AVE. NO. PALLETS WAITING/CYCLE	1	2.59	1.33	0.69	2.19	1.45	1.16	0.70	0.05	0.03	0.37	1.37
	2	4.60	1.66	0.83	3.46	1.91	1.64	0.91	0.05	0.03	0.46	1.68
	13	4.07	4.00	0.72	4.11	4.20	3.43	1.15	0.03	0.03	0.37	1.43
	14	2.85	2.00	0.49	2.65	2.56	2.09	0.79	0.03	0.02	0.36	1.03

RUN	NO. TRAILERS	INITIAL INDEX TIME MIN.	STATION LOADING CAPACITY	1	2	3	4	5	6	7	8	9	10	11
1	4	0.25	B	6	4	2	6	4	4	8	2	2	2	4
2	3	0.25	P	3	2	1	3	2	2	4	1	1	1	2
13	4	0.25	B	3	2	2	3	3	2	6	1	1	1	3
14	3	0.10	P	2	1	1	2	1	1	1	1	1	1	2

Figure 13

Figure 13 shows the average number of baskets waiting per cycle and the average number of pallets waiting per cycle. Comparing Runs 1 and 13 for baskets waiting at Station No. 1, the average number of baskets waiting is greater for Run 1 than for Run 13, in spite of the fact that the basket loading dispatching capacity for Run 1 at Station No. 1 is 6 baskets while the basket dispatching capacity at Station No. 1 for Run 13 is 3 baskets.

The average number of baskets waiting for each of the other stations for Run 13 is only slightly larger than the number waiting for Run No. 1 with one exception, Station 3. However, the station loading capacity per cycle for the system is 27 baskets for Run 13 as compared to 44 baskets for the system per cycle for Run No. 1. Nevertheless, the average number of pallets waiting per cycle at the stations for Run No. 13 is greater than the number waiting for Run No. 1. In this instance, the average number of pallets waiting was sensitive to the loading dispatching capacity of the system.

STATION / RUN		1	2	3	4	5	6	7	8	9	10	11
1	B	21	12	26	17	15	14	19	12	12	14	15
	P	20	17	20	16	19	17	14	20	12	16	16
2	B	79	15	36	34	15	14	23	25	14	16	24
	P	35	21	25	26	25	20	21	13	13	27	18
13	B	18	17	22	19	22	21	22	13	13	28	18
	P	31	53	22	31	47	50	22	13	13	17	18
14	B	23	12	16	19	14	14	14	10	10	19	13
	P	22	26	14	30	20	32	15	10	10	16	12

AVERAGE SERVICE TIME - MINUTES

Figure 14

Before we decide against the system in which we have a total load dispatching capacity of 41 units, it may be well to look at another system criteria and also point out that the reduction in load dispatching capacity represents approximately $10,000 less in equipment investment. Since the original design criteria called for the transfer of loads on the average within one hour, let us examine in the next figure the average service time requirement. Run No. 2 is not acceptable in that the service time for baskets to Station No. 1 exceeds the criterion. Both Runs 13 and 14 with the reduced load dispatching capacity satisfy the system requirements with respect to average service time.

SUMMARY:

It seems appropriate in summarizing to mention that the Naval Air Station Industrial Planning Division engineers originally considered 5 different material handling systems, including the tractor-trailer system. Their economic analysis revealed that the system we have been considering here today was the most promising in that it would permit the overhaul and repair department to realize an estimated annual saving of $107,500 and the total project cost could be recovered in approximately one year.

It is believed the proposed handling system will significantly reduce the aircraft engine overhaul flow time. Such a potential is available because there will be a reduction in the parts delivery time. Presently, the overhead trolley conveyer which handles baskets operates on a 2-hour cycle time with service times exceeding this value, whereas the proposed system for baskets will operate on an average service time of less than 30 minutes.

The proposed system will undoubtedly introduce a pacing effect in materials handling since the servicing of the dispatching stations will require attention at relatively uniform intervals of time, namely, a tractor cycle.

The simulation computer model has flexibility so that it can be adapted to changing conditions of input parameters, for example, changing the number of stations, modify load generating rates for variations in the nature of input to overhaul facility, etc.

Last, but certainly not least, the development of a flow diagram portraying the logic of the system will be valuable in writing a proper set of bid specifications even if a computer program had never been undertaken.

In closing, I wish to acknowledge the assistance of Naval Air Station personnel and again thank the Navy for permission to make this analysis and presentation.

THE WILL TO WORK

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The industrial engineering approach to getting a day's work for a day's pay eventually met a point of diminishing returns some time ago. Consequently, in the '40s we introduced a "human relations" emphasis, which satisfied employees and management for a time. Now we find that their results--good attitudes and good morale--are not clearly related to measured productivity.

Clerical Workers at Prudential

A recent major study of motivation was reported by Morse and Reimer with Prudential Life Insurance Company employees. The company was interested in improving the organization and efficiency of four parallel clerical divisions, and decided to use two different approaches: one program of changes to be formulated and carried out by the clerical employees themselves in two of the divisions, and the second featuring the traditional planning and coordination of such a program in two other divisions by management personnel at higher echelons. Supervisors were trained in appropriate techniques of either getting participation and decision making from their subordinates, or getting prompt compliance to instructions from above. Careful before and after measures were made in order to determine which of the two approaches would be most effective, and included in these measures were comprehensive productivity and cost figures as well as employee attitude scores. The actual improvement program was in effect for about a year, so there was a good opportunity to measure results.

Actually, two important hypotheses were being tested: first, that employee participation in decisions that affect their work helps to develop attitudes that are favorable to work and to the company. Second, that participating in such decisions helps to improve employee productivity. The findings have significance for all open-minded managers.

First, it was found that the clerical groups that participated most ended up with the best attitudes towards work and the company. This does not mean that they learned to love their jobs. On the contrary, as in the case of most low-level clerical employees today, they found their work largely unsatisfying. Nevertheless, clerks in these "autonomous" experimental groups improved in their attitudes, while those in the non-democratic groups deteriorated in their attitudes toward work, supervision, and the company. The first hypothesis was thus proved.

With respect to group productivity and costs good results were obtained for <u>all</u> groups --with somewhat <u>better</u> results for the groups that were not allowed to share in decision-making! That is, when management ran the show, costs were cut quicker and productivity was increased faster than when rank-and-file employees pitched in. Note that participation by clerical employees <u>did</u> result in substantial improvement in productivity, but was not the fastest way of getting results. This is understandable. Management could dismiss employees, transfer them, or change systems quicker than most employees can, but this raised the question as to whether there would be better <u>long-term</u> gains when attitudes are favorable than in situations where the attitudes have deteriorated.

To summarize, employee participation paid off in morale and in productivity. Greater gains in productivity, however, were brought about by more traditional, autocratic action, although the duration of these gains may or may not be as impressive as those in the democratic groups.

Supervisors At United Parcel

Victor Vroom, conducted studies recently at United Parcel Service, to determine the relationships between participation and personality. Ways of dealing with individuals who show certain characteristics may not work with persons differently predisposed. The subjects were 108 first, second, and third line supervisors in the company's two largest plants. These supervisors were measured on five different scales; (1) participation, (2) attitude toward the job, (3) need for independence, (4) authoritarianism, and (5) job performance. Vroom verified several important hypotheses. First of all, the correlation between participation and attitude toward the job was significantly positive. That is, the supervisors who reported that they took an active part in making operating decisions also showed the best attitudes. In addition, significant differences were found between the magnitude of these positive correlations for different personality groups; strongest relationships were found for persons high in need for independence and low in authoritarian characteristics. The lowest positive relationships were found for persons weak in need for independence and strong in authoritarianism.

Next, participation was compared with job performance. Significant positive correlations for the total sample were found, supporting the hypothesis that participating in making work decisions tends to improve job performance.

To summarize, it was found that participation in decision-making has positive effects on attitudes and on job performance. It was found further that the magnitude of these effects is a function of certain personality characteristics of the participants. Authoritarians and persons with weak independence needs were relatively unaffected by the opportunity to participate in making decisions. In contrast, equalitarians and those who have strong independence needs developed, through democratic participation methods, more positive attitudes toward their jobs and greater motivation for effective performance.

Blue Collar Workers At General Motors

In a study by James Kennedy and Harry O'Neil at General Motors, an attempt was made to find out if simple jobs breed more worker discontent than complicated jobs. Only a few empirical studies have been addressed to this problem and these generally support the view that job simplification may be a prime source of employee frustration.

A survey of worker's opinions toward supervisors and the general work situation was administered to assemblers and utility workers in four production departments of a plant. These were hourly workers in departments located adjacent to one another along the assembly line, each department performing a set of comparable assembly operations as the line passed through their areas. The assembly and utility jobs differed in the following ways: each assembly operator performed a specific task or set of tasks with a cycle between one and two minutes. The tasks were either identical for each make and model of car or were only slightly different. Each assembly operator's job was highly repetitive, routine, deskilled, mechanically paced, and atomistic with respect to the final product. Each utility job was varied, and included relieving assembly operators for scheduled or emergency breaks, helping assembly operators who were unable to keep up with the line, demonstating the job to new operators, and completing or correcting operations that were done wrong by assembly operators. The biggest difference between the assembly operator's job and the utility man's job was that the former performed a single routine and repetitive task while the utility man performed a wide number of these same routine tasks — as many as twenty or thirty — for lengths of time varying between one minute and one day. The assembly operators had no freedom of discretion in the performance of his job. On the other hand, the utility men could exercise some discretion and choice as to which situation to handle and how to approach it. This describes the situation in departments A and B. Shortly before the study was conducted, the utility man's job in departments C and D was changed and expanded to include additional training and methods functions. At the time the opinion survey was made, department C had been assigned new utility men who had completed a special five-week training period on work methods. Department D had been assigned new utility men but they completed only half of the training program. Opinions of the workers in the various jobs and departments were then compared for possible differences.

The first interesting finding was that there was no significatn difference between the attitudes of the operators and the utility men in the first two departments. This seems to challenge the thesis that job simplification promotes unfavorable attitudes; if this were so, assembly operators should hold less favorable opinions than utility men.

There was a significant difference in attitudes between operators and utility men in Departments C and D, with the utility men more favorably disposed than the operators. The high utility scores in these departments may have resulted from good recent training, or from the fact that these were former operators who had recently been promoted to utility man. Another possibility was that the mere change in status, rather than job content, influenced their attitudes toward the favorable pole.

Judging from the results in A and B, the favorable attitudes of the new utility men in C and D might be only temporary, and later drop to the level of the rank and file assemblers. This would make an interesting follow-up study.

These findings have implications for advocates of job enlargement or job rotation. It appears that greater variety of tasks may not increase satisfaction unless the tasks are part of a unified and clearly integrated whole. Mere enlargement of the job by adding a wide variety of unrelated activities as was the case of the utility men, or by rotating workers from job to job, may not have helpful effects on attitudes and morale.

Accountants And Engineers in Pittsburgh

In 1959 Herzberg, Mausner, and Snyderman published a book titled The Motivation to Work which reports some provocative findings on job motivation. They asked accountants and engineers in nine firms in the Pittsburgh area to describe occasions during which they felt exceptionally good and exceptionally bad about their jobs. They wanted to find out, using subjective case histories, how events on the job shaped attitudes and motives. A sample of two hundred such men were selected and interviewed in depth.

The factors most frequently mentioned as sources of satisfaction were recognition, the nature of the job itself, achievement, responsibility and advancement. Those most frequently mentioned as sources of dissatisfaction involved company policy, company administration, and supervision. Considerable data were subjected to statistical analysis and yielded a wide variety of provocative insights and hypotheses. The authors wrote: "Let us summarize briefly our answer to the question, "What do people want from their jobs?" When our respondents reported feeling happy with their jobs, they most frequently described factors related to their tasks, to events that indicated they were successful in the performance of their work, and to the possibility of professional growth. Conversely, when feelings of unhappiness were reported, they were not associated with the job itself but with conditions that surrounded the doing of the job. These events suggested to the individual that the context in which he performs his work is unfair or disorganized and as such represent to him an unhealthy psychological work environment. Factors involved in these situations we call factors of hygiene, for they act in a manner analogous to medical hygiene. Hygiene operates to remove health hazards from the environment of man. It is not a curative; it is, rather, a preventive. Modern garbage disposal, water purification, and air pollution control do not cure diseases, but without them we should have many more diseases. Similarly, when there are deleterious factors in the context of a job they serve to bring about poor job attitudes. Improvement in these factors of hygiene will serve to remove the impediments to positive job attitudes... Among the factors of hygiene we have included supervision, interpersonal relations, physical working conditions, salary, company policies and administrative practices, benefits, and job security. When these factors deteriorate to a level below that which the employee considers acceptable, then job dissatisfaction ensues. However, the reverse does not hold true. When the job context can be characterized as optimal, we will not get dissatisfaction, but neither will we get much in the way of positive attitudes..."

"The factors that lead to positive job attitudes do so because they satisfy the individual's needs for self-actualization in his work...Man tends to actualize himself in every area of his life, and his job is one of the most important areas. The conditions that surround the doing of a job cannot give him this basic satisfaction; they do not have this potentiality. It is only from the performance that will reinforce his aspirations. It is clear that although the factors relating to the doing of the job and the factors defining the job context serve as goals for the employee, the nature of the motivating qualities of the two kinds of factors are essentially different."

The work of Herzberg and his colleagues indicates the necessity for going beyond the basics of most approaches to motivation; that is, beyond merely providing good wage incentives, company benefits, and policies, to the heart of the work situation; the job itself.

Some Other Recent Findings

What are some other findings by invistigators of motivation?

Briefly, the following appear important:

1. Supervisors with good attitudes towards employees -- considerate, interested, oriented toward their men -- tend to develop the more productive groups. Likert at the University of Michigan, for example, has found a correlation of .64 between such supervisory attitudes and productivity in 52 group studies! Similar studies at Ohio State University confirm these findings.

2. The size and composition of work groups also have a direct bearing on productivity. Overwhelming evidence is in favor of small, closeknit groups. Among the interesting research findings recently, there is the work of Rice, who was able to increase productivity by decreasing work group size, after getting disappointing results from the introduction of new equipment and machinery. Primarily, he broke large production groups into smaller segments, with dramatic results in efficiency.

What are the implications for management in some of these studies? They may be summarized as the following points:

1. Management should recognize that there exists a wide range of methods of motivating employees and supervisors to better performance.

2. Among these methods, experience and experimentation show that some produce better results that others, both in terms of morale and productivity. Each method must be handled carefully to avoid pitfalls. This requires considerable familiarity with the literature on motivation.

3. Management should audit what it is now doing to motivate employees, and attempt to evaluate the effectiveness of each.

4. Management should identify each major program that depends on employee support for success. It should then select an approach to motivation that might yield best results.

5. Management should not hesitate to try fresh approaches, or some variations of the promising ones reported above.

We have not fully tapped our employees' resources or fully stimulated their will to work. This is our challenge today.

MANAGEMENT BY INTEGRATION AND SELF-CONTROL

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INTRODUCTION

I propose to tell you about an experiment in management by integration and self-control which has been going on for two and one-half years in my company, Non-Linear Systems, Inc. We develop, manufacture, and sell precision instruments used in measuring the basic electrical quantities of voltage, resistance, and ratios of these quantities. Necessarily, therefore, we are strongly oriented toward the engineering approach.

Most of our top management are professional engineers with many years of experience. Over the years we have seen many spectacular engineering achievements. We have come to understand that no matter what the apparent difficulty of the technical problem, if enough time and money are available, the problem can very likely be solved. And so I suppose, after many years of engineering practice, technical achievement began to pall. Consciously or not, we sought new worlds to conquer. Our opportunities came as, in time, we moved from the practice of engineering to its management.

As we began to study the many areas of management, we came to see the need for new ways, better ways of managing for the accomplishment of the technical task. Early in our study we discovered that an engineering degree did not give us the license to manage an enterprise. Being engineers by training, however, we thought that we ought to approach the general problems of management on some kind of rational basis.

We found that there is at the disposal of the inquiring mind today a growing and comprehensive literature, the result of forty years of investigation by skilled and competent researchers in the problems of the manufacturing and business enterprise. This data covers a multitude of the aspects of organization. Many facets of human effort involved in the business or manufacturing enterprise have been searched out over the years. The literature is scattered over a broad spectrum of research activity. Contributions come from many fields--sociology, physchology, business management, industrial engineering, human relations, general semantics, anthropology. We became intrigued by the possibilities of applying this data to our business. We decided then to enter into an experiment to see if we could reorder and restructure our enterprise on the basis of this research. Our experiment lay in what we may now call the general field of management.

How does one go about managing an enterprise? There is no single subject that I know of which may be labeled management just as there is no single subject called engineering one can study. If we consider current management theory, we find a number of different schools. Each is at odds with the others, each defends its own position, each claims that the others have major deficiencies. In a recent article, Harold Koontz of UCLA, outlines the major schools of management theory. Briefly stated these are'

1. The Management Process School

   This group concerns itself primarily with the management as a process of getting things done through and with people operating in organized groups. Management theory is regarded as a way of organizing experience so that practice can be improved through research, testing, and teaching of fundamentals involved in the management process.

2. The Empirical School

   This approach identifies management as a study of experience. By studying cases in which management techniques of various kinds were tried, by examining successes and failures, it is felt that one can develop the abilities to deal with the problems of management.

3. The Human Behavior School

   This school believes that the essence of good management lies in understanding how people behave and interact in groups Using the psychologist's clinical eye, the proponents vary from those who see the human behavioral aspects of management as a portion of the management job to those who see it as the total job.

4. The Social System School

   This group views management as an intact social system based on cultural interrelationships. They develop from a sociological approach the theory of management based on cooperation of systems involving persons able and willing to communicate with each other and act toward the accomplishment of a conscious, common purpose.

5. The Decision Theory School

This school believes that the essence of management lies in making decisions. It therefore concentrates on decision making as the central core of management theory. As an apparent outgrowth of economic theory it uses the tools of the economics theorists to develop its theses, expanding these to include the whole spectrum of management activity.

6. The Mathematical School

The theoretical development of this approach to management theory is an expansion of the methods of operations research. Heavily emphasized are the establishment of mathematical models and processes. By use of these techniques, practitioners believe they can develop the best of the possible choices in the solutions of any management problem.

From the consideration of the various possibilities I have briefly outlined, it became apparent to us that we were indeed entangled in a prickly thicket of management theory. We resolved, therefore, to hack a path through the thorns by relying on our training in the engineering approach. Just as the engineer draws on the particular discipline he requires to solve an element of a problem, we determined to use whatever tool, from whatever discipline seemed appropriate, to try to solve the particular management problem in which we were engaged. If an engineer wishes to design a cantilever beam, he uses theory from mechanics and the strength of materials. If he wishes to determine the voltages and resistances in an electrical network, he uses circuit theory. So we concluded we must do with our management problems.

We would take what we could from the several schools of management theory. But we would not limit ourselves to these. We would employ management process theory, or psychology, or group behavior theory, or industrial engineering, or whatever field of study or discipline seemed indicated to solve our problems. But first we had to acquire insight into the totality of our fundamental problem, that is, the nature of the enterprise and its organization.

THE HIERARCHY OF THE ENTERPRISE

We ultimately determined that there were four levels of abstraction with which we had to contend in organizing and managing our enterprise.

The Total Enterprise. We concluded that the whole of the enterprise must be treated as an element of society. We had to define our business, its goals, and objectives. We had to consider the nature of its responsibility to the social structure of which it is part. We had to assure to the best of our ability its capacity to survive.

The Organization of the Enterprise. We had to define the organizational relationships within the enterprise: the formal structure, departmentation, and departmental interrelationships had to be determined.

The Nature of Organization of the Departments. The way in which departments were to be structured, the groups of people within the departments, and the nature of their internal operations were problems which we had to solve.

The Utilization of the Individual. We had to consider the most desirable ways of employing the individual worker. We had to explore, test, and define ways in which his relationship to the group and to other workers could be ordered for maximum total effectiveness.

These four categories mark what I term the organizational hierarchy. Many disciplines must be tapped to find appropriate answers for the multiplicity of problems in each. To see how we approach our experiment at each of these levels of abstraction in the hierarchy, we should probably most properly reverse the order of the hierarchy and consider first the problems of the individual.

THE INDIVIDUAL

Every business operates on the basis of some kind of philosophy. This philosophy is seldom overtly expressed, if indeed it is considered consciously by management at all. Nevertheless, it can be shown that the organization of any business enterprise stems directly from the philosophy of those who run it.

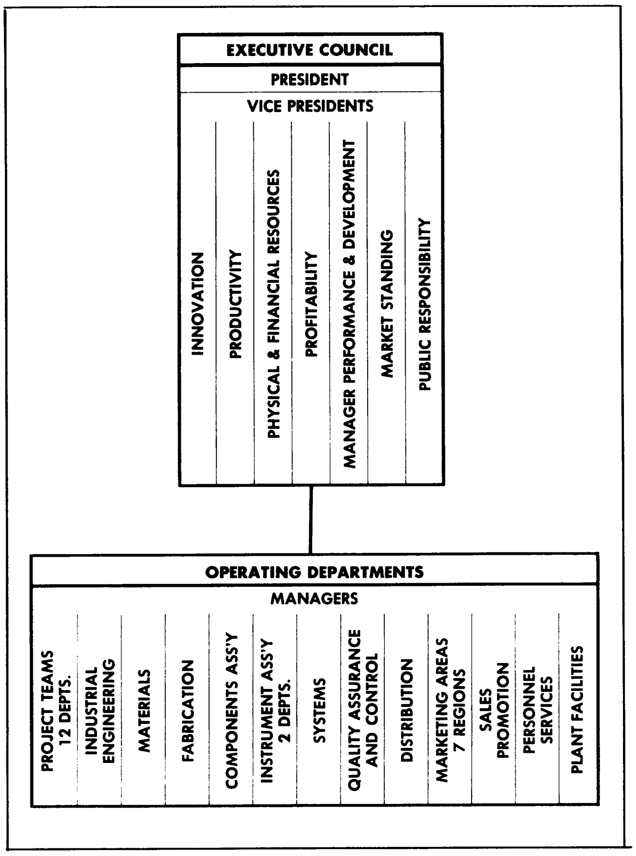
The business enterprise is a group of people banded together for the sake of an economic purpose. It is clear that the organizational structure and operational style must stem from management's view of the people who form the organization. The philosophical assumptions management makes about the behavior and nature of its people determine these patterns directly.

The covert traditional philosophy says that the employee is a pair of "hands." In fact, when industrial organizations hire people, they very often talk about hiring "hands." These hands are considered homogenous and interchangeable. They may be substituted readily for one another on the production line. Since production line tasks are usually cut down to a minimum number of small repetitive motions, no great skills are required. The tasks may be learned by the new worker with negligible training.

In addition, the average hand is thought to be really not very bright and essentially unmodifiable. He is inherently lazy, will shun work whenever possible, lacks sound judgement, is shortsighted and prone to error. On top of all this, he is probably a little dishonest. He must be watched closely if he is to give an honest measure of work for a day's pay. To sum up all these statements, we may say that he cannot be trusted. Therefore, the pattern and operational style of the organization are structured to detect and correct error. The kind of organization that results is very common in our conventional enterprise. It is often called the "accounting" model, displaying a complex pyramidal network of authority relationships with many layers of organization. The attendant difficulties in communication, the distortions in content, as directives and information flow up and down the communication ladder are well known to all of us.

On the other hand, what kind of organization emerges if management views the individual in a different fashion? Suppose we were to say that people are not "hands"; they are individual human beings. Each has a discrete and different complement of traits and talents. Suppose we assume that people are not lazy; work is a normal part of the business of living. Suppose we say that people are capable of being trained; their skills may be enlarged by adequate and proper coaching. They can do a bigger and better job if we make it possible for them to do so, if we assume that training is a major part of management's job. In addition, suppose we say that people are fundamentally honest; they can be trusted. We can tolerate error as a normal part of human endeavor so long as it remains within reasonable bounds. We can accept a mistake providing it isn't repeated. If we make these assumptions than we can organize our enterprise completely differently. We find then that we do not need time clocks to assure the worker is doing a full day's work. We can eliminate many layers of authority in the organization structure. We can improve our communications by shortening and paralleling the channels. We can adopt something closely resembling the organizational structure we are trying in our experiment at Non-Linear Systems, Inc.

If you will examine the diagram of our basic organization on this page, you will see how the organizational pattern at Non-Linear Systems looks. In it you will find a group of eight men in the top block called the Executive Council. This is the executive management of the company. It is concerned with the establishment of goals, the definition of the business, and over-all strategic planning. The next level, that of departments, involves those functions requiring day-to-day operations. The managers of these departments are concerned with tactical operations. They do the planning needed for day-by-day work, for procurement, for manufacturing, for sales, for collecting the monies for sales, for recording personnel data, for maintaining the plant, and so on.



Organization Chart, Non-Linear Systems, Inc.

Significant in our experimental approach to management is the way individuals are organized into working groups. We use the group method in every department in our company. Groups range in size from three to nine people. As an instance of how the group works, we might look at our engineering operation. The engineering group is known as a project team. It is under the management of a project manager. He is a highly-skilled, competent, experienced, electronic engineer. He has working with him in the minimum size group of three, a product designer and an electronic technician. Each project group works in its own rooms; sometimes two, sometimes three rooms. The project manager occupies a private office. His product designer has a private office and his technician works in a development laboratory next to the other two rooms. When a new project is started, the project manager receives from the Executive Council a specification for the instrument. The specification consists of a small sketch plus inputs, outputs, and tolerances. There may be some explanatory notes. An indication of the approximate sales price of the instrument tells the project manager how much he can spend for parts in the production instrument. He studies the specification and comes back with his recommendations. After consultation with the Executive Council, the changes that seem reasonable or desirable are made in the specification. The manager is told to go ahead with his work. He may now proceed in his individual fashion with the development of the instrument. He can buy any item he needs without countersignature as long as the amount does not exceed $2500. He develops the instrument. In time he comes up with an engineering prototype. His product designer and his technician have worked closely with him through all phases of the job.

When the prototype is ready, the Executive Council examines it. If we find that it meets its specifications and looks satisfactory generally, we proceeded into production. If there are deficiencies, we may ask that further development work be done. When we consider the item ready for production, we assign one or two people from an instrument assembly department to help build several prototypes. This is usually done in the project manager's quarters. We use the prototypes for sales, reserving one for a production model. Meanwhile the project manager and his little group have produced the necessary drawings and technical data needed for production.

We believe that the project manager should develop the original instrument, help build the production prototypes, consult with the people in our assembly department who must put it together, stay cognizant of technical and production problems throughout the active life of the instrument. The project manager has authority in technical matters as long as the instrument is made. No one may make a change in the design without his approval.

Now let us look at an instrument assembly department as an example of how a manufacturing group works. The average group in instrument assembly has seven people. One of the seven is an expert electronic technician. He has had years of experience and is extremely competent technically. He is known as an assistant assembly department manager. The group itself is made up of all kinds of people. When we made the switch from our old assembly lines two and one-half years ago to the present group method, we did not fire anyone. We simply reorganized the available people into groups of seven each.

Each group in the instrument assembly department is self-contained. By this I mean they do the whole job. They put complete instruments together from kits of parts, electrical components and hardware. They place components on the etched circuit boards, do the soldering, fabricate harnessing. They build up the hardware from the pieces delivered with the kits and assemble the total instrument. They then run the machines in, calibrate them, troubleshoot and repair if necessary. When they get all through, they sign the quality assurance tag on the instrument and place it in its shipping box.

There is no formal planning. The members of the group decide who will do what by mutual consent and decision. They know each other's strengths and weaknesses and will generally do a far better job of planning when left alone than if directed by some kind of authority.

There are some very interesting things happening in these groups. The capabilities of the people have been developed in two and one-half years to the point where they are able to write their own instructions for procedure in assembly. They write their own troubleshooting instructions. They help each other; they help members of other groups; they help write the service manuals we require for each instrument. They have acquired the skills and knowledge to build half a dozen or so different kinds of instruments in each group. By the way, as a company we manufacture over forty different kinds of standard instruments. It is very interesting to walk through the rooms where these groups are operating. You will see some groups building several different kinds of instruments, for example. They seem able to adjust readily and to accomodate to changes from one kind of an instrument to another with no apparent disorganization. It seems very clear to us that the experiment is showing markedly improved performance of the people in the instrument assembly groups since the change in the organization of two and one-half years ago. In fact, production figures now show performance 30% better than any time in the company's history.

Now I said that there is no formal planning in the procedures in these departments. By that I mean we do not have a formal planning office in our company. The planning done within the groups results from the group's ideas of what should be done and when things should be done. However, the total work of the instrument assembly departments must be planned from week to week. We accomplish this kind of planning by what we call our reservoir system of operation. The Executive Council establishes maximum and minimum quantities for each kind of instrument we build. We change the mix from time to time as conditions in the sales areas change. Now all the instrument assembly managers have to do to find what kinds of instruments to build next is to count the number of instruments in each stack in the storeroom, check against maximum and minimum quantities, and thus determine what instruments to stop and start building during the next few weeks. Additional data comes from weekly meetings of the instrument assembly department managers with managers of several other departments. Among these are representatives from the materials department, which is responsible for buying parts and components, and the distribution department which has inputs from the sales regions all over the country. The managers thus receive some notion of what sales prospects are for the next few weeks and even months. The instrument assembly department managers use this data in making calculated decisions to adjust their product mix.

The reservoir concept as I have described it for instrument assembly represents an idea we are experimenting with throughout the whole company. We believe that it is possible to develop reservoirs in all areas of operation in the company. These reservoirs produce what might be called feedback in a servosystem. Operations of the department are adjusted in accordance with the command signals of feedback from the reservoirs. For example, in our components department which makes precision wire wound resistors, stepping switch assemblies, and cable harnesses, a reservoir system similar to that in instrument assembly becomes readily workable. In the distribution department the reservoir consists of backlog of orders as yet unfilled. In the sales regions we have an idea that the reservoir concept can be developed in terms of potential for making sales and for creating new customers.

THE DEPARTMENTAL SYSTEM

We should now look at the structure of organization delineated by the department system in the organizational chart. One must ask the question when setting up the structure of an enterprise: What is the logical sequence or process by which to get from idea through development, production, sales, collection of receipts for sales, and to perform all the necessary other functions to keep the enterprise running? That is what we did in considering the structure of our departmental relationships. We tried to organize our company by the logical flow of process in getting from idea through development, sales, and collection of receipts.

We therefore set up our organization as shown on the chart, starting with development of the product in the project teams. Each department to the right represents the next logical step in the total process. The significant point in this is: We have at our command a very simple straightforward procedure to accommodate growth. All we have to do is duplicate departments. For example, we have twelve project teams shown in engineering. We have two instrument assembly departments. If it becomes necessary for the purpose of our continued growth to add engineering strength, all we have to do is create one, two, three, or as many new project teams as required. If we need more productive capacity for the assembly of instruments, we merely parallel the two departments we have with one, two, three, or four or more. We can do this in the other departments as required.

It is our opinion that the total department should be kept small, certainly not over fifty people. In this way we find that our strength of management is concentrated in depth in the performance of the job. We do not have to spread our management thin. We concentrate it so that its power is felt through every detail of the operation. We are able to sweep out the cobwebs from the dusty corners. We think this is a very effective way to use people; we think this is very efficient in total performance. We think we have discovered a simple key toward the perfection of our own operations as we aim to future growth.

THE TOTAL ENTERPRISE

The last level of abstration in the organization of our company might be called the total enterprise. This consists of the whole organization as it is indicated on the chart. As I mentioned before, the Executive Council is comprised of eight members. In addition to the president, who is chief officer of the Executive Council, we have a vice president for each of the eight areas in which objectives must be set and accomplishments measured in any kind of business enterprise.

The Executive Council is a strategic operating group. It plans for the long-range growth and accomplishment of the company. It sets the product line strategy. It establishes the policies governing the operation of the company and the departments. It initiates action in the eight areas of management, for example, innovation: the creation of customers, the creation of new ideas for new products, the creation of new ways of doing things in our company. We believe that the activities in these eight areas thread through the whole fabric of our operation. We do not compartmentalize the efforts of our vice presidents by rigid proscription. Each of the vice presidents works from what might be termed anchor points within his general area of operation. It is apparent that there will be times when there are overlaps in the functions of these executives. Therefore, we prefer to use the term anchor points to describe the key points from which each man operates. When there are problems of overlap, the vice presidents resolve the situation between themselves.

The departmental organization which I have previously described reports to the Executive Council in terms of functions. For example, problems having to do with capital investment are referred to the Vice President, Physical and Financial Resources; problems having to do with setting of prices go to the Vice President, Profitability, and so on.

We are oftentimes asked, "What will you do when you grow? Is your present organizational pattern good enough to carry you as you get larger?" Or sometimes we are asked, "How large can you grow before the present organization becomes ineffective?" We must truthfully say that we do not know the answers to these questions yet. We think that the present form of organization will be operable until we grow to two or three times our present size, that is, until the number of people in the company total somewhere between six and twelve hundred. At that time we expect that we shall grow by federal decentralization. This is growth in the fashion of the amoeba proteus. It puts out a little element which enlarges, carrying with it a portion of the nucleus of the parent cell. The element then separates from its parent. It continues to grow by itself and finally reproduces its parent in size. In other words, there become two entities similar to the original one. So we hope it will be with our company. When we reach the point of division we will probably split off on the basis of a somewhat different product line. We will very likely establish our division in some other geographical area. This division of the company will be set up in the same way as at Del Mar. That is, it will have its Executive Council and its departmental organization. The two divisions then will report through their Executive Councils to a central council, one added step in the hierarchy. We are of course, in the realm of considerable speculation. We do not know just how our plans will eventuate, but we expect to apply the same approach in the solution of these future problems as we have in trying to solve the ones with which we now live daily.

We have now briefly considered some of the ideas in what we call management by integration and self-control. The central core of ideas in this kind of management demands that the individual know what part he plays in the achievement of company goals. A management approach based on trust provides the permissive atmosphere in which he can set his own objectives, initate and carry through the appropriate activities required to achieve these objectives. The resources of the individual are more fully employed in this activity. His abilities are used and improved by training. He becomes a better human being and a better citizen. The enterprise begins to pay off its debt to society.

CONCLUSION

In concluding my remarks, it might be fruitful to consider briefly some of the philosophical implications of my thesis. Each economic enterprise is an organ of society. In the words of Professor Theodore J. Kreps, of Stanford University. "The economic enterprise is a way of life. It is not simply a segment of the community cooperating or competing with other segments, such as labor, consumers, or farmers. It is the community getting its daily bread. Its goals, its ethics, its welfare are inseparable from the goals and aspirations and welfare of the community."

The enterprise is therefore permitted to operate freely and openly under the mandate of the public. It may freely innovate new directions for growth, method, and scope of operation so long as it stays within the legal bounds which derive from the public consensus. So long as the enterprise does not violate the ultimate formulations of what society considers good it is free to pursue its future as it sees fit. In turn, it owes to the society which fosters it, obligations which it must honor. If it fails to honor its debts, it will ultimately perish under the remorseless pressure of social opinion.

Since the enterprise is the fundamental wealth-producing agent in our society, it must number among its foremost tasks that of survival. To survive, it must produce economic and social good. Its future, to be secure, must rest on a foundation of production for maximum utility. Only in this way can the markets it creates endure. Its operations must be fundamentally ethical; in conduct and act, its behavior must be ethical.

The enterprise in the same sense as man may be considered a time-binding entity. To endure under the public consensus, it must transmit social good through time. It must evolve by developing more socially valuable characteristics. Ultimately the value of its social contributions must devolve on its consideration and treatment of the smallest component of both its own structure and that of society--the individual.

We believe that the future of our economic and political society depends explicitly on the way in which we view and treat the individual. If we provide the kind of milieu in our industries such as that possible in managing by integration and self-control, if we encourage the intellectual growth of our individual workers, if we tap the latent resources of their minds, we cannot help but improve our industrial enterprise itself. We increase the capabilities of our people for becoming better citizens. We make the best social contributions in meeting the obligations of our enterprise to our community, city, state, nation indeed, the community of man.

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MANAGEMENT OF RESEARCH AND DEVELOPMENT

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Management in the broad sense is the process by which raw materials, men, and machines are organized to achieve an objective. For the accomplishment of the management process, we need, first, a vision of the objective to be achieved; second, detailed plans concerning the route, or routes, to be followed in reaching the objective; third, individual motivations for the people concerned which may or may not be related to the objective to be achieved; and lastly, we need a mechanism for evaluation which will tell us how well our management process has succeeded in achieving its goals.

SETTING OBJECTIVES

The manager in setting the objectives for his organization performs his most difficult and important function. In a completely planned society he might write in to the central planning authority and receive a copy of the mission for his organization with enough detail to relieve him of the goal-setting responsibility and allow him to proceed directly to plans. However, most of us would probably object to this procedure. We have an intuitive feeling that we want to set our own objectives without too specific guidelines and we would like to be judged by competition. This is the basic process in a free competitive system such as capitalism. It has only very broad general objectives, such as producing more goods, and each individual organizational entity can set its own local objectives and procedures to further the general goal. Our abilities to satisfy society's needs are judged by competition and rewarded by success or failure. This process provides high incentives and high motivation. People work best when they feel they have set their own objectives. The general management can be very loose and competition provides opportunities both to try and to judge all sorts of organizational procedures.

Paradoxically, this system seems to generate problems for itself merely because it becomes so successful that it satisfies all of our needs. At this point we are tempted to fall back on more centralized planning and more narrow definition of mission in order to control our output, rather than to undertake the more difficult task of broadening our objectives and increasing our needs so that competition can still have room to operate.

A similar paradox seems to operate also in Research and Military development. Here, too, the competitive system seems to function in such a manner as to overproduce and generate the need for more control. In Research we set a general goal of understanding the operation of Nature. Such an objective allows freedom for each research man to define his own areas of interest. Competition again provides a general management function as long as all the individuals can understand what the others are doing and can judge their own rate of progress relative to that of others. We again have a breakdown when the rate of progress exceeds our ability to absorb, and we have duplication through ignorance. This is obviously a waste and the demands for centralized planning come to the front. Again, we have a choice between broadening our ability to consume by discovering better methods for transmitting and absorbing information, or we can choose to limit production by instituting centralized planning as a substitute for individual goals.

In planning of military equipment with which I am most familiar, we have for centuries operated under the general objective of developing devices to more effectively destroy the enemy or his tools for making war. The competitive system to achieve this general goal does not have the rapid feedback characteristic of the other competitive systems because it requires a war in order to provide the checking process. However, until recently competition has been a very effective management system for achieving ever increasing effectiveness in our tools for warfare. Very little coordination and planning between nations has been necessary, and in fact within each nation also very little coordination between its different services has been used. We are now faced again with too much success. We have now developed, or soon will, the ability for any organization to achieve the means of killing all the people on earth. Again, through success of the competitive system we have overproduced and have developed strong pressures for more centralized planning and regulation.

To me, the crux of the problem of setting objectives for the management process is how to keep them broad enough and just impossible enough that people can generate their own methods of working toward these objectives and be judged by the impersonal process of competition. As each general goal tends to be reached, we have a choice between finding a better broader goal, or of slowing down progress by more central planning and curtailment of competition. I hope that the world will learn to generate enough more broad human objectives to allow each manager to set and follow his individual objectives and be judged by competition with his associates, rather than by some supreme centralized planner. I am not prepared to offer solutions in this area so let us assume we have an objective and proceed to our plans.

THE ESTABLISHMENT OF A PLAN

If a man knows where he is, and knows where he would like to be, then it would seem that a plan for getting from one place to the other would almost of necessity be obvious. Perhaps part of the present emphasis on the importance of planning comes from either having so many available routes open to us, or from the fact that sometimes our objectives are not clear and we are unable to specifically localize our present position. But in any case, from the manager's and budgeteer's standpoint, a planned course of action is essential if we are going to material the forces necessary to start moving.

Anyone who has managed research and development has generally experienced the violent reactions of research people to establishing detailed, specific plans for their work. I believe that this may very well be due to the fact that training in the scientific approach is a training in a method of procedure. Education of a man to do research makes the planning of his work so much a matter of second nature that he cannot understand why people are always asking him "foolish" questions about what he is going to do next. All scientific work proceeds according to a plan which is highly stylized; and if a man's work is not carried out according to this plan, he is judged by his compatriots to be incompetent.

In order to understand the research man's reaction, let us outline a work plan which can be used for any research program. First, we must find out where we are by studying the literature, contacting others in the field, and finding out where information is inadequate and where long standing questions are unresolved. Second, we must search for some new hypotheses as to how things work, or how questions might be better answered. Third, we must design experiments of a critical nature to test the hypoteheses which have been generated. Fourth, we must build equipment and carry out the experiments. Fifth, we will find that about once in ten times the experiment will be successful and the results can be published, recognized, and form the foundation upon which further work can proceed. Nine times out of ten the experiments will simply lead to new questions, new hypotheses, and a repetitive process of experimentation. I believe that it is primarily this low probability of success which makes the research man react so violently to the adoption of institutionalized management controls, such as PERT, etc. Once he has committed himself to a course of action on paper, in words which very few people understand, he finds it extremely difficult to change his course of action as his results dictate. If what he was doing was not understood because of its advanced nature in the first place, then the reasons he feels contrained to change his method of approach will be equally misunderstood. The only impression one can expect to generate from the normal budgetary planning of research and development is that the ideas proposed generally do not work, and will need to eliminate nine-tenths of our research effort in order to make the whole organization profitable. This would be a reasonable course of action _if_ we could solve the problem of picking the man with the correct degree of omnipotence to be able to eliminate the nine-tenths of the work which is unprofitable without also throwing out the one-tenth which represents progress.

I believe that external or organizational planning for research should concern itself with planning for the support and tools needed to encourage and assist good men. But we must immediately face the problem of how to choose these men. Judgement with regard to good research men is not an impossible management problem. Such men can be distinguished by their knowledge of the state of the art and knowledge of where the specific problems lie in their particular field. They have a high degree of enthusiasm for their work; they have more ideas than they have time to try; and they generally give the impression of having fun in the accomplishment of their job.

We often hear the philosophy that research cannot be planned. I feel that this is a gross mis-statement. All types of activity should be planned if objectives are to be achieved; and, as we have suggested, research in particular is highly stylized in its planning. However, if it is good research of a truly creative nature, it should be sufficiently near to the boundaries of knowledge that very few people other than the research man involved will be able to understand or utilize the detailed plans which he will prepare. If he is forced to make such detailed breakdowns on paper in place of in his head, he can well be forced into spending most of his productive man-hours trying to justify, with mathematical rigor, things which are likely to start out as informed, intuitive guesses.

If a management organization can't understand or have access to research plans, then it will, of course, ask how can it be sure of achieving an end result on a time schedule which will allow the rest of its operations to proceed effectively and congruently? I am afraid that this is generally not possible. Plans and operations for the rest of the organization should be based on the known results of research rather than on the hope for a breakthrough. If an organization feels that it must have breakthroughs, then it should proceed on the basis of competitive programs with the expectations that approximately only one in ten of such programs will be successful in achieving the purpose intended. This will not mean that nine-tenths of their money is wasted, because the competitive situation will promote progress in all groups, but not necessarily toward the specific plan goal. The desire to complete a program ahead of their competitors will narrow the objectives of the competing groups and eliminate wandering. On the other hand, the group which wanders in spite of the competitive pressures may have a sufficiently good idea that it may repay the organization's expenditures on research and development for the next fifty years.

INDIVIDUAL MOTIVATIONS

Man is a planning and purposeful organism. Before he will operate effectively in any organization, he must have an individual motivation for the actions which he performs. The invention of money was the single most powerful tool in simplifying the manager's problem with regard to inspiring individual motivation. The needs of individual people can vary over a wide range. They include such things as food, housing, entertainment, power, etc. As long as these can all be expressed in terms of money, the manager's problem in handling individual motivation is simplified to controlling the single variable of salary. Large scale organized activity probably would not be possible without the simplication in the generation of motivation which is provided by the instrument of money. However, one of the peculiar problems in the management of research and development is that many of the motivations of research people seem to bear very little relationship to the money involved. The research man tends to be more interested in the importance of the job then he is in the salary involved provided the salary is sufficient to provide those of his needs which are common with other people, such as food and shelter. Money cannot buy for a man the recognition of the importance of his scientific work which he needs in order to feel secure as a person. In fact, it may work in the reverse direction. The desire to create, which is inherent in the true development man, can be implemented through the acquisition of money, but not if the money is achieved at the price of relinquishing his freedom of choice in the selection of what is to be created. Like creative men in other fields, the research or development man is likely to consider the expression of his personality through his work to be more important than financial returns from this work.

In order to motivate the research man, the manager must be sure that the objectives of the organization are worthwhile, that the individual worker can see a relationship between the things he wants to do and the things which the organization would like to accomplish as a whole, and that the organizational attitudes are such that he can feel a strong sense of accomplishment when the goals which he sets as an individual are accomplished for the organization.

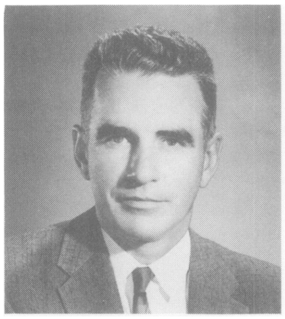
EVALUATION OF THE PRODUCT

For any organization or individual to feel successful there must be some mechanism for measuring the degree in which the goals which they have established have been fulfilled. In an organization which is profit-oriented, such an evaluation is straightforward, rigorous, and simple. If the figures are in the black, all associated with the organization are happy. If they are in the red, or tending toward the red, then something must be done to rectify the situation. Government organizations, military organizations, educational institutions, and research and development activities, whenever they are adequately removed from the profit making pressures, have a more difficult time in establishing a proper evaluation of the effectiveness of their processes and results. For all such organizations I believe the evaluation must be on the basis of competition similar to that involved in making a profit. The fact, however, that results cannot easily be expressed in terms of a single variable, such as money, tends to make the evaluation process much more difficult. Governments are judged by history, and military organizations by wars. These are very harsh and final judgements and do not provide a very adequate, self-rectifying mechanism.

I believe that one of the most useful things we can do to promote the improvement of research and development management processes would be to encourage mechanisms for evaluation competition between research groups. Instead of trying to eliminate duplication in the development of particular systems, we should concentrate on trying to establish generalized goals and techniques for judging the most satisfactory solution. Until publications become too voluminous to read, publication in technical journals performed part of this function for research. In the particular area of creative design, where I feel my special interest lies, I believe we should develop critieria for design, and evaluation procedures for design-critics very similar to those which have been developed in other artistic fields, such as music, paintings, sculpture, writing, etc. Such criteria are admittedly inaccurate, subjective and judgmental in character, but they do provide a kind of public recognition of achievement for skills which sometimes require a negotation of monetary reward for their proper expression. Evaluation of technical accomplishments is a function which needs seriously to be performed, and I believe it is one which society is now lacking.

To summarize, I believe that management for research and development is similar to other types of management in that it requires the establishment of an objective, the working out of a plan for accomplishment, the stimulation of individual motivation, and an evaluation of progress on the product in order to provide corrective mechanisms to insure continued improvement. It is particularly complicated by the fact that research people, in general, have individual motivations which cannot be adequately covered by the common denominator of money. Much more individual attention is therefore required on the part of the manager to take care of these differences in individual motivations.

Life would be easy if the management of research were as straightforward as I recently heard it expressed by a man concerned primarily with the management of funds. His process was to lay out a planned schedule for the accomplishment of research objectives. At the end of a period of time, he compared how the work was progressing relative to the established schedule. On the basis of this evaluation, those projects which were falling behind schedule were provided with increased amounts of funds taken from a constant budget at the expense of those projects which were proceeding ahead of schedule. If this highly plausible budgeteer's philosophy of management is applied generally throughout R & D organizations, I am sure that it is easy to see that all of our efforts will eventually be confined to impossible projects. I hope that this is not the case; but sometimes, when I look over some of our military programs, I become concerned that such a management technique may be at work undetected.



MANAGEMENT PROBLEMS IN A DYNAMIC SITUATION

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INTRODUCTION

Science and technology are progressing at a dramatic pace.

The consequences to all of us are evident. The potential consequences are the stuff of which dreams are made.

The word "impossible" has all but vanished from our vocabulary. We live in a "space age" - an "age of automation" - the "decade of the soaring Sixties." In our great scientific complexes we almost literally are scheduling inventions and technological breakthroughs. The day is not far off when machines will relieve us of much of the mental drudgery of thinking, just as machines relieved us of much of physical drudgery at the time of the Industrial Revolution.

We can foresee automatic crews, automatic oracles, automatic diagnostics, automatic designers, even - perish the thought - automatic secretaries. We can see new sources of foods and fibers, new means of communication, new methods of travel. Our progress is - just as it has been through recorded history - increasing geometrically, not arithmetically. For example, it has been calculated that 90 percent of all scientists who ever lived are living today.

We have seen the creation of whole new industries employing, directly or indirectly, millions of people. These have been constituted to exploit the galloping onrush of science. The majority are called "aerospace" or "electronic systems," because these are where the first needs were found and where the first money was channeled. But they are broadening into every phase of our life and can better be designated "scientific industries."

Advances in individual disciplines are so rapid that it is virtually impossible even for specialists to read even a significant fraction of all the scientific papers relating to their specialty. Further, scientific activities have moved out of the laboratories of a very few major universities and industrial concerns into literally thousands of companies throughout the world.

Those of us who are charged with the responsibility for managing this avalanche of scientific assets have come to realize, sometimes through bitter experience, that we are faced with new kinds of management problems. Furthermore, the solution of these problems demands some changes in time-honored management principles, perhaps less sensational but every bit as important as the changes wrought by the expanding universe of technology. Such facts have been repeatedly emphasized during the last ten years by lessons learned in the new, complex programs involving missiles, space and electronics. As a result, a whole new chapter of management principles and techniques is being written to deal with the dynamicism that characterizes the new industries of science.

FACTORS AFFECTING SCIENTIFIC INDUSTRY MANAGEMENT

A number of factors peculiar to the scientific industries are the principal sources of the dynamic management problems. Some of these factors are:

SMALL NUMBERS OF COMPLEX PRODUCTS

The products are complex and built in relatively small numbers. Each consists of large quantities of interconnected elements. Usually several different disciplines are involved such as chemistry, metallurgy, mechanics, thermodynamics, structures, aerodynamics, all types of electronics, human factors and the new discipline known as "reliability science."

HIGH TECHNICAL CONTENT

As a consequence of product complexity and multiple disciplines, the portion of total product cost associated with technical activities is becoming comparable with that associated with manufacturing, inspection and material. These hoards of technically trained, creative personnel must be motivated, coordinated, controlled and provided with facilities and equipment.

CONCURRENCY OF DEVELOPMENT AND PRODUCTION MEANS CHANGE

Production must be initiated long before the research and development have been completed. This makes inevitable a continuing pressure for design changes which must be evaluated, organized, analyzed for effects on other parts of the system, and controlled. As a result, long production runs of a frozen configuration are very unlikely. Nevertheless, the advantages of the concurrency concept seem to have been adequately demonstrated on a number of major programs from a cost as well as a schedule standpoint. This is because of the fact that, as the equipment becomes more complex, the effects of operational use are very difficult to anticipate in any normal R & D program. As a result, so many changes in production hardware may be expected from field experience that it is an advantage to be able to have an R & D program in being to verify the need for changes and the adequacy of the changes to solve the field problems.

GALLOPING OBSOLESCENCE

The rapid advance in technical specialties generates a rate of obsolescence which further reinforces the dynamic nature of management problems. This takes two forms - equipment which is rendered obsolete in conception by advances in techniques, ideas, components and materials; and first-generation equipment which acquires its obsolescence because of the inevitable imperfection of the first reduction to practice of new concepts. The scientific equipment industry is entering a new cycle of both types of obsolescence associated with the first introduction into complicated systems of those new products of solid state physics known generally as microelectronics.

CAPACITY TO SATISTY PENT-UP DEMAND

Industries dedicated to the exploitation of scientific assets are really in the business of creating new businesses. These involve not only new products, but complete new product lines. As a result, such industries must organize, capitalize and facilitize to create and fill a continuing succession of pent-up demands. This inevitably results in more capacity than is required for product lines to keep pace with markets generated only by early obsolescence. In addition, the types of organization, facilities and personnel needed for developing new product lines are substantially different from those which are optimum for a more steady-state type of operation.

SMALL NUMBERS OF COMPLEX CUSTOMER ORGANIZATIONS

Marketing activities must be geared to a relatively small number of highly complex customers. These customers are inevitably vulnerable to the same problems of internal coordination and communication that characterize any complex organization. Furthermore, the customers must be replete with a host of specialists - technical, production, reliability, financial, contract, operational, logistic and management - each of whom may have the authority to say "no" and therefore must be served and satisfied as much as possible.

A further characteristic of such complex customers is their demand for visibility into the detailed operations of their vendor's business. The extent of such visibility poses a major management problem involving a proper balance between the collection of information required to take action and make decisions; and the interference with progress which the generation of unnecessary information inevitably produces.

With such customer visibility goes a tendency to become concerned about detailed program problems and a consequent desire to "help" in their solution. A certain amount of this help can be useful, but once again, a management problem on the customer's side involves recognizing when to stop calling meetings, conducting surveys, instigating "for instance" study exercises and demanding reports which interfere with the ability of an organization's key people to spend time in solving the problems which cause the customer concern. Indeed, the situation can become so bad that the most qualified people in an organization can be rendered completely ineffective because of their requirement to oscillate almost continually from the customer with the questions to the second or third team members of the organization which now must be charged with the responsibility to provide the answers because they are the only ones with sufficient time to work the problems.

COMPLICATED CONTRACTUAL RELATIONS

Contractual relations are invariably complicated and tend more and more to involve a host of incentive clauses which provide bonus rewards for better than standard performance and penalties for substandard performance. These incentives may involve cost, equipment performance, reliability and delivery schedules. To complicate the matter even more, the tendency is growing to require fixed-price or fixed-price-incentive contracts even for large research and development programs.

NUMEROUS EXTERNAL INTERFACES

External interfaces are numerous and complicated. These not only involve direct customer agencies, but associate contractors and subcontractors. As a result, even the absolutely essential external communication and coordination requirements are tremendous.

COMPLICATED CONTRACTS DELAY DEFINITIZATIONS, INCREASE RISK AND REQUIRE MORE WORKING CAPITAL

A consequence of the customer complexity, combined with the inherent complexity of multi-incentive contracts for complex and unpredictable programs, is complexity in negotiation and contract definitization. Both the customer representatives and their industrial counterparts are dedicated to minimizing the duration of precontract activities as well as contract fact-finding and negotiation. Nevertheless, the increased complication of the whole operation, and the use of fixed-price contracts with limited progress payments, tend to extend periods during which the scientific industries usually cannot (if dealing with the government under present regulations) recover more than 70% of their costs. This poses problems of obtaining financial support considerably greater in magnitude and longer in duration than was required during the cost-plus-fixed-fee era of first-generation scientific systems. It also increases the financial risk of major disallowances.

Although such a situation may be considered a healthy manifestation of the operation of the free enterprise system, it does nevertheless constitute a significant increase in the financial problems attendant upon the management of scientific industries.

DIFFICULTIES OF COST AND SCHEDULE FORECASTING

Another management problem of the scientific industries concerns the forecasting of costs and schedules – particularly those associated with equipments or systems being developed and built for the first time. During the decade of the 1950's when both the products and the organizations were new, almost every major program fell victim to serious cost overruns and schedule slips.

The fact that there were as few financial casualties as there were among the scientific industries is only because the government customer (and ultimately the taxpayer) bore the brunt of such inaccuracies in forecasting via the medium of cost-plus-fixed-fee contracts. Many of us are familiar with the year-end rebudgeting, inevitably resulting in the stretchout, cutback, or cancellation of lower priority programs in order to obtain the funds required to finance overruns in high priority programs. The cause of such problems in forecasting involved the following considerations:

a. The only persons who could describe the product were scientists and engineers.

b. These scientists and engineers were often of the most advanced and creative type with no experience in production, field maintenance or operation. They sometimes seemed to feel that, once they had worked out an idea for solving a technical problem, some lesser beings without human fallibility would see that the idea was reduced to practice. They also were instinctively optimistic to the point where they biased their predictions of success without properly using even their own past experiences of failure. As a result, their estimates of cost and schedule were totally unrealistic – often by factors of several hundred percent.

c. The scientific industries themselves had no background of personnel or experience required for manufacturing, subcontract management, reliability, change control, maintenance, repair, and cost estimating.

d. The customer representatives had little experience with the new complex technical equipment or the industries which produced it. As a result, they often tended to play one contractor against another in a contest of promises with no means for evaluating their realism. This led to the "liars' contests" which were often so characteristic of competitions in the '50's.

e. The managements of the scientific industries were often either engineers or scientists with no general management experience or – just as bad – financial, marketing, legal or production experts with insufficient knowledge of the new technology to evaluate the estimates, promises and dreams of their "brilliant" technical staffs. Often, this lack of knowledge resulted in a tendency to approve little understood and unrealistic commitments, rather than risk appearing unprogressive. This tendency was underwritten by the fact that the cost-plus-fixed-fee contracts insured that the only risks involved percentage (not absolute) fee and reputation.

Although great progress has been made recently, the problem of forecasting costs and schedules for accomplishing complex objectives with no similar precedent remains one of the major management problems of today's scientific industries – particularly with the financial risks associated with modern fixed-price and incentive-penalty contracts.

DIFFICULTIES IN CONTROLLING COSTS AND SCHEDULES

Just as costs and schedules which can only originate in the minds of an organization's scientists are difficult to forecast – so are such costs and schedules, principally effected by highly intelligent and creative personnel, very difficult to control. This results from a number of factors:

a. The primary instinctive drive of creative personnel is toward perfection. This results in a tendency for such personnel to discover and conceive continual "improvements." Such improvements may be individually of small consequence to cost and schedule. Arrayed in their totality, they may result in changes which unreasonably and unnecessarily delay the final completion of anything, produce far-reaching changes in corollary equipments (often not recognized) and trade the solution of well-defined problems for a whole new set of problems whose existence has not even been suspected.

b. Most creative personnel instinctively disdain the use of ideas or techniques in their chosen specialty to which they themselves have not contributed. This makes it difficult for organizations involving large numbers of such personnel to avoid duplication of effort and achieve standardization of proven designs and techniques. Often, the creative individual takes refuge behind the rigorous (but unnecessary) requirements of specifications which require designs to be able to perform under highly improbably conditions. This is particularly inefficient under the many occasions when modification of the specifications would permit the use of a very much simpler or more standard, cheaper and proven design completely adequate to meet all but the most improbably conditions.

c. Large numbers of creative personnel – often highly specialized – working on many facets of a complex program provide extreme problems in communication. This results partly from the very large quantity and diversity of information which must be exchanged on a daily basis and partly from the fact that such creative personnel habitually abhor the routine records, procedures and disciplines which successfully handle large quantities of information among persons less steeped in originality.

d. Intensive specialists often have more difficulty understanding and speaking in terms and concepts outside of their specialty than less highly trained and less specialized individuals. For example, how many of us have heard briefings by electronic specialists to operational, financial or management experts in which the lingo used was replete with "db," "gain," "bandwidth," "nanoseconds" – plus an ample serving of alphabet soup to complete the incomprehensibility of the discourse to the audience? As a result, it is often found that coordination or joint action which, by procedure, should have taken place, in fact was not achieved. This can result in costly rework and delays involving critical parts of a program with consequent increases in costs for the whole program so delayed.

e. Complex systems, involving multiple interconnections inevitably will impose large demands for communication on the part of many key individuals. This reduces the time available for these individuals to carry out their non-communicative activities, thereby reducing their efficiency and productivity. Such reductions of time available to think are doubly destructive in scientific industries, because both their technical and management complexity require more consecutive time to review, analyze and synthesize than less dynamic operations.

Because of these factors, the control of costs and schedules in industry involving relatively large numbers of creative, scientific and specialized personnel constitutes a major management challenge for which many erstwhile "proven management techniques" need considerable modification.

TECHNICAL AND PROGRAM PROBLEMS MAY MAKE MANAGEMENTS LOSE SIGHT OF OWNERS' INTERESTS

Preoccupation of attention with the problems of meeting difficult commitments of equipment, technical characteristics, performance, schedule and cost may result in failure by the management of scientific industry to keep in proper perspective the complete financial obligation to its owners.

This obligation involves the exploitation of its organization's financial assets, proprietary positions and reputation as well as its strengths of personnel, creativity and facilities. It involves a ruthless dedication to maximizing the long term return on its owners' investment by meticulous attention to overall efficiency, accurate evaluation of market potentials and achievement of a profitable market position, as much by well-conceived license agreements, acquisitions or mergers as by investment in new product developments and their exploitation.

Such financial, marketing and long range planning activities – long the principal job of the top managements of industries with less product complexity and technical content – must take their proper place alongside the unusual problems of forecasting, financing, marketing, flexibility, motivation and communication on the dockets of the top managements of scientific industries.

LARGE PROGRAMS MEAN FLUCTUATIONS IN SALES AND NUMBERS OF PERSONNEL

Because of the tendency for end products of scientific industries to be involved in small numbers of very large projects which must progress through all phases – conception, development, production, field support and overhaul, it is very difficult for any but the very largest and most diversified of organizations to avoid serious fluctuations in sales, profits, and numbers and types of personnel.

SUMMARY

The foregoing factors delineate the peculiar management problems of today's complex scientific industries as arising from: small numbers of products of great physical and interdisciplinary complexity; requiring relatively high ratios of creative and technical personnel; involving concurrency of development.

production and field support; subject to the inroads of galloping obsolescence; tending to large oscillations in sales and numbers of personnel; requiring a continual creation of new products and product lines to avoid serious problems of excess capacity; involving a small number of complex customers demanging multi-incentive contracts; replete with the necessity for vast amounts of communication, coordination and control across external interfaces; with a requirement often not properly recognized, to exploit all of the assets allocated to each manager in a way to provide the best long term return on the owners' investment.

PRINCIPLES FOR SOLVING DYNAMIC MANAGEMENT PROBLEMS

It would be unrealistic to presume that a complete set of principles and techniques for the optimum solution of the management problems peculiar to a dynamic situation are even existent today. Too little experience has been gained from some of the actions which have been taken to provide an accurate evaluation of their successes. However, some broad and general principles can be enunciated which form a base from which to start.

These, in no way, should be assumed to replace or duplicate the vast background of good management principles and practices applicable to less dynamic situations. Such principles of good management, particularly involving administration and human relations, are equally applicable to the problems considered here. The discussions which will follow should, rather, be considered to represent areas for increased emphasis and supplemental information to normal good management practices.

DEMAND FOR FLEXIBILITY

The first of these is the principle of maximum flexibility. Nearly all of the characteristics mentioned previously require management actions capable of change - because the dominant feature of modern scientific industries is change - at rates often too rapid to be coped with by classical management techniques. This flexibility must reach into all elements of management activity.

Flexibility in People

Flexibility must begin with the motivation and training of the key people who determine the success of the organization.

First Loyalty Belongs to the Owners

The ultimate responsibility of all employees is to maximize the long-term return on the investment of the stockholders of the corporation. Management should bend every effort toward motivating employees to realize this, not only because of its truth, but also because it represents the surest signpost to correct overall decisions and action - particularly in the complex operations of the scientific industries. Such motivation demands a reversal of the natural instinct of people to give their greatest loyalty to the smallest organizational group with which they are identified. This does not mean that management should not foster the controlled competition among small groups which provides team spirit and motivation to increase output. It does mean that every employee's first loyalty must belong to the corporation as a whole because it is the only permanent entity in a situation where today's organization represents a temporary grouping of assets - hopefully optimum, but subject to change under the dynamic requirements of the business.

Motivation and Reward Must Identify and Emphasize Absolute Accomplishment

People must be taught to seek success through the excellence of absolute accomplishment as measured against the cost of obtaining such performance by an alternate means. This requires the development of methods for recognition and motivation, often unrelated to an organization chart. Thus, a brilliant scientist or idea man may be irreplaceable by thousands of individuals less peculiarly endowed. Such individuals should be able to obtain both financial recognition and organizational "status" without the necessity for dissipating their talents in directing the activities of large numbers of people. The dynamic factors of complexity, galloping obsolescence, concurrency of R & D with production, the necessity for continually creating new products, the risks attendant upon cost-plus-incentive-fee or fixed-price R & D contracts and the unusually high technical content of management decisions make it absolutely essential that a number of the very best brains available with broad technical capability and some experience in management be freed from administrative duties so that they can:

a. Review technical approaches on critical multidiscipline programs.
b. Lead task forces to investigate new ideas or solve critical technical problems.
c. Insure the solidity of the organization's proprietary position in new fields by generating and stimulating new ideas.
d. Insure the adequacy of the technical content of training programs.
e. Keep abreast of technical progress outside of their own organization.
f. Stimulate interchange of sound technical ideas within their own organization.
g. Advise line management on technical factors affecting management decisions.

Such rare individuals must have authority to effectively operate within the whole technical organization, and status at least commensurate with other line managers reporting to the same executive. These individuals may bear the title of "Chief Scientist" or "Vice President-Technology."

Correspondingly, individuals in management positions should be compensated and motivated toward advancement, not by how many people they have organizationally beneath them, but by how few they require to accomplish their assigned responsibilities.

Organizational Dynamicism Dictates Advancement by Lateral Moves

Because of the impermanence of any organizational entity but the corporation itself, motivation should be established, at least at higher levels of management, for advancement by lateral moves into new and different parts of the organization as much as by promotion vertically to take the jobs of their immediate superiors. This motivation is important, not only because of the realities of the organizational situation but, also, because by such motivation there is more tendency for objective collaboration and less likelihood of competition and "back-stabbing" between subordinates and their immediate superiors – thereby making feasible a much more effective use of "assistant managers" than is normally possible in a more static organization.

The Need for Broader Backgrounds

Further, regarding the requirement for flexibility among the people in a scientific business, it is important that they be trained in the arts of efficient communication – written and oral – involving disciplines beyond their own specialties. Thus, the manager must have a broad background which permits him to at least understand the motivations and language of creative, technical personnel. By the same token, such creative specialists must be schooled in the principles and language of contracts, manufacturing, sales, politics, finance and management to the extent necessary for them to take a broad and flexible view of the non-technical decisions which affect their assignments, budgets and environment.

The Need for Generalists

The need for breadth of background goes beyond the requirements for cooperation and communication among specialists. It is an important characteristic of many of the key management and technical personnel of a scientific industry. Such a need for "generalists" is becoming increasingly well-recognized in educational institutions and industry alike. These are not "Jacks of All Trades and Masters of None," but rather individuals whose training in several disciplines is cemented together with a firm foundation of technical fundamentals, practical experience in the real world beyond the ivory tower, complete objectivity – and an ability to specialize temporarily but intensively as necessary.

It is probable that the ultimate limitation to man's ability to exploit the on-rush of progress in individual disciplines, will be the number and capability of the generalists required to create, comprehend and control increasingly complex combinations of interacting elements, characteristics and human endeavors. As a result, one of the major problems of managing a scientific industry is to find or develop the relatively small number of generalists required to fill key management and engineering positions – particularly general managers, sales managers, program managers, engineering managers, project engineers and systems engineers. This is not only because the type of person with the mental acuity, memory and objectivity to absorb and effectively use a broad training is relatively rare – but also, means for developing such abilities are just beginning to be offered in universities and industrial training programs. Because such formalized training programs are in their infancy, it particularly behooves the scientific industries to cooperate with our national institutions of learning and with each other to accelerate progress in identifying the potential generalist and providing him with the optimum combination of motivation, training and experience.

It is probable that the best results can be obtained by intensive courses in the fundamentals of mathematics, physical sciences, business, speaking and writing combined with background courses in various specialties presented as applications of the fundamentals. These should then be interwoven with a liberal sprinkling of social, athletic and political activities involving qualitative factors and human relationships – all topped off with the responsibilities and experience of practical application of the training in temporary work requiring specialization. This last is most important in developing a true generalist (capable of understanding those specialties with which he must deal) as contrasted with a "wheeler and dealer," who often is capable only of a glib superficial appearance of many-faceted ability.

Organizational Flexibility

Principles Controlling Form of Organization

Another requirement for flexibility involves the organization itself. This includes not only the form of the organization, but the several factors which delineate its operation. First, with respect to those factors establishing the form of the organization:

Generally speaking, any organization can be made to work if its people are determined to make it successful. However, the principal criteria for establishing the form of the organization are the principles that:

a. Decisions must be made at the lowest competent level.
b. Essential communication must be expedited and rendered as efficient as possible (an important factor in geographical decentralization).
c. Each level of management must have clearly defined objectives and rela-

tionships with subordinates, peers and superiors.

d. Each manager must have consecutive time effectively to discharge his assigned responsibilities and wield his authority.

In modern, complex scientific businesses there are generally three types of organizational arrangement. These are "functional," "product," and "project."

The Functional Grouping

A functional organization involves the grouping of persons in accordance with similarity of specialization, discipline or skill. Thus, a functional organization gathers together separately those people engaged in research, design engineering, manufacturing, master scheduling, quality control, contract administration, pricing, sales, personnel, plant operation, logistic support, finance, administration, etc.

Such functional groupings almost inevitably are established at some level of every organization. This level depends upon the size of the whole organization; the maturity of the products being produced – maturity being measured in terms of lessening requirements for continual change – and whether the group's essential communications are inter- or intra-disciplinary. Thus, in almost all organizations, the lowest (from a standpoint of the organization chart) level of groupings is functional. However, in a steady-state business, having high production rates of stable products, in a single location, the functional groupings may extend throughout the whole organization. Similarly, organizations less than a given size will also most probably be optimized by a functional grouping.

Product Team Grouping

On the other hand, large scientific industries normally operate in such a continually transient condition that the functional organization is too much of a hindrance to effective teamwork if carried much beyond the third level. For such organizations, one or both of the other types of groupings normally appear at the highest level. Where the largest volume of activities of the personnel in the group is internal and aimed at producing a line of products which can be marketed as end items, the "product organization" is indicated. Such an organization normally is headed by a general manager with profit and loss responsibility and contains, in functional form, nearly all of the elements of an autonomous business – marketing (both sales and contract administration), material, manufacturing, quality assurance, engineering, master scheduling and administration. It may also have some or all of its own financial, personnel, logistic, industrial engineering and legal departments – or these may be supplied in toto or in part as centralized services.

Such a product organization is the prototype of decentralization. It has the advantage of providing a tight, efficient, internal communication system and a clear-cut identity for all of its personnel which can be a basis for powerful team motivation. It also tends to give individualism the best chance to flourish in the truest sense of the free enterprise system.

However, such product decentralization is only optimum by itself so long as the product line continues to flourish as a profitable, separate entity.

The characteristics of organizational esprit de corps and individualism which are the product organization's bulwarks of strength during periods of product health, tend to produce an inflexibility which renders cooperation and communication across the organization's boundaries very difficult. Then, when it is necessary to cooperate with other organizations to produce a composite product such as a weapon system or spacecraft – or when the market for the product line shrinks so that an organizational regrouping is indicated, the decentralized, self-sufficient, parochial, product organization with its team pride is often at a disadvantage compared with the less closely knit functional organization.

Project Grouping

The third type of organizational grouping combines a considerable fraction of all individuals working on a single, large contract, project or program (as it is now generally called). Such a "project organization" only has meaning in an organization which has several major projects – for if an organization grows up around a single major project, the whole organization is by definition a "project organization." In this most extreme example, a project organization includes all individuals working on the project and is headed by a general manager who is, at the same time, the "program" or "project manager." Within such an organization, there will certainly be one or more functional sub-organizations and, if the project is large enough, perhaps even sub-organization by major subsystem (which is somewhat similar to the product organization discussed previously).

The disadvantages of the project organization have been recognized for so long that they have actually delayed the establishment of such organizations. The greatest disadvantage is the fact that the project organization is impermanent. It lasts only as long as the project which it is formed to expedite. After the project is essentially completed, a major reassignment of key personnel and facilities must be effected. Indeed, the complete project organization never achieves stability, because its form, facilities, personnel and emphasis must be geared to the evolving phases of the project – from preliminary engineering, through development, to production and, finally, into logistic support. Such a history obviously requires a change in management characteristics, if not in managers themselves.

A second major argument against a project organization is that there are never enough good personnel to insure the optimum execution of each of a number of projects if each good man is not available for more than one project.

Nevertheless, it now appears that the requirements for very large amounts of coordination and communication across the organization's external interfaces – and the complexity of internal communication and coordination so necessary to insure the effective execution of today's military and space projects involving thousands of people, working to solve many parallel problems without precedent, on a tight schedule and a tight budget – can best be met by a project type of organization.

It is a fact that project grouping cannot ensure the application of the best men of the whole organization to each project as is theoretically possible in a functional grouping. But this has been shown to be a lesser evil than the complete saturation of these best men which often renders them less effective than others without so much native ability, but with enough uninterrupted time to apply their talents efficiently as they can in a project organization.

Again, impermanence and instability can be minimized by including only those functions whose general form is subject to minimal change as the project passes through various phases. Consequently, a project organization usually is embedded in a larger functional and/or product organization which normally includes a majority of the personnel assigned to the project – at least at peak effort.

In such an arrangement the project organization deals with the functional and/or product organizations somewhat as though they were subcontractors. Thus, the project organization is normally the guardian of specifications, schedules, and expenditures. It is also responsible for control and execution of communications across the external interfaces for the organization as a whole. In this way, it is the organization's chief representative to the customer and the customer's chief representative within the organization.

Early concepts of program management tended to favor a relatively small program management office having as its principal responsibility the more administrative functions of program control, master scheduling and interface, with a corresponding program office in the customer's organization. Such offices had little or no directive authority over the elements of the organization actually doing most of the work. They had to attempt to administer the program by persuasion and approval authority only.

Experience has shown, however, as programs have tended to get larger and more technical, that the original concept of a program office does not provide enough capability to justify the kind of directive authority over all principal program activities in the whole organization which has become evidently necessary for successful program control. As a result, the current trend in the management of large technical programs is toward a project organization much larger and broader in scope than an administrative office – with real authority to direct the activities of product or functional personnel assigned to the program.

The activities of such a project organization vary, depending upon the phase of the program. In its first phase, the project organization may include most of the personnel assigned to the program. This is because the primary efforts are analysis, system engineering and planning. As the program reaches a hardware phase, the project organization probably includes most of the following:

a. Formal customer contract
b. Systems engineering
c. Configuration control
d. Change control
e. Contract administration
f. Overall pricing
g. Reliability assurance
h. Master scheduling
i. Material review
j. Make-or-buy determination
k. System assembly
l. System test
m. Purchase, inspection, distribution and control of material peculiar to the program
n. Pilot-line production of elements peculiar to and critical for the program
o. Selection or approval of subcontractors
p. Approval of activities with associate contractors
q. Execution and/or approval of logistics support activities for the program

Actual hardware detailed design, non-unique material acquisition, subcontractor management, detailed manufacturing, detailed quality assurance, detailed logistic support and services – such as the personnel department, the financial department, the traffic department and plant maintenance, would be accomplished by the more permanent elements of the organization.

If a modern, scientific equipment program were to reach a steady-state condition, the need for the project organization could be greatly diminished, and it might be expected that the most efficient operation could be achieved with a return to the concept of the program administrative office.

The Compound Organization

The foregoing discussion of the three

principal types of organizational groupings has made it obvious that no single type is optimum for a large, multi-program scientific industry. As the result, it is not surprising to see attempts to solve the problems of flexibility and communication by organizations which involve combinations of functional, product and project groupings. In discussing such combinations, it is necessary to make certain that a clear understanding exists regarding the meaning of functional staff as opposed to line organizational activity.

As used here, functional staff activities involve no directive authority but, rather, include the following:

a. Expert advice and information to a line executive
b. Representation of the organization in functional activities such as committees, professional societies, and conventions
c. Establishment of functional policy
d. Establishment of functional operating procedures and practices
e. Evaluation of the applicability and use of functional policies, procedures and practices within the organization
f. Stimulation of communication among personnel engaged in functionally similar activities working in different organizational entities
g. Accumulation of functional statistics
h. Maintenance of a knowledge of the capability and assignments of top functional specialists throughout the whole organization as required to plan reassignments
i. Conduct of special functional studies
j. Formation and direction of crisis teams or "fire brigades" to solve critical problems in one part of the organization, with the help of other parts of the organization not normally involved in the problem
k. Establishment of the content of training programs within the functional specialty

In this connection, the staff activity does not normally involve control, although it often may be desirable for the superior line executive to require staff review and approval of commitments or plans which meet certain criteria of importance (such as dollar value).

In contrast, line management activity is concerned with the direction of personnel whose output contributes identifiably and measurably with the salable output of the organization as a whole.

In a multi-product, scientific business, the optimum combination may include a central functional staff straddling product organizations and project organizations. The central staff is in a position to plan for, and effect the redistribution of, assets required to meet changing market conditions. This often involves the planning necessary to form new project organizations to handle new major programs, or contracting other project organizations as their programs phase out.

The product organizations provide the main bulk of the organizational assets and the stabilizing influence to counter the transient effects of project organizations. This stability can be enhanced very greatly if the product organizations have major markets not involving the programs of the project organizations.

In contemplating such an organization it is desirable to consider a more or less continual flow of people into and out of the product organization for assignment either in project organizations or central staff organizations. This is partly the consequence of the changing phase of projects, and partly for its broadening effect upon the individuals who can gain experience in at least two of the three types of organization. Such personnel transfers ensure flexibility, promote improved communication, increase the objectivity of individuals and establish the motivation for promotion by lateral movement as contrasted with competition for in-line positions. They also tend to minimize the parochialism which normally grows within permanently established teams, thereby making it possible for the degree of cooperation and efficiency of communication so essential in the scientific industries.

Hypothetical Organizational Arrangement

Figure 1 shows a hypothetical organization of product, project and staff-service functions arranged in three top-level groupings. These are assumed to be 3 project divisions, 5 product divisions, a systems division and 10 staff-service functional divisions.

The systems division is an organization constituted to perform studies, analyses and preliminary designs of systems, making use of the products of more than one product division. It also assumes the lead in preparing system proposals, promoting system sales and negotiating the first system contracts following successful proposals. In these pre-proposal and proposal activities it assumes the lead of temporary teams recruited from product and functional staff divisions. These teams normally form the structure on which a project division is constructed to execute a successful major systems program.

The existence of 19 separate top level organizations poses a span-or-control problem for the executive office. Three methods illustrated by organizations A, B or C provide possible solutions to this problem. Each has advantages and disadvantages depending upon the individuals involved and the character of the business. In all of them, the President is assumed to have to be free for a considerable amount of operation across external interfaces. It should also be noted that all three organizations are careful to maintain the functional staff executives of the same organizational level as the line executives. This appears to

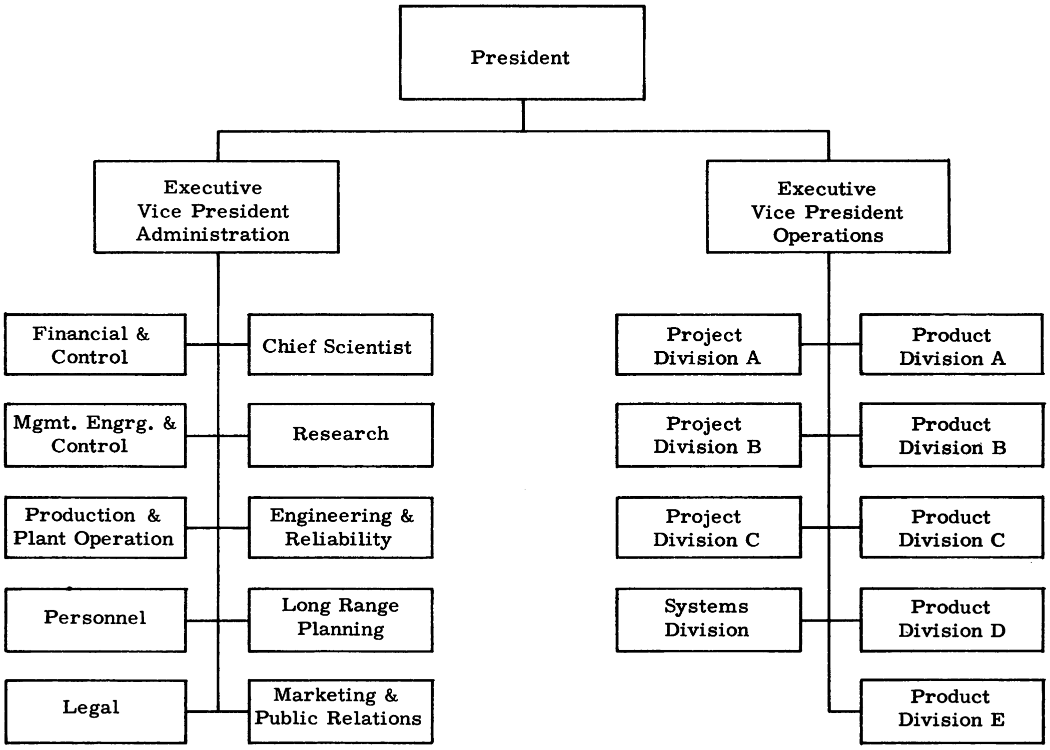

Figure 1-A: ORGANIZATION A

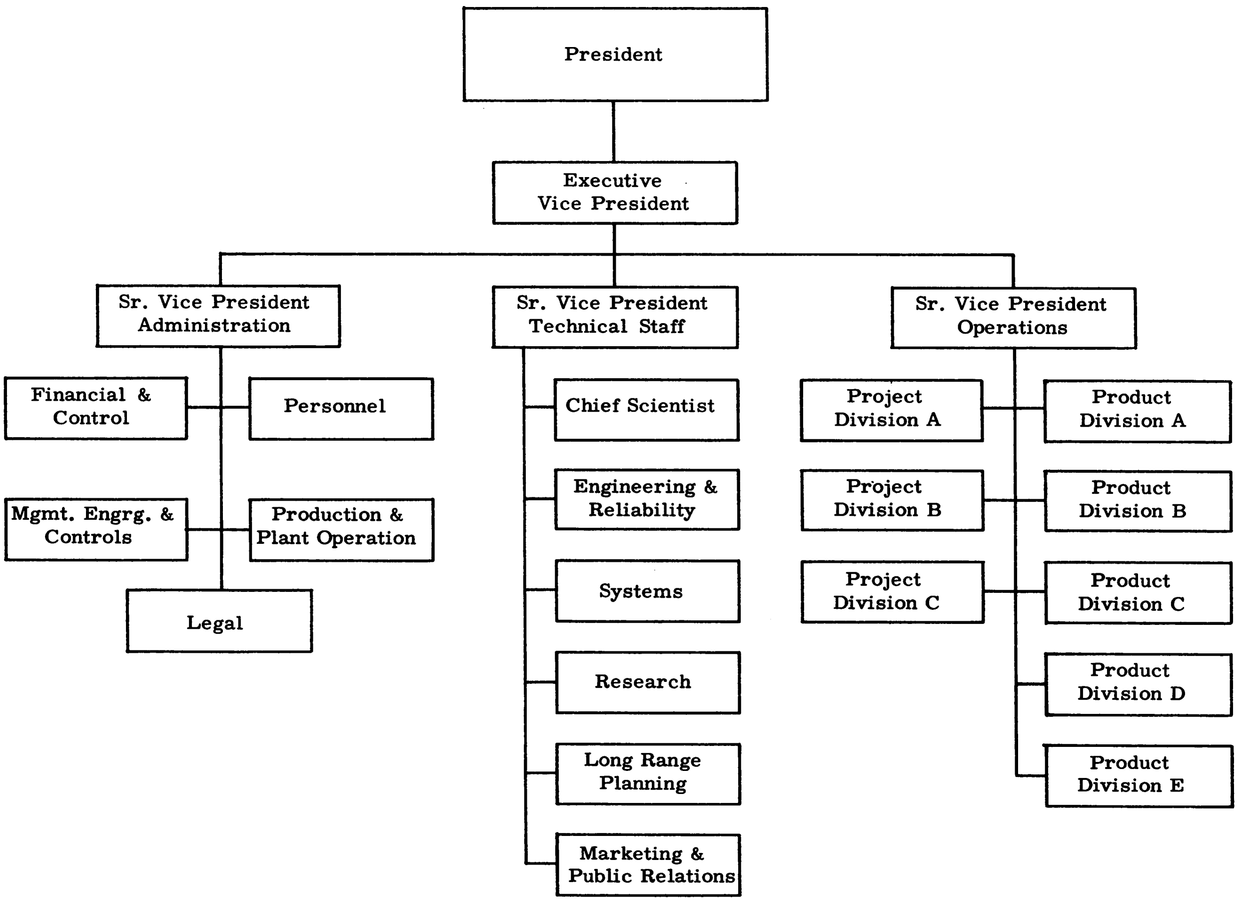

Figure 1-B: ORGANIZATION B

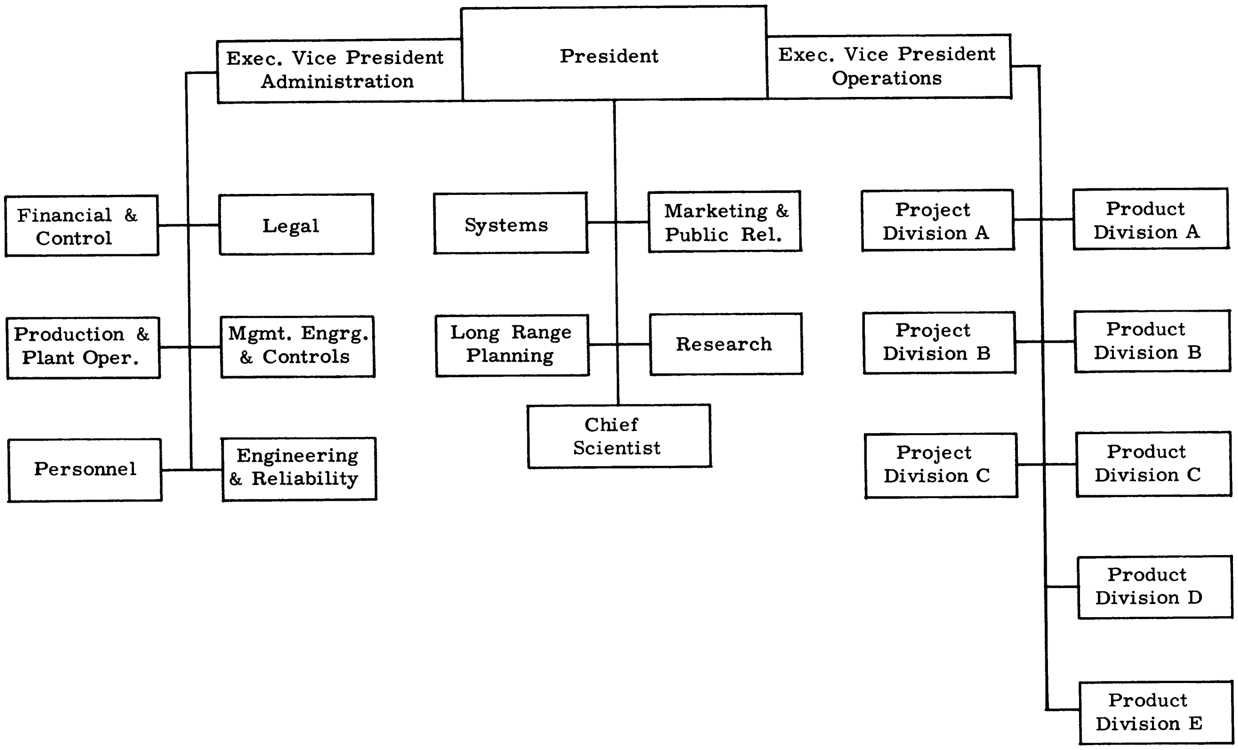

Figure 1-C: ORGANIZATION C

be absolutely essential for their acceptance within the line organizations which is so important for staff effectiveness.

Organization A divides the whole operation into line and functional staff-service functions. All of the product and project divisions and the systems division report in through the Executive Vice President-Operations. All of the staff-service functions report in through the Executive Vice President-Administration. Both of these Executive Vice Presidents report to the President.

Organization B recognizes that the same kind of individual is not necessarily able to handle both the technical and administrative staff functions. As a result, three Senior Vice Presidents are shown reporting to the President and Executive Vice President. In order to reduce the span of control of the Senior Vice President-Operations, the systems division is shown reporting to the Senior Vice President-Technical Staff.

Organization C involves an Executive Office with a President and two Executive Vice Presidents. These are purposely shown as nearly parallel in authority because one feature of such an organization is the fact that each Executive Vice President, as well as the President, has complete authority over all elements of the organization. Normally, the product and project divisions report in through the Executive Vice President-Operations, the administrative and service divisions report in through the Executive Vice President-Administration, and those divisions associated with external interfaces and the future of the whole organization report in through the President. Here it should be noted that again the systems division is shown normally reporting through the President in order to lessen the span of control of the Executive Vice President-Operations. If this executive span of control were not so large, the systems division might better normally report through the Executive Vice President-Operations.

The advantages of organizations A and B are the clear-cut lines of authority through the Executive or Senior Vice Presidents. The disadvantage of organization A is the imbalance between the small span of control of the President and the large spans of control of the Executive Vice Presidents, as well as the difficulty of finding an Executive Vice President-Administration who has sufficient breadth to contribute effectively to both administrative and technical functions reporting to him. The short span of control of the President may be an advantage or disadvantage, depending upon external demands on his time. Other difficulties of organizations A and B involve the possibility of communication barriers between elements of the organization reporting directly to different Executive or Senior Vice Presidents, and the problems of command during periods of unavailability of the President or his immediate subordinates.

Organization C requires a strong compatibility among the President and two Executive Vice Presidents. It also requires effective communication within the Executive Office. It has the advantages of a relatively balanced span of control and a flexibility of command during periods when any of the three members of the Executive Office are not available. It also simplifies the regrouping of the divisions of the organization, because of the recognized authority over the whole organization of each member of the Executive Office.

If external demands on the President's time are not so large that he has difficulty communicating with and directing the number of individuals reporting to him; and if three individuals with the suitable combination of competence and mutual compatibility can be found; organization C probably provides the best solution to the management problems of a large, diversified scientific industry.

Of course, the organizational considerations here have not specifically included a geographically separate group or "branch plant." Wherever such a group reports, it obviously is a strong contender for having its own "housekeeping functions," even under conditions when such functions might be centralized for several product or project divisions on a single site.

The Need for Management Pools

Another requirement of organizational flexibility is to have available key personnel about whom new organizational entities can be formed. This refers to some individuals with general management capabilities and others who can be assigned to new functional management positions.

One way in which such a management pool can be maintained involves the use of assistant functional managers and assistant general managers. This "two-deep" concept is at variance with classical theories of organization designed to optimize more static situations. However, it has the advantage of increasing the amount of communication which is possible from the dual-management office. This is often important, not simply because the complexity of the management problems may overload the ability of a single individual (to meet all of the people, attend all of the meetings, read all of the reports and answer all of the telephone calls which may be required), but also because it becomes possible to divide the work between an "inside man" and an "outside man." In these days of complex customers, program associate organizations and very active communications across the external interfaces of the organization, a manager may find it impossible to spend all of the time necessary for his external activities and still have any left to direct his internal organization.

In the dual-management office, this problem is solved by splitting the duties between those generally concentrated outside of the organization and those generally concentrated inside. It should be noted that the word "generally" was used here because either manager should be capable of operating across the external or internal interfaces. Since the customer usually prefers to deal with the top man, the external interfaces are usually handled by the manager and the internal interfaces by the assistant manager.

Another way to provide the management talent required for the creation of new organizational entities or the replacement of managers lost by attrition, involves the use of individuals designated as "assistant to," who are hired into such positions, normally reporting to an important executive, in order to ensure the proper status and compensation required to attract men of sufficient competence.

Such "assistants to" can initially be assigned to jobs in which they will learn about the organization and its business. Following such an indoctrination they may be given short-term, high-priority jobs or longer-term, low-priority assignments until the requirement for expansion calls for them to take their places in the organizational game of musical chairs. This may involve moves into positions, for example, as assistant general managers to replace men selected to head up new organizations. Of course it is always possible that the heads of the new organizations can be selected directly from the group of "assistants to."

It should be emphasized that such a use of "assistants to" can only be justified under conditions of incipient expansion and relatively negligible effects upon cost factors. This means that every effort should be expended to make the use of the members of the management pool during their "limbo" period productive enough to justify their retention on the payroll.

Business System Flexibility

The requirement for flexibility has so far been discussed as it pertains to people and organizations. However, because both people and organizations can only work if the proper business systems are available to ensure effective communication, information handling and operating procedures, it is equally important to provide flexibility within the business systems which provide the road-map for the operation.

Operating Directives

The first elements of business systems involve standard policies and procedures. Henceforth, these will also be termed "operating directives." Such operating directives must be consistent with the form of the organization (including the titles of individuals in it) at all times when these policies and procedures are applicable. Some of us have witnessed the chaos which can result from a carefully planned and executed organizational change which was effected in advance of a corresponding change in operating directives. Under such a condition, confusion is rampant and discipline breaks down because the operating directives are not applicable to the new organization and may even refer to old organizational entities which no longer exist. In order to avoid such chaos and reap the full benefits of organizational flexibility, it is desirable that the operating directives be reviewed, modified and approved by the same individuals who plan the new organization and by those key managers who must operate within it.

Formalization of Deviations

One sacred rule of management holds that any operating directive must be followed by all members to whom it applies unless deviations from it are themselves recorded, formalized and approved by proper members of management. Since it is particularly impracticable in scientific industries to expect operating directives to be optimum for all the situations to which they might apply, or even to keep pace with the changing operational situation, it is essential that there be a formal procedure for deviation. Such a procedure should provide for a permanent record of the deviation, a suitable authority to approve the deviation, and a follow-up by the appropriate business systems organization to determine whether the procedure needs permanent modification. Furthermore, the approval should not involve a series chain of several people but, rather, if it is desirable to have approvals by several individuals, they should be interrogated in parallel and have the authority to reject the deviations within a specific (relatively short) period of time. Failure for such individuals to exercise this authority should be taken as evidence of their approval.

Information Accumulation, Processing, Display and Retrieval

The requirement for flexibility in business systems must also apply to the accumulation and presentation of the information required to run the business. This information may involve operating costs accumulated by organizational entity or by output component of deliverable items. It may also involve status of the various activities involved in the operating plan including analyses, reports, drawings, tests, cost estimates, proposals, issuance of purchase orders, receipt of material, position in work, delivery, billing and payment.

Again, because the essence of the business involves change, the business systems must be able to accumulate, process and display information regarding equipment configuration and the effect on cost and schedule of changes which are either proposed or have been approved.

All of this requirement for flexibility of business systems seems to dictate the well considered use of modern data processing equipment. Despite the wide application of such equipment to a variety of business activities (from accounting, through production control, to data retrieval), optimum use of electronic data processing has not yet been achieved. There is reason to hope that the intensified interest of the Department of Defense in command and control systems will result in significant progress in business systems as well. Further, the recent breakthrough in the practical utilization of microelectronics, in conjunction with the progress made in input-output and display equipment for command and control systems, can result in the replacement by decentralized computing centers of large immobile computing installations with their masses of data storage equipment and requirements for large amounts of power and complex communication systems.

Decentralized Data Processing

The decentralized or "satellite" centers should be physically located close to the source of their inputs and those parts of the organization having the greatest need for their outputs. Because of their tremendous computing speed, they can provide desired information in answer to specific interrogations by nearly instantaneous fabrication from minimal basic data, rather than generating and storing all of the information which, someone has determined in advance, might conceivable be useful.

Of course, such satellite computing centers should be connected to a headquarters center from which they can be interrogated and to which they normally transmit only summary information, thereby greatly lightening the load on communication channels. Because such satellite centers soon will make use of microelectronics to achieve easily portable, low-powered equipment, they can be rearranged or set up in new locations as required for maximum flexibility, without requiring special installations, cooling and power.

Operational Evaluation

No modern system is complete without feedback. This is particularly true if the system is complex and subject to relatively rapid changes. In a modern, dynamic organization this feedback might be called "operational evaluation." The military services have long used the "Inspector General" concept. This concept may be modified to provide the feedback that is so necessary to make certain that a business system is operating with minimum error. Operational evaluation has two primary purposes. The first consists of measurement or audit of the adherence by personnel in the organization to the policies, procedures and good practices which constitute the operating directives and are part of the operational plan. The second consists of evaluation of these operating directives themselves – determination of their adequacy for the organization as it is constituted at the moment and their consistency with one another.

Operational evaluation as a function of management must be carried out in some form by every member of the management team. However, in order to gain the benefits of professional evaluation, objectivity and an assurance that the best practices existent in any part of the organization are available for all parts of the organization, it is probably desirable also to have a separate operational evaluation organization under an operational evaluation manager. Such an organization can consist of teams expert in each function to be evaluated. For example, it can have a manufacturing team, a material or purchasing team, a quality control team, a contract administration team, a pricing team, a marketing team, a logistic team, etc. These teams should include representatives on temporary assignment from the functional elements of either staff or line organizations as well as a few professional operational evaluators. This has the advantage of maintaining continuity as far as the evaluation techniques are concerned, while at the same time assuring expert functional opinion – both from the standpoint of evaluating adherence to operating directives and the adequacy of these directives.

Further advantages of including men on a temporary assignment (say for six months to a year) result from the currency of functional information which such men bring to their evaluation and the objectivity which results from their knowing that they are on a temporary assignment and must live in another capacity with the people whom they are evaluating. Such team composition also assures flexibility because the use of individuals on temporary assignment makes it possible to adjust the size of the operational evaluation teams as required by the newness of the organizational grouping, its operating directives and its personnel.

Operational evaluation may be carried on by random sampling or by specific intensive projects where the information required can be pin-pointed or an evaluation has been deemed to be useful. The latter may often best be handled by an ad hoc committee directed from an appropriate functional staff office. Whichever technique is used, the greatest care must be exercised to make certain that operational evaluation is not considered to be a spying operation. The onus of spying can be minimized if the operational evaluators are careful not to be super-critical. As much as possible, they should omit from formal reports the names of individuals who have been found to deviate from operating directives for the first time, while simultaneously reporting the existence of deviations to the individuals involved and their immediate supervision.

When an organization is new or when its procedures have just been revised, and when operational evaluation is being carried out for the first time, a much larger effort will be desirable than that which is optimum when the organization has more or less reached a steady-state, when the procedures have become stabilized and widely accepted, and when the personnel have learned to operate in the organization and with the procedures. Experience has indicated that competent, objective operational evaluation organizations play a key role in minimizing the operating difficulties inevitably accompanying the dynamicism which characterizes the scientific industries of today, provided that they maintain competence, objectivity and the flexibility to adjust to changing situations.

Training Programs

A most important element in the ability of an industry to cope with the problems of complexity and change, is a well-conceived, continuous training program administered by a competent, permanent training department. Many of us have seen the effects which such training programs can have in creating whole new industries. In the technical areas we have seen courses in servo mechanisms convert electrical engineers into automatic control specialists, and electronic engineers or mathematicians into computer design and programming experts.

Time and again, training programs have represented the only recourse to make up for lack of experience. The organizations which were able to exploit the advent of the transistor did so primarily because of their ability to train people in the use of transistors. More recently, we have seen an increasing number of training programs in many fields, technical and non-technical. In the technical areas of the electronic equipment industry, these programs have involved (for example) reliability, value engineering, microwave circuitry, inertial navigation, analysis of 3-dimensional systems, operations analysis, statistical error theory, celestial mechanics, and micro-electronics.

Other important training programs are designed to teach production and support personnel specific skills necessary to perform their tasks, and logistic support personnel how to operate, maintain and repair complex systems. When relatively significant changes are made in any part of an organization's operation, it becomes essential to provide training programs to acquaint the personnel with the latest general techniques being employed by industry at large, and the specific techniques which have been adopted by the organization for which they work.

Of primary importance in any program for training people to work together and advance inside the organization are the various types of management training courses. They are most essential during periods of organizational change and rapid growth, both of which can be effected only if competent supervisory and management personnel are available. Training programs for managers range all the way from courses on the most rudimentary of supervisory skills to more advanced programs in management techniques, plus programs designed to acquaint the managers of a particular organization with the specifics of the organization and its business systems.

Training programs may take a variety of forms. They may vary as to duration, location, time of day, intensity and the organization which conducts them. They may be held on the job during working hours, partially on the individual's own time, completely out of working hours and either on or off company property. They may be conducted by the organization's own training department, by paid consultants who conduct the courses for the client organization, or as part of general courses given by institutions of learning or professional organization such as AMA or AIM.

Items which all formal training programs should have in common are:

a. They should be part of a formal program with carefully established plans, personnel, and objectives.
b. They should be carried out under the cognizance and evaluation of a training department and the applicable functional organization. (Either should be continually monitored for effectiveness.)
c. The students should be required to participate in the program by mandatory tests and projects. It is only in this way that the students can make certain that their time is spent in actually learning instead of merely auditing.
d. Recognition should be accorded the students for completing the courses.
e. The more important courses should be followed-up by both formal and informal evaluation of their effectiveness and utility. This can be accomplished by requiring formal comments at a later date by both the students and their supervisors. It can also involve the completion and submission of a formal project as much as a year after the course, which project is generated by the student and his supervisor with approval of the training department.

Finally, all courses should be designed with the idea of maximum efficiency in mind. A training department should continue to strive for efficiency, just as all elements of the operating organization must attempt to maximize their effectiveness in achieving their objectives. A common fault of formal courses is their tendency to spend large amounts of time on topics which have low probabilities of being useful to the particular students in a given class. Streamlining of such courses can be more effectively achieved if it is possible to form classes of students with homogeneous backgrounds and objectives as far as the material in the course is concerned. To this end the courses should be carefully screened to make certain that their content is stripped of non-essentials and provides maximum motivation for the students to learn, with plenty of opportunity for them to apply what they have learned in adapting to new situations and hastening their progress along the road of personal advancement.

Facility and Capital Flexibility

Other management problems characterized by a need for flexibility involve facilities, capital and planning. First, with respect to facilities, the necessity for organizational rearrangement, as well as expansion and contraction with variations in sales imposes unusual requirements for flexibility in facilities. This flexibility involves both brick and mortar and severable items. In order to provide for the rearrangements attendant upon the formation of new project organizations, it is desirable that buildings be properly sized to house integral numbers of complete operations which must be able to communicate internally with the greatest of ease. Furthermore, these buildings should be laid out to permit the modular construction of rooms, laboratories and work areas which can be modified "over-night" by merely changing prefabricated walls.

Flexibility to facilitize changing numbers of personnel can be obtained by providing some relatively short-term leased buildings and equipments, properly phased as much as possible to match predicted personnel load variations.

Flexibility to handle variations in sales can be obtained by the judicious use of overtime along with contracts for time and material for for the actual accomplishment of contractually defined tasks with outside suppliers.

Flexibility in capital requirements can be provided by the judicious linking of leased capital equipment with that which is owned by the organization; and by the use of outside labor and facilities, under contract to help provide the equivalent of additional working capital. These means are, of course, in addition to the normal financial arrangements which are well established in most businesses and the use of progress payments by the customer.

Flexibility in Planning

The ultimate key to success in achieving the flexibility required for the dynamicism of the scientific industries lies in proper planning. Such planning should include short-range (1 year), intermediate-range (3 years), and long-range (10 years). It is most desirable for any organization to formalize and regularly update its planning even if unforeseeable conditions and rapid changes render this planning increasingly inaccurate as its time span is extended. Even such inaccuracies form a basis for determining possible faults in the planning data or systems, and possible improvements which can be made in the operation.

The planning itself should be flexible and should cover all aspects of the business. The requirement for accurate forecasting is, of course, proportional to the minimum lead time for accomplishing the plan. Buildings cannot be erected over night, key people cannot be hired and instantaneously become effective on a predictable basis; and even the training of people in new job skills to the point of effectiveness takes considerable time.

Planning may be approached in at least two ways with respect to what future business can be obtained. The first of these is based on the capacity of the organization and the faith that it can remain competitive as required to generally fill its capacity. The second is based upon the probability of obtaining specific programs and their effect on the operation. Whereas it is often not possible at the time of planning even to know of the existence of programs which may become most important during the period covered by the plan, it is often feasible to recognize the probable growth of a particular product area into which such programs will fall. Of course, when programs are already in existence within the organization, it is relatively easier to predict their requirements for people, capital and facilities.

A most important management problem is associated with the difficulty of obtaining large new programs at the time when the organization is loaded with large existing programs. As a result, if the organization depends entirely upon large programs for its business, the planning may have to be based upon a predictable (and sizeable) variation in sales. The only alternative to this requires a very large organization with a greatly diversified product base. Even here, where it is feasible to expect large programs to be captured on a more or less continuous basis, accurate planning must be accomplished to provide for the shifting of personnel assignments and organizational changes required to phase one program smoothly in behind another.

Of course if an organization has a relatively large number of small programs, its ability to maintain a planned load without violent oscillations is greatly increased. On the other hand, in the scientific industries, even organizations with a large number of small projects are still unlikely to achieve steady-state mass production and, therefore, must plan for continual personnel reassignment, reorganization, and change in facilities.

One of the greatest problems in planning lies in "betting on the right horse." The aerospace and military electronics industry can count numerous examples of large programs which were not carried to completion, because it was determined after they had been started that they did not provide an optimum expenditure of government funds. Consequently, an organization must be prepared to evaluate the probabilities of continuation of any program which it attempts to obtain. This probability of continuation is an important part of the planning which leads to the original proposal on the program and the planning for providing people, capital, and facilities, once the program has been captured. This planning is often very difficult because it can be affected by so many uncontrollable factors.

Probably the best criterion for judging such a program is to determine whether or not it "makes sense." This requires an appraisal of the validity of the overall objective; the program's ability to accomplish the objective economically and in a timely fashion compared to alternatives; the probability of funding; and the reality of associate programs, schedules and cost upon which it is based.

COMMUNICATION PROBLEMS

One of the greatest problems facing managements of scientific industries involves all aspects of the tremendous amounts of communication which are required to accomplish the industries' objectives. This problem involves the complexity of the information which must be communicated, its quantity and its accuracy. It includes attention to both transmission and reception of the information.

Because of the quantity, it is absolutely essential that management concentrate on eliminating all communication which is not necessary and increasing the information content efficiency of that which is.

Courses in Better Individual Communication

The efficiency of each person's communication can usually be improved by courses in writing and speaking, and by other courses in reading and listening. Such courses, however, will probably prove sterile unless followed up by continuing appraisal of the effectiveness with which individuals apply them; and by strong motivation for continued improvement in these areas by the individuals. Such follow-up and motivation is properly a function of management.

Elimination of Unnecessary Communication

Control of the quantity of unnecessary communication is also a management responsibility. Each of us, in thinking over his daily activities, will recognize that he is acting as either an information receiver or transmitter much of the time. The media for these transmissions or receptions involve letters and reports to be written and read; telephone calls to make and receive; informal conversation; and formal meetings or briefings. Each of these can be subject to abuse from the standpoint of necessity.

Pride, Correspondence and Meetings

One great underlying cause of such abuse is the fear of key individuals to be found ignorant on questions which they might be asked. Another factor revolves around the status associated with being included on distribution lists and in meetings. How many times have valuable man hours been wasted by including persons on distribution lists or as attendees at meetings simply because they might "feel hurt" if they were left out?

Correspondingly, many managers bring their experts with them to meetings on the offhand chance that the expert might be able to provide answers to questions which just might be asked. Much valuable time could be saved if managers were willing to say "I don't know, but I'll find out" at such time as a question is asked, instead of requiring their experts to sit through complete meetings in which most of the time they have nothing to contribute. A considerable amount of valuable time of key people could be saved by a policy which makes it an honor not to be included on a distribution list or not to be invited to a meeting, unless the necessity for each is clearly established.

It must become well recognized that the choking effect of too much communication, and the time which it unnecessarily requires of the individuals involved, is often far worse that too little communication which every now and then creates a "horrible example." Unfortunately, the horrible examples are clearly identifiable. It is much more difficult to measure the loss in efficiency of key individuals who must spend too much time in reading unnecessary correspondence and reports, listening to unnecessary telephone conversations, and unnecessarily attending meetings.

Minimizing Unproductive Exercises and Studies

Another way in which too much communication affects operational efficiency involves a widespread tendency toward repeated requirements of "for instance" exercises and studies to handle situations which only might occur, to a degree of detail which most probably would not be required. This should be resisted firmly by management.

Plan Communication to Minimize Interruptions

Managers should also be careful to avoid calling their subordinates unless it is absolutely necessary, thereby risking an undesirable interruption of the subordinates' activities. Rather, communication with subordinates and peers should be limited as much as possible to meetings or telephone calls scheduled in advance so as to avoid disruption of the individuals' opportunity to concentrate for long enough periods of consecutive time to complete their work assignments.

Don't Travel in Herds

Another improvement in efficiency can be achieved by avoiding the tendency to send herds of specialists on trips to answer questions which just might be asked of a manager. Not only does this involve unnecessary travel expense but, of greater importance, it represents a non-productive use of key people. It often is possible for a trip to be handled by one or two individuals, if these individuals can obtain sufficient information in advance to permit them to do their homework and to rely on the telephone to obtain answers to questions which they did not anticipate.

Problems of Information Accuracy

Other communication problems are associated with the accuracy of the information involved. This is one of the characteristics of the scientific equipment industries, particularly those having complicated products being designed, built and tested for the first time. As a result of this it is not unusual to find information which is a basis for action or decision, distorted to the point where it may be worse than useless.

Distortion by Series Transmission

One way by which this distortion occurs is by a transmission through a series of individuals. Such a chain normally follows the organizational lines and is characterized by a misapplication of the principles that a manager does not give direct commands to his subordinate's subordinates and a subordinate does not call his boss's boss. Whereas these principles are normally sound, they definitely do not apply if the sole purpose of the communication is the transmission of information and is not a basis for action which bypasses a level of the organization. Much of this distortion can be eliminated by the use of parallel communication and by the motivation of individuals away from the desire to be involved directly in every communication between their subordinates and their bosses.

Regular Multi-Echelon Meetings with Planned Agenda

One way by which the accuracy of communication can be improved is by the use of periodic, scheduled meetings with planned agenda. Thus, it is desirable for each manager to meet regularly, say once a week, with the persons reporting to him, both as a group and individually. The distortion of series-transmission of information can be further reduced if one of the group meetings each month involves the subordinates of the individuals reporting to the manager. Meetings involving three or more echelons of the organization can also provide improvements in communication and motivation, as well as the opportunity for a powerful boost in morale of the organization as a whole. Obviously such large meetings provide only limited opportunities for group discussion and should probably be limited to a planned program of presentations with question-and-answer periods. As a general rule, it is essential that each meeting have minutes including both information items and action items. It is also important to follow up on the action items of the minutes and to review them at the following meeting.

Formal Critical Problem Identification

Experience in the management of complicated, rapidly changing programs has shown that it is often very difficult to bring problems to the attention of authoritative management in a timely fashion. This is partially because of the natural reluctance of a person to admit the existence of a problem to his superior or to seek his help short of an obvious inability to solve the problem himself.

A corresponding difficulty involves the tendency of very busy individuals to neglect taking immediate action on problems which have a deadline for solution considerably in the future. If the lead time required for the solution of such a problem is long, such failure to initiate action in time, because of the lack of immediate urgency for the solution, can produce catastrophic delays and increases in cost. It is important to realize that problems under discussion here are of the unexpected, unplanned variety not covered by normal management visibility and review systems (such as Pert for development programs).

One attack on this type of communication problem can follow the lead of the Air Force Systems Command's Ballistic Systems Division's "Dynamo System." Such a system, adapted for application in an industrial organization provides formal recognition of the existence of a problem which meets certain criteria and simultaneously initiates action to ensure its most effective solution. These criteria are designed to ensure that the problem can have important effects upon the organization and its commitments in comparison to lesser problems. Such effects may involve schedule, cost, performance or commitment of assets.

Autonetics' Dynamic Management System

At the Autonetics Division of North American Aviation, this formal problem identification is accomplished by the "Dynamic Management System." Briefly, the system starts with a list of key people in each part of the organization who can approve the identification of a problem and initiate a formal "Dynamic Management Action." Just as certain individuals can approve the identification of a problem, so there is a list of other designated individuals at management level to whom the problem can be directed for requested solution. The vehicle is called a "Dynamic Management Action Request," and the manager who receives such a request must reply to it, indicating his planned action, within 24 hours.

Following initial acceptance of a Dynamic Management Action Request, an assignment of responsibility for working the problem is made to a specific individual. Periodic reports are produced showing progress toward solution and naming the individual at the lowest level with complete responsibility for the problem until a solution has been effected. This is formally recognized by the closing out of the Dynamic Management Action with the approval of the originator.

Formal reports of the 10 most pressing Dynamic Management Actions within each organizational entity are prepared weekly and reviewed by the executive in charge. The 10 most important Dynamic Management Actions within the whole Autonetics Division are reviewed by the Executive Office.

Such a formalized procedure of identifying critical problems and making certain that action is taken to solve them can go a long way toward improving the communication within the organization associated with problem solving. It can prevent lack of timely attention on critical problems which otherwise might have "fallen through the crack."

PROBLEMS OF APPROVALS

The more complex an organization becomes the more individuals, management levels and staff members can become involved in the review and approval of important operating or commitment documents. These may involve operating directives, budgets, authorizations to spend money, proposals, contracts and other documents with financial, legal, security or corporate image overtones.

Under such conditions there is every opportunity for force approvals up through a long chain of signatures to the highest organizational levels. If these are requested sequentially, the result can be unreasonable delays in action both from the time spent on each approver's desk and the time in transit between desks. Furthermore, the total load on higher levels of the line organization can become so great that it is physically impossible for such executives to find enough time to give all of the documents which they must approve the consideration to which their signatures should testify. The result is a tendency for the higher level executives' signatures to represent only their faith in those who signed before them (or their staffs to whom they may have referred the document for review). Conversely, lower-level signatures often represent a lessening of the feeling of responsibility for critical review because these people know of the responsibility for review and approval at higher levels. It can be seen, therefore, that a long sequential approval chain can be damaging on at least five counts:

a. It delays the final execution of the document.
b. It quite possibly actually lessens the quality of the review and the validity of the approval.
c. It imposes additional duplicate loads on key members of the organization who attempt to find time for some type of review.
d. It imposes a considerable load on the communication system of the organization with the attendant increase in cost for reproduction, transmission, and filing of documents.
e. It increases the probability of multiple, sequential rework of the documents to fit the desires of individuals who review the material sequentially and feel impelled to contribute to it.

There is no single, clearcut solution to the approval problem. However, some actions can be taken which in part or in toto can reduce it. These actions are obviously dependent upon the situation which exists at any given time, the competence of the individuals and the optimum tradeoffs among the different courses of action available. These actions include:

a. Parallel review in a single meeting of the significant features of the material by several levels of the management chain. This can save time, force attention by all members present, promote discussion, and reduce the costs and delays caused by sequential rework and document handling. The tendency to wait until the material has been "prettied up" or reproduced in final form before review by high levels of management should be avoided if possible. This, of course, requires an attitude on the part of individual managers which does not "mark down" the individuals who prepare the material because of mistakes which are found and changes which are deemed desirable.

b. Establishment and execution of a policy which balances the negative effects of occasional "horrible examples" against the overall cost in time, money and quality of work required to take maximum precautions against mistakes.

c. Realistic evaluation of the consequences of and risks involved in making various types of mistakes. Such an evaluation should determine the number and level of the minimum approvals absolutely required. Thus, in some instances it is absolutely essential that material be reviewed for possible violations of security regulations, legal implications, effects on the public and financial commitment as well as the quality and accuracy of its technical, marketing or management content. Other material may not require review by each or all of these specialists.

d. Approval and review should be held to the lowest level commensurate with realistic ability for individuals to spend the time and have the competence for the review, together with their responsibility and authority. Such "lowest authoritative levels" should have the responsibility to call special cases to the attention of higher authority and have the required access to this authority.

e. Wherever possible, review should be conducted in parallel and the reviewers should exert their authority by disapproval or comments within a specified reasonable time. Lack of such disapproval, in writing, with reasons should be taken as tacit approval. This provides one of the single most effective ways to avoid the problems of multiple approvals in sequence.

IMPROVEMENT OF INDIVIDUAL EFFECTIVENESS

Some of the actions which can be taken by management to improve each individual's effectiveness have already been discussed as problems in training, motivation and communication. There are other considerations.

Make Sure the Problems are Real

It is obvious that maximum efficiency can be obtained only if individuals are assigned to work on real problems of unquestionable importance to the achievement of objectives of the organization. Nevertheless, one of the greatest dangers in complexity and rapid change, is the "spinning of wheels" of the key people in the organization, either by working on the wrong problem or working past the point of diminishing returns.

In a less complicated operation, it would be possible to require each supervisor accurately to direct the work of those people reporting to him. But under conditions of massive communication complexity and change, along with work which is often being attempted for the first time, each individual must be indoctrinated with the idea that he has the responsibility for identifying the point of diminishing returns and for questioning the importance of his assignment.

In order to be able to carry out these responsibilities, it is important that each key individual in an organization be made aware of the broad objectives of the organization and the activities of others in it which are necessary to fit with his own activity in achieving these objectives. It is also desirable, as mentioned earlier, to train specialists in disciplines beyond their immediate specialty so that they can understand and appreciate how they fit into the organization and can communicate efficiently with others working on different aspects of common problems.

Although it is usual for individuals to assume no responsibility beyond their immediate assignments, a great advantage can accrue to the organization as a whole if personnel are encouraged to point out difficulties or suggest improvements wherever they recognize them, regardless of the direct relationship to their assigned work.

Motivation to Report Mistakes is a Must

Another management challenge is based upon the tendency of individuals to cover up their mistakes rather than reporting them. It has been demonstrated several times by spectacular failures of complex system, that such a natural human tendency can be catastrophic if it affects the reliability of equipment. This tendency can be just as catastrophic, if less spectacular, when applied to the reliability of information which is the basis for important action and decision. Of course, the tendency to cover up has evolved from the very common use of penalties for mistakes and rewards or pride in reputation for doing a good job.

Although management must always take every step possible to minimize the number of mistakes which individuals make, it is even more important, under the dynamic conditions of the complex scientific industries, to motivate individuals to discover and report their mistakes as soon as possible. This type of motivation can take many forms, but certainly one which should be effective is to rely upon random sampling to detect mistakes and to make it well known that the penalty for covering up or not reporting a mistake is far more severe than the penalty for making it. Correspondingly, the dissemination of information - the probable accuracy of which is not delineated and which is biased by half-truths, old truths, and untruths - must rank high among the categories of "mistakes" which must be avoided if possible, and reported when identified.

Motivation to Control Originality

The problem of motivating highly creative individuals to use the ideas of others and work already accomplished elsewhere, requires continual management attention. Sometimes a very fine line must be drawn between the exercise of controls designed to avoid the inefficiency of unnecessary originality and the stifling of creativity which could result from too much restriction on originality. To this end, rewards of remuneration and a status must be realined to give proper credit for maximizing the use of standard techniques, designs or equipments. Such use of standards often actually requires more ingenuity than the invention of substitutes. There are at least two reasons for this.

Requirements are Not Sacred Until Questioned

First, the requirements or specifications for new work are often written without a knowledge of work which has been done in the past; and, therefore, cannot be satisfied by the use of, or relatively simple improvement or modification of previous work. Under such a condition, the first step should include a re-examination of the validity of those parts of the requirements or specifications which render previous work inapplicable. It is often found that the originator of such requirements or specifications is quite willing to modify them, if he can be shown that by doing so he will not be trading new problems for old and can have the corollary benefits of experience, with its improvements in cost, schedule and reliability.

Information System Must Simplify Discovering What Has Been Done

The second reason is associated with the problems of finding out what work has already been done. To this end, it is most important that a formal system exist for recording and indexing such work to permit its discovery with relative ease. The problem is even more difficult where the work has gone on outside of organization. Here, one of the most important services of a functional staff can be the maintenance of a continuing survey of information available from outside the organization, and a system for making such information readily available on call when identified in any one of several different ways.

Problems of Priorities

All individuals have a continuing problem of establishing priorities with respect of their own activities. This ranks high in importance of the list of items affecting an individual's management of himself and the value of his output. Great weaknesses can exist if individuals tend to give equal priority to all assignments or highest priority to the most recent assignment, to the latest task, to those having the loudest voices ("the squeaking wheel"), to the activity which is most interesting personally to them, or even to the directives of their superiors' bosses.

It is important that personnel be able to develop their own assessment of the time requirements to accomplish their assigned work, and of the relative importance of the various jobs for which they may be simultaneously responsible. It is essential that they do not hesitate to inform their superiors of these estimates and of their personal ideas regarding priorities. They must realize that they can only perform a service for the organization as a whole, and their boss in particular, if they inform him of the consequence of new assignments on the discharge of previously allocated responsibilities, and make certain that he at least understands their evaluation of the priority of each task for which they are responsible.

The failure to question the boss and the boss's latest directive, when such a directive can be carried out only at the expense of previous assignments, is a most common failing at all levels of an organization. It is one which requires intensive objectivity; willingness to admit personal fallibility inconsistent with the organization chart; courage; and a degree of tolerance of the line relationships often inconsistent with the normal tendencies of human beings.

It is, of course, possible to mention qualitative factors (which must seem obvious but are quite difficult to quantify) affecting the establishment of priorities. Each task can be assigned a certain importance relative to the others. This importance varies as a function of time. A first step in assigning priorities is to establish the relative importance of each task in terms of tradeoffs among the quality of its accomplishment, the date of completion and the cost. Each task must require a certain total time out of the personal budget of the individual and a certain calendar time, since often the individual's activity must be performed intermittently around the series work of others. A second step in the establishment of priorities involves an ability to make accurate estimates of total hours required. Obviously, those tasks which require a long calendar time to complete must be started sufficiently in advance to meet their schedule. Often the amount of time required can be varied radically by the quality of the results achieved. One important consideration is the minimal acceptable performance consistent with commitments and other elements with which the task must combine to produce an organizational output. By the proper mix of importance and time it is theoretically possible to establish a list of priorities on any given day. It is normally patently impossible to meet all of the requirements imposed to optimize all tasks separately. The best solution can be obtained theoretically if we try to push our efforts until all incremental outlays (or efforts) are just equal to incremental returns.

Since such a criterion is most difficult to quantify, we must end up applying our best judgment to establish personal priorities, hopefully avoiding the pitfalls mentioned above, but always guided by the practical fact that our superior has the authority to override our own priority schedule.

One important consideration, particularly for manager, is not to schedule each day completely. This is for two reasons: First, to handle unscheduled interruptions requiring time not possible to foresee in advance; second, and perhaps more important in a scientific industry, it is most important that time be allowed for intensive analysis and concentration to a degree not normally required of managers, on the special problems and considerations which lead to significant action.

The Conservation of Consecutive Time

Finally, a factor which is often not recognized although obvious to anyone from his own experience, is the importance of avoiding an overload an any key individual in the organization. This overload may arise from the assignment of more work than he can possibly accomplish, but it is more likely to result from unnecessary and unproductive interruptions and diversions which do not provide the sufficient consecutive time for him to complete his thoughts. The importance of this is emphasized when it is recognized that the complexity of topics requiring mental activity in a scientific industry is so great as to make it necessary to use relatively longer periods of time to complete thoughts than must be emphasized in less dynamic industries.

How many of us, who have been repeatedly interrupted in the performance of a task, have not felt that our output might be increased several hundred percent if we only had twenty percent more consecutive time available? This is because every interruption of thought requires a certain amount of "setup time" when thought on the problem is once again resumed, analogous to the setup time on a machine in advance of the actual accomplishment of work. Consequently, the recognition of the importance of minimizing interruptions and trying to schedule those which are necessary, to maximize the consecutive time of key individuals, can probably increase such individuals' output dramatically with a corresponding improvement in efficiency of the organization as a whole.

SELECTION AND DEVELOPMENT OF MANAGERS

Two dangers – too much management by specialists and too little technical competence and ability to concentrate as necessary – make it most important for the board of directors of a scientific industry to make certain that their top management understands the peculiar problems of their industry and the special characteristics of managers which it requires. Just as important, their organization must be able to select men with adequate intrinsic management capability and provide means for their training and development.

Inadequacy of Classical Methods

The problems of selecting and developing various types of managers for the whole spectrum of classical and industrial organizations has received broad attention by institutions of learning, management professional societies, management consultants, and industrial organizations. Most of the basic principles of such selection and development processes are applicable to the scientific industries. This is particularly true in areas involving human relations and administration. Accordingly, only those characteristics of managers and factors affecting their selection which are peculiar to the scientific industries will be considered here. Such items, as almost all others discussed herein, involve the unusual complexity and dynamicism of these industries.

In the selection of managers it is first necessary to identify individuals having the proper inherent characteristics and ability. These can then be augmented by knowledge obtained from training courses, personal study, and, most importantly, experience. Finally, it is necessary that they have the opportunity to manage under conditions which permit their continued development. This opportunity to practice management as well as the acquisition of knowledge must involve "feedback," obtained by measurement against such standards as performance relative to others, performance relative to established objectives, and the recognition and correction of deficiencies.

The cliche that a good manager can manage anything is not nearly as applicable to a complex, dynamic industry as to the more classical type of management position. One reason for this is the fact that the problem of interpreting standard management performance indices and trends is much more difficult because of the amount of data which must be summarized, the great diversity of this data with its attendant difficulties of standardization, and the rapidity of change of information from which such data are derived.

As a result, the managers at all but the lowest levels in a scientific business cannot rely on delegation and report as a basis for discussion and decision to the same extent as the managers of more stable operations. It is not enough for a manager to be a good administrator, a master of delegation, a writer of clear directives, a rapid reader of reports and an inspirational leader. This is because:

a. The changing nature of the business and the organization makes it less possible for the people reporting to a manager to develop automatic competence in their jobs by long experience doing a type of work which changes slowly if at all.

b. The great diversity, quantity and rate of change of information used as a basis for decision and action makes it continually important for managers to evaluate the information which subordinates supply in terms of its accuracy, completeness, consistency and obsolescence.

c. The quality, complexity of content and rate of change of information which is the basis for directives makes it much less possible to rely upon the accurate interpretation of these directives by the individuals receiving them without occasional intensive discussion and followup.

d. The requirement for technical ability and creativity in subordinates resulting from the type of work which they are called upon to perform, tends to make them speak and listen in a highly specialized lingo of their own. More than normal care must be taken to ensure that directives are understood by them and reports from them are properly interpreted.

e. The creative, technically trained subordinates mentioned in (c) are often driven by the urge to obtain ingenious and unique solutions to special problems which may produce chaos in complex efforts, if not properly identified and controlled.

f. Technical, creative personnel resist being motivated by, or taking direction from, bosses whom they consider their intellectual inferiors, who do not qualify as technically competent and who cannot explain to them in their own frame of reference the reasons for action or lack of action with which they may disagree.

The characteristics of subordinates which require particular abilities in their bosses, apply in reverse to the characteristics which the boss must in turn exhibit to his own superior.

Characteristics Peculiar to Managers in a Scientific Industry

As a result, any manager with a significant position in a scientific industry has special need to varying degrees (depending on his level and function) for the following basic qualities and capabilities:

a. Knowledge and analytical ability which permits him to probe intensively into the work of his subordinates, as required, to help them solve their problems and make certain that they understand his directives and requests.

b. Knowledge and tolerance which permits him to communicate well with his peers and superiors and to appreciate the basis for their actions and requirements.

c. A broad understanding of disciplines beyond those of his particular job which indirectly bear upon his own activities and decisions.

d. Practical imagination and ability to think in terms of complex patterns and multi-move strategy.

e. Ability to "cover ground" requiring an unusual mental flexibility and alacrity.

f. Ability to communicate relatively large quantities of complex information effectively and efficiently.

g. Ability to "bound" a complex problem in such a way as to exhibit its fundamental limitations and identify inconsistencies or errors.

h. Ability to recognize strategic factors among a complex mass of interacting situations and data.

i. Ability to recognize intuitively "old truths, half truths, or untruths" presented as a basis for action.

j. Ability to conduct meaningful inquisitions designed to bring out hidden factors, evaluate the uncertainty of information and determine priorities for action without involving personalities.

k. Willingness to undergo intensive inquisitions without feeling or acting defensive.

l. Complete objectivity.

m. Willingness to risk being wrong, recognize or admit being in error and take corrective action without feeling personally involved.

n. Courage to make decisions and take action on the basis of minimal information.

o. Understanding of the degree of uncertainty entering into his decisions, directives and the data which he receives and produces.

p. Confidence which does not permit him to be swayed by rumors, attacks, discouragement and misunderstanding.

q. Ability to assess the effect of unusual situations on the performance of subordinates, associates and superiors in evaluating their capabilities applicable to other situations.

r. Physical, emotional and nervous stamina which will permit him to survive, without ulcers or a nervous breakdown, the frequent demands for evening and weekend work and the intense pressures of a complex, dynamic business.

s. A family which understands the unusual requirements of his job in terms of time and pressure.

t. Understanding of the dynamic and complex characteristics of the scientific industries with its unusual demands for flexibility, personal efficiency, technical competence and effective communication.

Selection of Managers

Selection of New College Graduates

These special manager characteristics and capabilities seriously affect the method of selecting and developing managers for a scientific industry. Thus, an unusual premium is placed upon identifying men with the physical, emotional and mental capabilities of an extensive generalist, yet capable of intensive inquisition, analysis and investigation required to handle a special situation. College graduates with these capabilities usually make good grades in a technical major, while at the same time taking part in several, and leading at least one extracurricular activity either on or off campus. Often these students are recognized debaters and public speakers, athletes, editors, student officers and active participants in social activities. They seek responsibility and discharge it effectively. They carry an unusually heavy and diversified schedule of courses and activities. They often hold down jobs in addition to their school activities. They learn early what the real world is like and develop the broad and balanced personal perspective necessary to recognize and define important problems – yet they are able to specialize as necessary to achieve a high scholastic standing and solve the key problems which they identify.

As a general rule, it is better in seeking potential manager talent to hire a college graduate with a B average (containing some A's) and a heavy load of extracurricular activities than one with an A average and a very light extracurricular involvement. Such completely specialized individuals are necessary to carry on advanced analytical and creative activities on problems identified as important by generalists – but, if given positions of authority, they very often end up by concentrating on problems which challenge and interest them personally but are of secondary importance in the business.

Of course, it would be a grave mistake to assume dogmatically that a student who did not take part in extracurricular activities will never continue to mature after graduation and develop the characteristics of a generalist which will make him a good manager. However, such a change in individual characteristics can only be identified after it has occurred, and hardly constitutes a good gamble in the hunt for potential managers among the college graduates.

Manager Development Programs

Once good manager material has been identified, he should be put to work on at least one and preferably more specialized assignments, while at the same time being encouraged to continue his education by taking a carefully selected series of courses in basic management skills and supervisory techniques. It is important that the individual selected as a potential manager should be under continual surveillance of the organization's manager development organization. This organization should keep track of his training activities and on-the-job progress – acting as advisors to both the individual and his superiors on his training program and assignments. The training should involve, in addition to general courses on management theory and practice, a specific course in responsibility, authority, company policies, and applicable procedures and practices peculiar to his own organization.

The progress of the man with management potential should continue to be evaluated by the manager development organization as well as the organization's higher-level managers. Additional specific training programs with on-the-job application, combined with progress interviews and planned rotation of assignments, should continue the manager's development. Such rotation of assignments can be most useful if it involves at least two of the three types of manager activity – line operation, staff and program management.

Selection of Managers from Industry

The foregoing represents an idealized situation such as would not normally be achievable until an organization had existed in a mature form long enough to permit the time which such a manager selection and development program would require. A more usual case in the scientific industries involves an organization which evolved from a handful of analytical or idea technologists through the phases of development, production design, production and logistic support. For such an organization the majority of managers must often be selected from the personnel at hand, who have shown some capabilities of leadership and administration. To this end, it is important that the characteristics and requirements of managers in the organization be clearly and widely distributed. A smaller number are hired from other companies where they presumably have acquired manager experience and demonstrated their capabilities.

Managers selected from either source must undergo the same kind of evaluation and counseling that was outlined for new college graduates, except that the activity cannot usually be as well planned and must be more intensively sandwiched into the manager's schedule as a higher-priority commitments may permit.

Here, to an even greater extent than for the new college graduates, it is most important to be able to identify in the individual those potential characteristics and qualities outlined above. Since these men are often older and with their high-priority job assignments, have less time available for training. Also, the loss of a key technical man of unusual competence to become a second rate manager constitutes a loss to the organization and a disservice to the individual. There is no single, certain method for doing this. However, each of the characteristics should be carefully defined in terms most applicable to the performance, opportunities and constraints under which each individual has been known to operate. Then all means of obtaining this information should be interrogated, and a composite characteristic profile prepared for each manager or candidate. This profile should be used in the now standard manner to point the way to items needing improvement. All normal methods – counseling, studies, and training programs – can then be considered to achieve the desired progress and capability. Further, the performance of such managers on their jobs must be closely monitored and used to update their evaluation and profile of important characteristics and capabilities and to point the way to action which will improve their capabilities.

CONCLUSION

The industries which have grown up to exploit the wonders of science have problems of management which are unique. Our ability to solve these problems may provide the ultimate limitation on our ability to take advantage of the work of our scientists. Much progress has been made in identifying these problems, but much remains to be done in accomplishing their optimum solutions. Yet upon these solutions depends the brightness of our future and even the survival of our way of life. The people of the Free World have been made well aware of the deadly challenge of the scientific race now being run. We must also realize that, to win this race, we dare not be second best in solving problems of management essential to convert the scientific breakthroughs to usable reality.

INCREASING PRODUCTIVITY THROUGH JOB ENLARGEMENT

Irwin A. Rose
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It is a pleasure to meet with you and tell you of our experience in The Maytag Company with job enlargement, or job enrichments, as compared to our experience with excessive job specialization.

When excessive specialization results in unnecessary de-skilling of the task, an examination of other alternatives in job design calling for an increased number of skills, responsibility, and variety in the task may be in order.

Our experience on a number of jobs indicates quite clearly that product quality, direct cost, indirect cost, and relationships within the organization can be improved by designing more operations into a single job, resulting in a longer cycle of time.

Since jobs in mass production plants are frequently planned along lines that call for a great deal of specialization, many of the tasks will have the following characteristics: (1) small repetitive increments of work (2) minimum skill requirements, (3) mechanical pacing of the work, (4) operator difficulty in relating the task to the finished product and, (5) adherence to a rigid time cycle.

By contrast, job designs which provide the operator with a variety of work, along with responsibility for quality of the product which the operator checks and for which the operator is held accountable, together with operator freedom to set the pace within limits would, for the purpose of this discussion, meet the requirements of an enriched job.

Where products are assembled on a progressive line, there may be a limited choice of means of assembly, related to the design of the product. The layout or equipment may also control the sequence of operation. This results in either the grouping of certain operations or the possibility of limiting an operator to the performance of a few motions. Where there is no choice, I see no point in taking exception to the excessively specialized task.

The simple question that arises at this point is to what extent can we design jobs and modify conditions so as to increase the number of opportunities for cost reduction by the use of job enlargement? Looking at our fragmented tasks in retrospect it becomes apparent that many forces operate to obscure the attractive possibilities of the enlarged job design and after jobs are in production, force of habit operates to perpetuate the over-specialized job.

The physical layout and material delivery systems which have been developed to serve continuous lines at times can influence both planners and supervisors to limit the choice of methods to be considered. Innovations can be employed to overcome these limitations when there is an appreciation of the advantages of the longer work cycle.

One very effective installation which I saw in a mass-production plant demonstrates this clearly. The operator performs a number of operations ----- including assembly, soldering and testing ----- the supply of parts are made available by making use of a simple spiral chute, fed by the main assembly conveyor, which places the component close to the work station. The operator is not paced by the conveyor and merely flips a switch to position the work. After completing her work, she manually prepositions the finished part in such a way that it is automatically picked up and moved to the next station when a free position occurs on the conveyor. The important materials-handling advantages of the progressive line are preserved while providing the operator with a variety of work, including the responsibility for the quality of the work, which she checks. In this case, a refinement in the method of delivery and removal of the parts opened up the way to improve the method at the work station.

Over-emphasizing the importance of mechanical pacing of the work may cause some supervisors to be predisposed in favor of excessive specialization, whereas, other methods would be more productive. What I have in mind is best illustrated by the following questions, taken from an industrial study.

*" Why were relations with men so important? Did not the moving line determine how men should work and keep them at it? Some foremen said it did and that this mechanical compulsion made less human supervision necessary."

"The line does a lot of work for you. The men have to keep up with it. If I stand down at the end of my section, I can see if anything has been done wrong by one of my men, and I can find out why."

*The Foreman on the Assembly Line - Walker, Guest and Turner

"I like the moving line because you know where your people are. The first thing I do when I come into a department is to try to do away with subassembly operations. I don't like them at all. The line here, the moving line, controls the man and his speed. Then, no matter how slow a man is, he has to keep moving. We're all human, we like to go as slow as we can unless we are pushed, and this line controls him perfectly."

Advantages of Job Enlargement

While it may seem paradoxical, our total training costs for enlarged jobs are somewhat less than our total training cost when training for the fragmented job. The following comparison is offered by way of explanation of this fact.

When a 20-per-cent increase in production is required on a line employing 100 people, all operations normally require rebalancing. As a result, all of the jobs of the people presently employed have to be changed, and, in addition, new people have to be trained. Learning is only one of the factors present when dealing with resistance to change. Informed professional people have agreed that the setting of an accurate labor standard is relatively easy. Acceptance of the standard is the important consideration, and it is a prerequisite to serious effort on the part of the operator. This makes our task harder because of the large number of people involved in the adjustment which occurs when all the jobs are changed.

Contrast this situation with the condition that prevails when the job is enlarged so that each operator performs the entire job. Assume that at a production level requiring five full-time operators,there is a need for a 20-per-cent increase in output. A new operator is then brought in for training, with proper allowance for training time. The five operators continue to produce at full-capacity, since there is no change in their jobs. As a result, the new operator has a very good example set for him by five different individuals who are performing at a particular standard, and this standard is not likely to be questioned. The new operator, under these conditions, will generally strive to develop competance within a reasonable period.

A change in the labor standard, regardless of its cause and character, can always be the basis for doubt and concern on the part of those employees affected. Since this is so, production level changes on the paced line, with the resultant modification of grouping of elements and the "new standard" introduce this factor of doubt concerning the standard.

By the use of the job enlargement principle, such changes are accomplished by the simple process of removing individuals ----- the labor standard is not affected. The only time the standard is modified is when there is a change in design, specification, or method. These are obvious to the worker, and he understands that a change has actually been made. As a result, he is much more inclined to accept it rather than a mere "regrouping" of the same work which involves no such change. The fact that alterations in design are relatively infrequent makes for a high degree of stability and the avoidance of confusion. Because new standards are not required, much costly staff time is saved; and in addition, the staff is freed to do creative work.

If assembly jobs are planned so that the worker becomes more skilled, we can take care of our present production more efficiently. Because of the versatility developed in the operator, his future job assignments are easier to learn. The more skills an operator acquires, the easier it is for him to master new ones. It would appear that in addition to enjoying lower training cost, the developing of greater operator skills also provides greater flexibility.

Most subassemblies in our plants seem to be logical items to be considered for job enlargement. There are, of course, those assembly jobs which involve simple repetitive motions that might be profitably mechanized. These include such items as the assembly of washers to screws and the prepositioning of parts on conveyors and similar items. Our experience with job enlargement indicates that more rather than less mecanization of simple operation is apt to occur.

A careful analysis of methods ----- with attention focused on opportunities for eliminating, combining and simplifying to permit expansion of the job ----- will be far more profitable than pre-occupation with balancing time values on the fragmented job.

The complete assembly of our automatic pump, for instance, consists of 25 component parts ----- a variety of materials ranging from small screws to the largest component, a die cast housing approximately seven inches in diameter. After assembly, the unit is given a run-in test, and a water-immersion test. Each pump permanently carries the operator's identification.

Before job enlargement, a progressive assembly was made on a bench and on a power conveyor which then moved on to the water-immersion test. The major portion of the work was performed on moving conveyors. Four to six operators were employed, depending on production schedules, and this resulted in a very high degree of specialization. For some operators, the work involved only the assembly of a couple of parts and the driving of several screws.

With job enlargement, each operator performs the complete assembly and is individually responsible for the quality of the assembled pump. The operator's work time for the enlarged job is about 90 seconds as contrasted with 20 seconds for the previous group assembly.

A U-shaped assembly bench was developed that provided, within the operator's work area of about 3 square feet, convenient location of the 25 component parts, three assembly fixtures and the water-immersion test unit. Relocation of equipment for performing the last machining operation on several of the larger components allowed the use of chutes and roller conveyors to supply the assembly benches, eliminating considerable material handling.

Application of work simplification principles resulted in double-station assembly and testing fixtures that were designed to allow the use of simultaneous motions during the major part of the operation. Other innovations were incorporated which reduced the assembly time and consolidated material locations to allow maximum use of motion economies. This degree of refinement was not possible for the previous conveyorized assembly group.

Thus, we have provided an operator with a variety of work and a responsibility for quality as well as the pace of the work ----- not just more work of the same kind. There has been less bidding off the job, and therefore, less training has been required. Grievances on labor standards have been reduced, and the operators' earnings have been maintained at a satisfactory level. Housekeeping is better, and because of the stability, supervisors are able to do a better job in this area. In addition, two economies were realized: (1) an annual cost reduction of $9,000 and, (2) an improvement of quality with a refuction in the number of defective parts from a five-per-cent to less than one-half per-cent.

A total of 15 installations of different jobs produced in a similar manner to the pump assembly have been completed, an additional 7 installations are in the process of being developed and should be completed in the next 60 days. In every instance, total costs have been reduced with a reduction in such significant items as cost of rework and cost of quality control. These savings are due to improved methods, improved materials-handling and operator responsibility for quality, coupled with operator accountability for quality. Included in the new installations are several complete washer and dryer assembly jobs of special models that are not produced in great volume. By revising existing delivery and assembly conveyor systems we were able to provide improved job designs and facilities of the non-paced type of installations for the production of complete assemblies.

It appears to me that based on our experience to date we can enjoy the full benefit of the improved job design described on our main assembly lines. In order to do so it will be necessary for our engineers to clearly see the advantages of the improved job designs and to make the necessary changes in facilities. The challenge of providing the creative changes in facilities required, can, and will, be accepted by engineers, the over-specialized operations are not the only way of doing the job. Further flexibility is required in order to enjoy a wider choice of methods.

Employee Response

While no mention has been made of job satisfaction, we have a genuine interest in the subject. For many years, we have used our Employee Idea Plan which is based on work simplification principles as a means of stimulating interest in matters of mutual concern.

Our conviction that a man's job was the logical point to develop our mutual interests suggested the use of work simplification as an appropriate means to this end. An indication of the importance attached to our efforts can best be demonstrated by the fact that all of the officers of the company actually spent three days evaluating the complete program before endorsing its adoption by the organization. Finally, every employee has at least ten hours of training in work simplification. Each group of workers taking such training is addressed by a member of management, who explains the need for employing the best methods and solicits the worker's interest and suggestions. As a result, in addition to enjoying a substantial monetary benefit each year, we have established a relationship which is conducive to change. The understanding achieved by the employees has resulted in far less suspicion of the motives of management, and an appreciation of the necessity for improvement in order to serve our customers better.

Our endeavors in this field were followed by a very thorough attitude survey and feedback conducted by the Institute for Social Research at the University of Michigan in 1951, 1952 and 1953. It is interesting to note that continued research gathered by this same group in several enterprises has confirmed, to a considerable degree findings of their study of The Maytag Company and has supported the approach to job design described earlier in this paper. These findings are well described in Rensis Likert's recent book, entitled,* "New Patterns of Management." Some of the conclusions related to attitudes that came out of this survey provide an interesting contrast to the present attitudes reflected by our job enlargement experience.

Our early survey indicated that many workers thought they were working somewhat faster than they would like to work. Many workers also said that changes took place which reduced earnings. When asked if this affected them personally, nearly all replied, "No, but someone whom I heard of had his rate cut." With grievance procedures readily available, the probability of overlooking an error in standards seemed rather remote. Even allowing for the self-interest involved in this proposition, the prevalence of the opinion that the pace was excessive indicated the need to look at both the way the job is designed and the interpersonal relationship, particularly in supervision. It is our considered opinion that changes which we are now making in job design will favorably modify worker conclusions concerning pace of work.

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*New Patterns of Management - Rensis Likert, McGraw-Hill, 1961

The following are some of the benefits which have resulted from job enlargement: (1) more stability because of a reduction in the number of operators bidding off of jobs; (2) more stable operator earnings as a result of not being dependent on other persons' effort; (3) better relationships with supervisors because of this stability; and (4) clearer understanding by the operator of his responsibility for quality.

Effect on Supervision

The opportunities for job enlargements are not confined to the highly organized manual jobs that are paced. Some of our instruction and oversight jobs classified as weekly salaried supervisory assignments. As a result, every time a schedule was changed men were transferred in or out of the Union ranks. After careful consideration, we were convinced that with proper standards the work of instruction and supervision could be more effectively performed by a working foreman who was eligible for membership in the bargaining unit.

The effect of this change was to increase the responsibility for performance at both the worker's and the working foreman's level and to upgrade the jobs of the remaining salaried foreman at the same time.

Quite aside from the high cost of having this level of supervision, the weekly salaried men performing these services were not getting the experience in shop practice that was required to maintain respect for their job contributions. By making the instruction and supervision a part of the responsibility of the working foreman as a member of the unit, it was our intention to emphasize the importance of results and to require operator responsibility.

Traditionally, too much of supervision's time has been spent reacting to current problems and situations. The working foreman, in the proper discharge of his duties, relieves the salaried foreman of much of this burden. The salaried foreman, therefore, is now in a position to fulfill the true responsibilitiies of his job, including in ample measure, foresight and judgement. *Attention to future planning and events on the part of the foreman is a major factor in the execution of the responsibilities properly delegated to salaried supervision.

Two areas of job enlargement have been stressed in this discussion: that of the worker and that of the supervisor. Increased productivity can be secured through the employment of the concept of job enlargement. While we are enthuisiastic about our experience at the Maytag Company there are difficulties. Many of our people seemed to regard "de-skilling" as evidence of an efficient operation, which does not necessarily follow. Since job enlargement requires a reversal in thinking as contrasted to the "de-skilled" approach to job design, the necessary change in concept and in practice presented a considerable difficulty.

Job enlargement is one of the most appropriate and effective devices with which industry can respond to the demands of change, which are now upon us because of the rapid strides being made in mechanization. We can now design and put to work increasingly complex mechanical and other systems to do the work for us, but we have done only half the job if we ignore the human equation, whether it be the supervisors or the supervised. Work demands a meaning if it is to be of value, and job enlargement introduces this purpose and meaning. It provides challenge, interest, and satisfaction; and it enhances results in terms of both quality and cost.

Based on our experience up to this time, it is our feeling at The Maytag Company that results achieved to date justify critical examination of individual situations for the purpose of employing enlarged job designs to the extent which the individual situation may permit.

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*Executive Foresight: Definitions, Illustrations, Importance, by Stanley Stark, The Journal of Business, University of Chicago. Vol. XXXIV, No. 1 - January 1961

LEGAL AND MANAGERIAL CONTROL OF WORK RESTRICTIONS IN INDUSTRY*

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This paper will take an objective but firm view of featherbedding in American industry, will note its cost, will study the inadequacies of current law and of management's rights in dealing with the problem and will recommend changes in the law, and will review both the public and the private programs currently invoked to aid retraining and job security while seeking to accelerate the pace of technological change.

I. Inducing Causes

Work-restrictive practices are commonly thought to be desired by workers merely to secure a larger or more prolonged share of industrial income, or to enable them in the absence of any work strain to do a lesser amount of work for the current rate of pay.

They may also be a result of unjustifiable speed-up, stretch-out, or rate-cutting policies or ill-timed technological changes by management.[1]

Yet their effects are just as harmful when they are a counter-attack upon managerial action, if going beyond whatever is, objectively, "reasonable" protection. Controls of such practices are imperative if American commerce and industry are to function with optimum efficiency.

II. Definition

Such practices generally include limitations on the use of labor-saving techniques and machinery, the requirement of more workers for a job than are needed, retardation of the amount of output in established periods of time, cutting down on total hours of work, elimination of competitive products from the market, insistence on an excessive number of work operations, forcing the replacement of one group of workers with another, and the refusal to supply workmen to certain employers on a long-run or continuing basis.

To name but a few, relevant make-work and work-restrictive practices have included the enforced three day work week of John L. Lewis and the United Mine Workers;[2] the refusal to use labor-saving devices by the cigar makers, painters, masons, plumbers, and stonecutters; certain refusals to supply workmen by unions controlling the available skilled manpower;[3] insistence on "bogus" (or unused) typesetting when printing is to be done from plates cast by use of a "matrix" or cardboard impression, which type is unnecessarily proofread, corrected, and then destroyed;[4] the "quote" and "standby" rules and the control of recordings by the organized musicians, including minimum sizes for dance and theatre orchestras, a requirement of hiring standby musicans, and the forcing of radio stations to use "live" musicians when recorded music is

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[1]On this duality of motives, see Daykin Walter L., "Featherbedding", 7 LAB. L.J. 699 (1956).

[2]In the Matter of United Mine Workers, Dist. 31, CIO 92 N.L.R.B. 953, 960 (1950), enforcement granted per curiam, 190 F. 2d 251 (4th Cir. 1951).

[3]Such a refusal by New York stone carvers occurred on the stated grounds that the prices were getting too cheap in the industry. Rochette and Parzini Corp. v. Campo, 301 N.Y. 228, 231, 93 N.E. 2d 652, 653 (1950). Analagously, the I.L.G.W.U. demanded a 35 hour basic work week to protect New York manufacturers from destructive competition; Los Angeles Times, May 18, 1953, pt. I, p. 18.

[4]American Newspaper Publisher Ass'n v. NLRB, 345 U.S. 100 (1953).

used;[5] the mileage, switching and work specialty limitations, and the minimum crew requirements imposed on the railroads;[6] similar minimum crew requirements in the longshore, construction, printing, motor carrier and textile industries;[7] the insistence by carpenters that the work be done at the site of the job even though it already has been done, or it would be cheaper to do the work, at some other place, and by painters that their members repaint or go over with a dry brush painted articles that are furnished by a factory; the restrictions of work in the construction industry by limiting the size of the brush used in painting, limiting the number of bricks that a bricklayer can lay in a day, limiting the number of laths that a lather can tack in a day, and limiting the number of barrels of lime a plasterer can handle in a specified period of time;[8] the instance by unionists on doing work formerly performed by small business owners;[9] the combination of closed shops or union shops with arbitrarily closed unions to limit the size of the available work forces;[10] picketing of retail outlets with the purpose of getting more work by permanently eliminating competing products;[11] and engaging in slowdowns and forcing the discharge of employees who "work too fast."[12] We all know to our sorrow of many such types of restrictive action employed in past years during the construction and equipping of our nation's missile bases.[13]

III. Extent of Injury

1. To the economy. The existence of such practices as these results in enterprise after enterprise having to pay money for labor services which contribute nothing toward increasing the quantity or quality of their final products. These costs must be passed on to the consumer of the particular goods or services in the form of higher prices. The firms are just not able to absorb those costs and still operate profitably. Such increases in labor costs without commensurate increases in productivity create an inflationary force upon the general economy.

As noted by Dr. John J. Quigley, Staff member of the New York Regional Renegotiation Board and former Chief Economist of the New York Regional Office of the Office of Price Administration:

> Nearly every person in the country is injured to some degree by raising prices. The most harmed are the people who live entirely on fixed dollar incomes, millions who depend on pensions, others who receive all or most of their income from bond interest, dividends on preferred stocks or the proceeds of insurance policies . . .
> In this same group are those with income fixed for considerable periods by law or custom, to whom increases always come long after the cost of living has risen. Even the member of a powerful union which is able to stay ahead, or abreast of the rise in living costs, through increases in wage rates and fringe benefits, has much of the increase offset by rising prices....[14]

The extent to which wages increase at a more rapid rate than does productivity, to bring such hardships, may be illustrated by the following. From the period 1947 to 1958, in basic steel the output per man hour increased 27%, while wages (not including fringes) increased 100%;

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[5] NLRB v. Gamble Enterprises, Inc. 345 U.S. 117 (1953); Countryman, The Organized Musicians; I and II, 16 U.CHI. L.REV. 56, 239 (1948-49).

[6] Levinson, Railway Labor Act--The Record of a Decade, 3 LAB. L.J. 13, 19 (1952). For a detailed presentation of specific state crew laws and of railroad contractual arrangements, see Backman, Jules, The Size of Crews, 12 LAB. L.J. 805 (1961).

[7] Backman, supra n. 6.

[8] Daykin, supra n. 1.

[9] See Gitlow, Union Stabilization Programs and Competition, 3 IND. & LAB. REV. 236, 238 (1952).

[10] James V. Marinship Corp., 25 Cal. 2d 721, 725, 155 P. 2d 239, 332 (1944).

[11] Such as the attempts of the Butchers Union to eliminate the competition of frozen food products. Kold Kist, Inc. v. Amalgamated Meat Cutters, AFL, 99 C.A. 2d 191, 211 P. 2d 724 (1950).

[12] Such was involved in Printz Leather Co., 94 N.L.R.B. 1312 (1951). The given definition and examples have appeared in other writings of the author.

[13] Van de Water, John R. Application of Labor Law to Construction and Equipping of United States Missile Bases, 12 LAB. L.L. 1003 (1961).

[14] Quigley, John J., Sharing Increased Productivity The Best Inflation Control, 189 COMM. & FIN. CHRON. 2307 (May 21, 1959).

in tobacco products, the increases were 52% and 78% respectively; in the railroad industry, output per man hour increased 56% while wages increased 105%.[15]

2. To particular Industries. While there are strongly differing points of view as to the harm caused by such conduct,[16] there is general recognition that certain industries have been substantially hurt[17] and that individual businesses have been completely ruined,[18] by make-work practices. For example, the American merchant marine carried two-thirds of the U.S. trade in 1946, but by 1960 this figure was reduced to 10½% through slowdowns, cost-increasing, and work-restrictive practices.[19] The need for controls in some industries is urgent.

IV. Legal Protection of Employer Against Unjustified Output Restrictions

Legislation on both the federal and state levels currently provides certain legal controls of such practices. Some are effective controls and other are not.

Section 8 (b) of the Taft-Hartley Act[20] makes it illegal for a labor organization to force payment for services not performed. But the section is useless in reality, since the United States Supreme Court has held that a violation of this section can occur only from demands for payment where no work is to be done. No violation occurs if services are proferred, however useless and unnecessary they may be.[21]

Other provisions of Taft-Hartley have been enforced, however, to preclude certain make-work activities, even though those provisions are not drawn as ''anti-featherbedding'' legislation on their face. Thus it has been held a violation of sections 8(a) (1), 8(a) (3), 8(b) (1) and 8(b) (2), to discharge or to force the discharge of an employee who refused to slow down his work operations to a union-determined speed,[22] And a violation of Section 8(b) (1) was found in coercing non-union employees into working a three-day work week.[23] The secondary boycott section was violated by inducing employees to refuse to handle prefabricated materials coming from another employer in order to force the less efficient processing of materials at the job site.[24]

The Anti-Racketeering Act[25] has been used to impose fines, under its prohibition of obstructing commerce by robbery or extortion, upon the forceful compelling of employers to pay wages for unwanted, superflous and fictitious services.[26]

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[15] Business Week., p. 113, Jan. 13, 1960.

[16] See SLICHTER; THE AMERICAN ECONOMY (1948); TRADE UNION ATTITUDES AND THEIR EFFECT UPON PRODUCTIVITY, in INDUSTRIAL RELATIONS RESEARCH ASSOCIATION, INDUSTRIAL PRODUCTIVITY 110, 125-129 (1951); Wolman, Industry-Wide Bargaining, 1 LAB. L.J. 167 (1949); Chartener, Trade Unions and Productivity, I EDITORIAL RESEARCH REP. 63, 71 (1950).

[17] Elisha M. Friedman, consulting economist, has estimated that, ''A six percent saving in labor costs would easily be possible with the cooperation of the railroad unions in abandoning featherbed rules, restrictive labor practices, and by having the states repeal the excess crew laws enacted under union pressure...'' Chartner, supra n.16, at 77. Mr. Neitzert, attorney for the railroad, in his appearance before the Presidential Board created during the 1960 railroad strike, stated that outmoded working rules were costing the railroads $600,000,000; a year. See Gomberg, Wm., The Work Practices Problem, 12 LAB. L.J 643-659, at 651 (1961). For an excellent demonstration of these costs, see also 114 RAILWAY AGE 18 (1958).

[18] See the fact situation in Senn v. Title Layers Protective Union, 301 U.S. 468 (1937).

[19] Strother, Robert S., Our Strike-Strangled Merchant Marine, Reader's Digest, Feb. 1963, p. 75.

[20] The National Labor Relations Act, 49 Stat. 452 (1935), as amended, 29 U.S.C. §§ 151-68 (1952).

[21] American Newspaper Publishers Ass'n v. NLRB, 345 U.S. 100 (1953); NLRB v. Gamble Enterprises, Inc. 345 U.S. 117 (1953).

[22] Printz Leather Co., supra n. 12.

[23] NLRB v. United Mine Workers, supra n. 2.

[24] Joliet Contractors Ass'n v. NLRB, 202 F. 2d 606 (7th Cir.) cert. den., 346 U.S. 824 (1953). For a discussion of how these sections operate to affect the permissibility of make-work practices, see Van de Water, The Secondary Boycott Provisions of Taft-Hartley; Their Potential Influences on Make-Work Activity, 28 So. Cal. L.R. 33 (1954).

[25] 47 U.S.C. § 506 (1952).

[26] United States v. Green, 350 U.S. 415 (1956).

Union conduct has been found to be within its intendment.

As an example of state controls, an attempt to make work for union members by restraining the sale of competitive products has been held illegal[27] within California's anti-trust law.[28]

These legal controls over union make-work practices are for the most part hit or miss, inconsistent, uncertain of enforceability, or ineffectual. It is submitted that careful reconsideration of controls in this field is desirable in the public interest, with due care for properly protected bargaining areas and for the legitimate interests of employees, employers, consumers, and the national welfare.

V. Legally Permissible Employer Self-Help Techniques

Throughout the nation, employers have taken it upon themselves to exercise their managerial right to conduct their businesses as they see fit, which in their minds includes the right to rid their businesses of wasteful practices. Individually and collectively employers have themselves taken the initiative to eliminate make-work activities. The courts have endorsed many of these actions as being legally privileged.

1. Managerial right to control the work force. The judiciary has recognized a right in the individual employer to control his work force so as to obtain maximum production and minimum waste from its employment. This right includes the ability to hire whom he chooses, discipline employees, and discharge incompetents, with the one limitation that he cannon interfere with the exercise of employee rights established by the federal Labor Relations Act.[29] It includes the ability to discharge for criminal activity,[30] vandalism,[31] dishonesty,[32] disloyalty[33] interference with production through absenteeism, talkativeness, or other misconduct[34] including slowdowns,[35] irregular work speeds,[36] violation of company rules,[37] insubordination,[38] and failure to follow the production schedule,[39] and for failure to work overtime.[40] The employer has the right, also, to lay off employees or shut down or remove his plant for economic reasons.[41]

2. Permissible opposition to concerted restrictive activities. The courts have established that the employer may collectively bargain to obtain a management prerogatives clause,

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[27] Kold Kist, Inc., *supra* n. 11.

[28] CAL. BUS. & PROF. CODE §§ 16720-58 (Deering 1951).

[29] The determining factor, in deciding the legality or illegality of employer conduct, is the absence or presence of an anti-union motive, and whether employer conduct "naturally and probably resulted in encouragement (or discouragement) of membership in a labor organization . . . ." Note, 39 CORNELL L.Q. 747, 754-55 (1954).

[30] Chicopee Mfg. Corp. 85 N.L.R.B. 1439 (1949) (family battle); NLRB v. Federal Bearings Co., 109 F. 2d 945 (2d Cir. 1940) (petty larceny); Kentucky Firebrick Co., 3 N.L.R.B., 455 (1937), *enf. granted*, 99 F. 2d 89 (6th Cir. 1938) (shooting non-union workmen).

[31] River Falls Co-Operative Creamery, 90 N.L.R.B. 257 (1950); NLRB v. Montgomery Ward Co., 157 F. 2d 486 (8th Cir. 1946).

[32] NLRB v. West Texas Utilities Co., 119 F. 2d 683 (5th Cir. 1941); Columbia Pictures Corp. 82 N.L.R.B. 568 (1949).

[33] NLRB v. Local 1229, IBEW, CIO, 346 U.S. 464 (1953).

[34] NLBR v. Russell Mfg. Co., 191 F. 2d 358 (5th Cir. 1951).

[35] Wyman-Gordon Co. v. NLRB, 153 F. 2d 480 (7th Cir. 1946); Elk Lumber Co., 91 N.L.R.B. (1950).

[36] Swift & Co., 11 N.L.R.B. 809 (1939) *enforced as modified*, 108 F. 2d 977 (7th Cir. 1940).

[37] NLRB v. Montgomery Ward & Co., *supra* n. 31.

[38] Lloyd A. Fry Roofing Co., 85 N.L.R.B. 1222 (1949).

[39] Goodyear Aircraft Corp. 63 N.L.R.B. 1340 (1945).

[40] C.G. Conn Ltd. v. NLRB, 108 F. 2d 390 (7th Cir. 1939).

[41] NLRB v. Jones & Laughlin Steel Corp., 301 U.S. 1, 46-46 (1952).

including the unilateral discipline of employees and determination of the work schedules, without violating Secs. 8(a) (5) of Taft-Hartley.[42]

It has been added in the past that a company need not continue to bargain with a union which orders a slowdown during negotiations.[43]

Defensive lockouts by all the members of an employers' association are a lawful form of opposition to whipsawing tactics.[44]

The employee may hire replacements and retain them in preference to strikers who were out for a make-work objective.[45]

He may refuse reinstatement to violent strikers.[46]

He may enforce his rights against any employees who breach contract terms.[47]

But incentive plans and work rules must remain bargainable issues.[48]

VI. Balancing the Competing Interests Through Legal Controls

1. The Problem. Labor law deals with an area fraught with complex human motivations toward good and ill, conflicting interests and organized and loudly proclaimed group prejudices.

Inherent in our national philosophy is the belief that the fundamental right of labor to organize, to engage in collective bargaining, and to engage in other concerted activity for mutual aid or protection, should remain under legal safeguard.

However, the mutual obligations of organized labor and management to bargain in good faith and not to intimidate each other in the selection of their representatives should likewise remain as legal duties.

Thus the problem arises as to where to draw the line between (1) the rights of free collective bargaining and of other concerted activities for mutual aid or protection on the one side, and (2) the duty not to engage in undue work restrictions on the other.

2. Factors in balancing these interests by control. Unions have a legitimate interest in relation to the production process (1) in protecting employee health; (2) in protecting employee safety; (3) in the question of sharing financial benefits from technological advance; and (4) in the practicability of limiting or avoiding technological displacement and its effect on the worker, in process of methods and equipment improvements.

There are sound grounds also for making illegal union-enforced demands of payment for services not relevant or useful, especially if (1) the evidence of lack of relevancy be required to be that degree of evidence which lies "beyond a reasonable doubt", and (2) establishment of work safety rules, the protection of employee health, and the practicability of avoidance of technological displacement, all be considered "relevant", and therefore bargainable, issues.

3. Summary. In summary, it is submitted that Taft-Hartley should be amended appropriately to make illegal the forcing of clearly irrelevant and useless work and to apply administrative hearings and the injunctive process to halt such conduct. There should be established a similar control policy over the railroad and commercial airline employees who are subject to the Railway Labor Act rather than to Taft-Hartley. Further, Federal legislation is needed to clarify the right of state protection through controls consistent with those under amended federal law, in the "twilight zone" where the National Labor Relations Board can but will not act under its current jurisdictional standards. And the United States Department of Labor should draw up uniform legislation in this field and propose it to the state legislatures.

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[42] NLRB v. American National Ins. Co. 343 U.S. 395 (1952).

[43] Phelps Dodge Copper Products Corp., 101 N.L.R.B. 360 (1952).

[44] NLRB v. Buffalo Linen Supply (Truck Drivers Local Union No. 449), 353 U.S. 87 (1957); Morand Bros. Beverage Co., v. NLRB, 190 F. 2d 576 (7th Cir. 1951), subseq. opinion 240 F. 2d 529 (7th Cir.), cert. den. 346 U.S. 909 (1953).

[45] NLRB v. Mackay Radio & Tel. Co. 304 U.S. 333 (1938).

[46] NLRB v. Fansteel Metalurgical Corp., 306 U.S. 240 (1939).

[47] NLRB v. Sands Mfg. Co., 306 U.S. 332, 344 (1939).

[48] Libby, McNeill & Libby, 65 N.L.R.B. 873 (1946).

If labor's legitimate interests are candidly recognized and left a matter of free collective bargaining, it is believed that organized labor's support could better be won toward improved work efficiency. Official union support for obstruction to technological advances is lessening,[49] and there is substantial evidence of positive union aid toward increased productivity, Certainly the workers, as a whole would benefit from a program which improves the efficiency of the general work force.

An imperative need in the field of law and human administration is for personal and government action to bring organized labor and management together in a spirit of voluntarism to reach decisions based not on class self-interest, but on the absolute moral standards, and on the intelligence arising from a conscious search for what is right for everyone, which is so essential to democracy's answer to Leninism. This objective provides one of the great challenges in the United States, today.

VII. Current, Managerial Methods of Control of Make-Work Practices. Many employers across the nation, large and small, have initiated programs of their own which may be worthy of other's adoption.

1. Exchange of other job security for elimination of work restrictions. The most prevalent means employed by management to control or eliminate make-work practices is to promise some other job security guarantee, in exchange for a promise by the union to cease its insistance on such restrictive practices. Commonly the employer will agree that no employee will be displaced by automation if the union will not resist efficiency improvements. These workers are then retrained at company expense, rather than laid off, to enable them to remain employed in other capacities with the company or in the community.

a. Promise to eliminate work restrictions in exchange for fund to provide employee benefits on displacement. The foremost of such plans is that executed in 1960 between the Pacific Maritime Association (on behalf of the employers) and the International Longshoremen's and Warehousemen's Union. The union agreed to the following clause:

> "(1) The . . . agreements shall be revised to eliminate restrictions in the contract and working rules, as well as in unwritten but existing union unilateral restrictions and arbitration awards which interfere with the Employers' rights dealing with sling loads, first place of rest, multiple handling, gang sizes, and manning scales, so as to allow the Employers to:
>
> a. Operate efficiently
> b. Change methods of work
> c. Utilize labor-saving devices
> d. Direct the work through Employer representatives while explicitly observing the provisions and conditions of the employees and avoiding speed up. 'Speed up' shall be understood to refer to an onerous workload on the individual worker. It shall not be construed to refer to increased production resulting from more efficient utilization and organization of the work force, introduction of labor-saving devices, or removal of work restrictions."

The agreement is thus referred to as a modernization of longshore work rules,[50] since this clause would seem to allow the employers to change or eliminate any rules which are wasteful.

The employers, in turn, agreed to establish a fund and to contribute to it $5,000,000 per year for five and one-half years. This in effect, is the price they agreed to pay to 'buy out' the restrictive work rules and the longshoremen's

[49] "Opposition to technological change has almost no overt and few covert supporters in union leadership ranks." Steiber, Jack, Work Rules and Practices in Mass Production Industries, SCHOOL OF LAB. & INDL. RELNS., MICH; STATE UNIV., REPRINT SERIES NO. 48 (1962-63).

[50] Killingsworth, The Modernization of West Coast Longshore Work Rules, LAB. & INDL. RELNS. CENTER, MICH. STATE UNIV., REPRINT SERIES NO. 46 (1962-63); Fairley, The ILWU-PMA Mechanization and Modernization Agreement, 12 LAB. L.J 664-680 (1961).

resistance to mechanization."[51]

The agreement is to terminate on July 1, 1966. During its term, all men who were fully registered longshoremen and clerks at the inception of the agreement are entitled to the following benefits: (1) It is guaranteed that there will be no layoffs. (2) Voluntary early retirement is available at age 62, at a benefit of $200.00 monthly, which equals the combination of maximum Social Security benefits and the amount due as the regular longshore pension. When receipt of Social Security benefits begins, when the employee is 65 years old, the fund will provide the worker with only $115 monthly. If a man continues to work until the time he normally would retire rather than retiring early, he receives the equivalent of $220 per month for the 36 months from age 62 to age 65, which he would have received had he retired early, or $7,920 in one single payment. (3) If work opportunities decline, the parties are free to invoke compulsory early retirement, in which event the men, as an inducement to retire, would receive a higher benefit; $320 per month. 60% of the annual contribution, or $3,000,000 is to be used to finance these provisions, as "the men's 'share of the machine' ".[52] (4) If a worker's average weekly earnings fail to meet the equivalent of 35 straight-time hours per week (roughly $100), this amount becomes due weekly as guaranteed, This provision is to be financed with the remaining 40%, or $2,000,000 of the annual contribution, as the price "the men are to receive for selling a portion of their property rights in the work rules . . . which they have struggled to obtain and which they are loathe to relinquish."[53]

Furthermore, these benefits accrue only to fully registered workers. There are in the working force also men known as "B" workers, and men known as "casuals". The former are men who eventually wish to become fully registered longshoremen and union members. They are willing to work for lower wages in order to earn the opportunity to become fully registered.[54]

[51]Killingsworth, supra n. 50, at 300. See also Kossoris, Working Rules in West Coast Longshoring, 84 MONTHLY L; REV. 1 (1961) on the "sharing savings" plan the employees discarded in favor of the "buying out restrictions" plan.

[52]Killingsworth, supra n. 50; Fairley, supra n. 50

[53]Fairley, id, at 672.

[54]Killingsworth, op. cit.

Casuals have no particular attachment to the industry. They work only on peak days when the lists of fully registered and "B" men have been exhausted. These are men having such other regular jobs as teachers, firemen, and policemen, who obtain an extra day's work in this way.[55] The parties have given the fully registered men a further cushion against the effects of work opportunity declines due to rising productivity, by agreeing to reduce the percentage of work going to the "B" men and casuals from 12% to 5%. Thus more of the available jobs will go to the fully registered men.

It has been reported that "The employers are confident that the savings made possible by the agreement will be far greater than the fund contributions. What the employers are paying comes to between 4 and 5 percent of total payrolls . . .

"It is noteworthy that this unusual agreement was reached without any participation of any kind by third parties."[56]

However, this program did not establish work measurements which completely insure against slowdown by other than through relying on the good faith of the men.

A similar plan, which did not prove successful, was instituted at the Armour Company. In 1959 an "automation fund" was established in the amount of $500,000. A formula of 1¢ for each hundredweight of tonnage shipped served as the basis of company contributions. The money was to be used initially to study the problems of retraining the employees and promoting employment opportunities within the company, and secondarily to execute the findings. The fund was administered by four representatives of Armour; two each from Amalgamated Meat Cutters, and Butchers, Warehousemen and United Packinghouse Workers; an impartial chairman, Dr. Clark Kerr of the University of California; and an impartial executive director.

The fund was eventually used to finance the retraining of Oklahoma City plant workers, but only for those who could show an aptitude for a particular different job and "reasonable job expectations" as a result of retraining; and then only in courses offered by a competent agency. The fund was to pay the first $60 of the cost of the course, and one-half of the remaining cost,

[55]Fairley, op. cit.

[56]Killingsworth, op. cit., at 304-305.

up to a total of $150. Thus for some workers a substantial personal investment was necessary.

Of 400 laid off, a lesser number applied for retraining, and 60 were screened as eligible. They were trained in "typing, office methods, blueprint reading, upholstering, welding, basic electronics, real estate procedures, air conditioning, and auto mechanics."[57]

An experimental plan was instituted under which laid-off employees could be transferred to other Armour plants, and they were provided with moving expenses.

Severance pay was awarded to laid-off employees, as well.

But the plan has not really worked. The employees were reported generally to be low-intelligence people. They were, in addition, no job openings either on transfer or in the community. Only the highest-rated and the highest-paid qualified, as easily adaptable and easily trained, and these men got jobs at less than what they had been making at Armour.[58]

b. Promise to eliminate restriction in exchange for employer financing retraining of displaced workers. A like plan, based on an agreement to create a fund for that purpose, was initiated at Xerox.[59] The Haloid Xerox Corp., Rochester, New York, and the Amalgamated Photographic Supply Workers Union, established an agreement which provided for sending selected men from the paper-sensitizing operation back to school, training them, at company expense, as machinists, and relocating them as needed in the machine manufacturing operations.

The estimated cost of all 72 eligible employees taking the course was $150,000; but is cheaper than laying off proven employees and hiring new, unknown machinists from the general labor force. The retrained men are proven employees; retaining them produced valuable rewards in the form of "high morale, confident employees, good community relations, and the trust and cooperation of the union." The cost is therefore small.

To be eligible, an employee had to have 10 years' service, a willingness to work and the ability to offer 10 more years of service. The courses were given at the Rochester Institute of Technology, for 6 weeks in duration. During each of the first two weeks, 2 days of machine-shop theory were taught, and during the final two weeks the class was split with 6 men to take advanced machinery and the rest to learn mechanical assembly.

The plan worked because it was in "an expanding company with enough diversity to absorb the retrained men;" because of "proximity of a good technical school"; because of the company's history of favorable union relations; and because of "alert, responsible management.[60]

c. Additional participation by other community businesses and local government. One commendable variation of such plans engaged not just the cooperation of the immediate union and employer in seeing that displaced workers are retrained, but also the cooperation of the neighboring employers and the local government as well. The Ford Motor Company, in its Chester, Pa. plant, first offered laid-off employees an opportunity to work at its Mahwah, New Jersey, plant. But most owned homes in Chester, and wished to take their chances there.

The company therefore instituted retraining classes for them.[61] Courses were conducted five days a week from 8 a.m. to 2:30 p.m., in two buildings of the Chester School District. The town contributed the use of those buildings. The state put up $21,000 for teachers' salaries and equipment, under a 1957 law for training the unemployed. And local industry, the Vertol Division of Boeing Co., Baldt Anchor and Chain Division of Boston Metals Co., and Sun Shipbuilding and Dry Dock Co., supplied machinery and materials on loan or as gifts. Those plants, in addition, told what jobs they had available and retraining was done specifically to fill them. Then the state planned to place those employees without

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[57] This plan is described in Business Week, p. 135-138, April 15, 1961, from which the discussion in the text is adopted. For a discussion of plans in the maritime and meatpacking industries generally, see Daykin, Work Rules in Industry, 12 LAB. L.J. 380-386 (1961).

[58] Business Week, supra, n. 57.

[59] This plan is described in Factory, 118:86-89 (July 1960), on which the textual discussion is based.

[60] Factory, ibid.

[61] This plan is described in Business Week, p. 74, July 29, 1961, which serves as the basis of the textual discussion of the plan.

appitude for retraining, in less demanding specialties.

Here, too, the advantage of using proven workers was present, with the added advantage of assured places for the retrained workers right in their own town.

d. Federal legislation. Another variation does not even require mutual agreement between the employer and the union. The federal Manpower Training and Development Act[62] allows the employee who has been displaced to apply for retraining benefits. "Enacted in 1962, this program is designed to retrain those whose present skills are made obsolete by technological change and to equip those who have no skills. Training is geared to skill needs as determined by the Labor Department in labor market surveys. The training is done primarily through vocational schools supervised by the Department of Health, Education and Welfare, although on-the-job training also is possible. Eligible workers received training allowances which are about the same as state unemployment compensation.

"To receive a training allowance, a worker must have had three years' employment experience and be the head of a household. For young people age 19 to 22 who have not had enough work experience to qualify for regular benefits, training allowances of up to $20 per week are provided. Individuals under 19 may be admitted to training facilities and also be eligible for the travel and subsistence allowances provided for all classes of trainees. These amount to $35 a week and 10¢ a mile car allowance for those who have to go away from home for training."[63]

e. Exacting an agreement to abolish make-work practices without having to agree in exchange to retrain employees. Occasionally, management may be able to exact an agreement to abolish make-work practices without having to offer promises of retraining in exchange. For example, the American Oil Company operated its plant with management personnel during a 191-day violent strike, inducing the union to settle. In the settlement agreement,[64] management obtained a work assignments clause permitting the company "to assign men to minor jobs outside their regular classifications if the work is incidental to their main work", giving the company "new flexibility in making work assignments." In addition, the company retained its right to prescribe the work to be done in each of nearly 100 job classifications and to determine the qualifications necessary to perform each job", with no veto power in the union.[65]

Similarly, the Swift and Wilson companies in the meatpacking industry, "rather than accepting automation funds and other union demands which they felt would limit management initiative, both long strikes and eventually settled for somewhat larger wage and fringe benefits but without concessions on management rights".[66]

f. Ability to abolish practices unilaterally by exercise of management prerogatives. Or, having exhausted the available administrative procedures in an attempt to reach agreement with the union over the compromise of restrictive practices, the employer may, it has been held, exercise his management prerogative unilaterally to discontinue the wasteful practices. A Federal Court of Appeals, in Brotherhood of Locomotive Engineers v. Baltimore and Ohio Railroad,[67] held that the trial court had properly dismissed a petition by the union requesting an injunction restraining the employers from putting into effect proposed work rule changes. The Employers, said the court, had negotiated with the unions to the fullest extent required by the Railway Labor Act, had accepted the recommendations of a special Presidential commission, and had agreed to submit the dispute to arbitration, and were therefore free to exercise their management prerogatives to effect the rules changes unilaterally when confronted with the union's unyielding position. The court was express, that:

> "(a) There is an area in the administration of a railroad business in which management is free to operate without consultation with the representatives of its employees.
>
> (b) The exercise of management's prerogatives is, however, subject to the employees' right to bargain collectively in areas covering rates of pay, rules and

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[62] 42 U.S.C. § 2571, P.L. 87-415 (1962).

[63] BUREAU OF NATIONAL AFFAIRS, LABOR RELATIONS EXPEDITER, p. 366.

[64] This agreement is described in Business Week, p. 113, Jan. 13, 1960, which serves as the basis of the textual discussion.

[65] Business Week, ibid.

[66] Steiber, supra n. 49, at 10.

[67] CCH LAB. RELS. Para. 17,929 (CA-7 Nov. 28, 1962).

working conditions of the employees, and on the question of whether these areas include the proposed rules", relating to the operating employees of the railroad.

(c) When, after compliance with the procedural requirements of the Act relating to a proposed change in an existing agreement or the introduction of new terms where no agreement exists, resort to collective bargaining fails without the fault of management, it may thereafter freely exercise its managerial prerogative in such areas of operation as may have been up to then disputed."

Thus the employers were allowed to institute the following changes as outlined by the Court: (1) the elimination of existing rules and agreements requiring the use of firemen on other than steam locomotives when used in yard and freight service; (2) the revision of rules governing the basis of pay and the assignments of railroad operating employees used in through freight and straightaway passenger service; (3) the elimination of rules requiring the use of a stipulated number of trainmen in road train crews and a stipulated number of brakemen in ground crews; and (4) the elimination of rules requiring the use of operating employees on motor cars and self-propelled work machines used in inspection, construction, repair and maintenance work."

2. Employee Indoctrination

(a) Without financial incentives. A second major means of controlling make-work activities is an intensive effort by management to demonstrate to the employees that they gain by the economies resulting from elimination of work-restrictive practices. For example, the Hudson Pulp and Paper Company instituted an "Operation Capacity" to inspire enthusiasm and boost morale of its 4,000 employees in five plant communities.

Included in the 14-point program where the goals of strengthening the organizational structure, expanding the sales force, reemphasizing customer service, improving company-employee communications, increasing supervisor training, reducing unnecessary paper work, and waging an all-out war on featherbedding.[68]

The plan operated through the plant managers meeting with the employees. They showed slides and gave talks on contemplated departmental projects. All activities were coordinated by a steering committee of company executives.

[68] 263 PRINTER'S INK 56-7 (June 27, 1958), from which the textual discussion of the plan is adapted.

The slide program introduced O.C., or Ossie, the symbol for "Operation Capacity". It was shown that if Hudson, then operating at a full activity level, were to drop to the industry level (5/6 of capacity), some of the employees would lose $52.50 per month in wages and many others would be laid off. It was explained how a 3½¢ reduction in costs would allow increases in the sales force and in advertising, to open new markets and thus assure their jobs. The employees were also told how they could save that 3½¢, such as through finding new ways to do their jobs faster and cheaper, keeping quality high and reducing scrap and waste and not tolerating slackers and featherbedders.

As incentives, score cards were kept for the best departmental achievements.

The plan is reported to have achieved the goals sought.[69]

(b) With financial incentives. Additional insurance can be afforded to the employer that the employees will in fact reduce or cease their wasteful activities by offering them a monetary inducement to do so. This inducement would take the form of granting to them a share of all savings resulting from increased productivity. The leader in the use of such a savings-sharing plan (as distinguished from the common profit-sharing plans) is Kaiser Steel Company. Their plan[70] provides for the monthly sharing with employees of 32.5% of the total net dollar gains from increased productivity of labor and the use of materials and supplies. That figure represents the historical ratio of labor costs to total manufacturing costs at Kaiser. It provides that no worker will be laid off because of technological advances, with workers who would otherwise be laid off because of the introduction of new machinery being placed in an employment pool and retrained as needed for new jobs. The company predicts that there will be no long-standing labor pool, since the attrition rate is higher than the rate of job losses due to technological improvements.[71]

The base year for determining costs of sold products is 1961. These expenses include both labor and material costs for each ton of finished steel. As technology increases output, unit costs should decrease, and the resultant savings will be placed in the fund for distribution monthly. The parties may agree to use those funds to improve existing vacation, holiday, retirement, and other fringe benefit programs.

[69] PRINTERS INK, ibid.

[70] These descriptions are adapted from the description of the plan in Los Angeles Times, Dec. 18, 1962, PART II, P. 1.

[71] Los Angeles Times, ibid.

Employees are guaranteed as a minimum any economic gain negotiated in the future in basic steel. However, it is believed that the Kaiser employees' share of the savings resulting from improved technology should always exceed any such amounts.[72]

Any of the 40% of the Kaiser employees now on incentive plans may elect by a majority vote to transfer to the sharing plan.

The plan is to operate for a four-year period, subject to annual review and revision. It eliminates periodic negotiations and corresponding contract deadlines on wages, fringe benefits, and technological changes. Thus it is designed to eliminate strikes arising over those issues - a commendable objective, indeed.

The nine-member committee whose studies produced this plan is headed by Dr. George E. Taylor of the University of Pennsylvania. Other public members are David Cole and Dr. John T. Dunlop. Edgar Kaiser, head of the firm, represented the company, and David J. McDonald, president of the Steelworkers, was the union representative.

The benefits to be derived from such a reduction in operating costs while at the same time increasing productivity are not realized solely by the employer. Undertaking such a program by the parties on a voluntary basis, as was the case with the Kaiser management and employees, can be said to display an appreciation by the parties of the role which they can play in managing their affairs, not only to serve their own interests, but also to serve the public welfare. Utilization of this anti-inflationary device may prove commendably to serve the interests of labor, management, and the public alike.

The principle involved, and the potential benefits to be derived, have been described by Dr. John J. Quigley in this way:[73]

> "To put the problem briefly -- each party to production and sale would like increased income, but would prefer to avoid rising prices of the things he wants to buy. The business owner would like higher profits, but he cannot continue to get them if the wages, raw material costs, and other prices he pays continue steadily to rise; the wage-earner wants ever increasing wages, but he would prefer to avoid a rising cost of living; the consumer wants the same or better products, but he does not want to pay ever rising prices for them.
>
> "Is it possible for all three of these groups to receive increased benefits from more efficient manufacturing operations over a long period of time? It is, if we continue to obtain increased productivity, <u>and we are willing to share its benefits</u>...
>
> "During a good part of the last 13 years, owners and organized labor have alternated in seeking to appropriate for themselves all or most of the gain from increased productivity. Typically, such gains flow entirely to owners for a few months to a year, then a new wage bargain brings a part, or all, or sometimes more than all, of such gains to organized workers, until a further period of production improvement has witnessed a further increase in productivity, with consequent gains to owners, then workers, etc.
>
> "What if, instead of continuing to seesaw struggle of the past, owners and organized workers were to agree to share increased productivity, as it occurs, not only between themselves, but with consumers (in the form of lower prices)? . . .
>
> "In order to get an idea of what would be likely to happen in such a case, let us make a few fairly realistic assumptions:
>
> "(1) That for an appreciable period of time, say five years, productivity throughout manufacturing, and in some areas of mining, transportation, and distribution continues to increase steadily at something like the rate which has been secured in recent years.
>
> "(2) That this increase consists partly in the average physical volume of output, and partly in absolute reductions in dollars of direct and indirect labor production costs.
>
> "(3) That benefits are received almost immediately after the increased productivity occurs, that is, during the same year. For example, a labor contract might be based on the agreed state of the increased productivity to be secured during the year, with the workers getting one-third of the estimated amount. Owners would, of course, benefit quarterly as higher profits were recorded, and consumers would benefit when prices were lowered.
>
> "On the basis of these assumptions, we can calculate approximately how much increased productivity will occur each year. In the first year, the labor cost of the quantity produced the previous year is reduced 3%. Since total labor cost before the saving was about 50% (35% direct labor, and about 15% as the labor part of factory overhead) of the cost of sales, that total labor cost was 35%

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[72] <u>Ibid.</u>

[73] Quigley, <u>supra</u> n. 14.

of sales. Total labor cost now becomes 34% of sales (2.9% reduction of labor cost). So here is 1% of sales as an increase in productivity to be divided.

"But total production has increased 2% in the first year, which means that the non-labor part of factory overhead (formerly at least 10% of sales) is now 10/102 or 9.8% of sales. Here is additional increased productivity of 2% of sales. . .

"If the total increase in productivity is divided equally between the three groups directly concerned, profits (which seldom exceed 10% of sales) will increase 4%, wages will increase 1.2%, and yet prices can fall .4%. Thus wage earners and the several millions of small stockholders will receive benefits from two directions.

"If the same plan were followed for five years, the result would be approximately as follows:

Year	Owner's Profits	Wages	Prices
1958	100.0	100.0	100.0
1959	104.0	101.2	99.6
1960	108.0	102.4	99.2
1961	112.3	103.6	98.8
1962	116.0	104.8	98.4
1963	120.6	106.0	98.1

". . . All that is necessary is that the majority of those most concerned understand what is possible and desirable, and agree to share the increased productivity of industry in the future."

Although it has recently been contended that such voluntary arrangements are impracticable,[74] it should be noted how closely the Kaiser plan approximates the hypothetical labor contract constructed by Dr. Quigley, and every encouragement should be given for experimental means toward reduction of our current work-restriction problem.

3. Building teamwork to reduce resistance to introduction of improvements. Thirdly, in the exercise of their managerial ingenuity, various employers have created a spirit of teamwork between management and employees and among employees, so that introduction of technological changes as they become wise is not unyieldingly resisted by the workers. They have come to feel, through management efforts, that the team benefits by reduction in operating costs, and that they benefit as members of that team. The workers have no fear of management installing new procedures for its benefit without regard for their potential displacement, since the feeling of mutual trust and confidence developed by management precludes such concern by the workers. They will freely allow experimentation with and introduction of new systems, relying, correctly, on their belief that successful negotiations will ensue to provide a means for protecting their interests - perhaps one of the means already discussed.

Varying devices are employed to build the requisite teamwork. The most prominent among small businesses is through management mixing with the workers and showing a genuine interest in their problems by inquiring about them. In the Weyerhaeuser Company for example, the office staff at Tacoma headquarters were questioned as to which areas were those about which employees were requesting answers. On obtaining that information, a Tacoma Office Employee Committee was formed to recommend to the Personnel Department the most appropriate program for providing those answers, and the officials most capable of providing the right answers. A series of meetings on company time was suggested, at which the best informed men in the given topic area would answer the employees' questions. The program is reported as having met with success, in developing a feeling in the employees of being a part of the organization.[75]

At the Kansas Gas and Electric Company in Wichita, company officers and department heads tour each of the seven division offices in seven cities, for two weeks in August of each year, spending the day visiting with employees and their spouses for an informal gathering. There employees visit informally with officers on any subject, after the one hour meeting in which they have reviewed company progress. The company feels that the meetings, on the employees' own time, have sparked increased interest in the company.[76]

At the unionized American Velvet Company in Stonington, Connecticut, the emphasis in communications is also on informality. At eight o'clock each morning the president and top company executives visit every department in the shop. "The president and his aids are usually called by their first names, and there is no fear or resentment on the part of the employees when

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[74] For an argument that increasing wages only with increases in production will not work, because of the practicability of business and investment decision-making, see Thulin, [Productivity Guides Won't Work, 40 HARV.] BUS. REV. 70 (1962).

[75] Newcomb & Sammons, Communications Clinic, 36 PERSONNEL No. 6, p. 75-78 (Nov-Dec. 1959), from which the description of the plan in the text is adopted.

[76] Id. at 76.

they see top management coming".[77] "An opportunity exists for all to talk to the boss, offer ideas, or lodge complaints." "There are no barriers between departments or individuals. When a problem arises it is everybody's problem."[78] A finer example of teamwork and mutual trust and confidence would be hard to find.

The same company has a unique committee known as the "Pops' Committee", composed of all the former presidents of the local union and acting as a top advisory board to both the company and the union. Though it has no authority to change existing regulations, its recommendations carry much weight -- reportedly much more than would the suggestions of outside consultants.[79] Rapid expansion and the development of new fabrics have brought on such problems as excess overtime in some departments while none is worked in others, piecework rates thrown out of line by changing methods and equipment, and uneven work loads. A "Planning Board" was formed as a subcommittee of the "Pops' Committee". In an on-the-job study the opinions and advice of affected workers are obtained. Suggestions to management follow. Three members of the Board are Union members, displaying management respect for and recognition of the union as an interested and responsible party, able to make contributions in establishing and developing an efficient program production.[80] Here would appear to be another fine example of mutual trust and teamwork.

Among large companies, General Motors Corporation was a leader in imaginative devices for raising employee morale and instilling a feeling of belonging to the team. The company began a "My Job Contest", awarding prizes for the best employee essays entitled "My Job and Why I Like It". Attitudes were improved by accentuating the positive aspects of the employees' jobs.[81]

The essays could, of course, be analyzed to learn about employee attitudes about their jobs such as by noting what aspects did not receive favorable mention; but the approach, in addition to getting information, "confirmed to the employee that Management was interested in his viewpoint and that he could get them to the top if we wanted to do so."[82] The requisite feeling of belonging was accomplished.

4. The "Bubbling Up of Ideas" Through Outsider Interviews

In recent years the writer has found another means of improving participation and productivity to be helpful to many corporations. That method is referred to as the "Bubbling-Up of Ideas". As an outsider, in work with corporations in recent years, the writer has often interviewed all levels of management and supervision and at times selected non-supervisory employees to secure their suggestions for the benefit of the company and themselves on a myriad of topics.

At an introductory steak dinner, a presentation is made on certain fundamentals of management, communications, morale and decision-making. Each person attending is promised three things, in reference to the forthcoming individual conferences where his suggestions will be elicited:

(1) That every idea he has to suggest will be passed on in a written report to top management;

(2) That no individual will be quoted as to which ideas come from him, though where necessary the department or work area referred to will be pinpointed; and,

(3) That regardless of the proclivity for condemning individuals, which some interviewers may have, no such condemnation of individuals will be passed on because the program is seeking positive improvements at no person's expense.

The following are some of the amazing number of topics which are covered in such interviews

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[77]Case study by Paul, George S., for the National Planning Association, reproduced in their COMMITTEE ON THE CAUSES OF INDIVIDUAL PEACE UNDER COLLECTIVE BARGAINING, CASE STUDY NO. 11: AMER. VELVET CO. & TEXTILE WORKERS UNION OF AMER., p. 30 (April 1953), from which the textual discussion is adopted.

[78]Paul, ibid.

[79]Id. at 31-32.

[80]Ibid.

[81]DAVIS, HUMAN RELATIONS AT WORK, pp. 90-91 (McGraw-Hill 1962).

[82]Id. at 375.

during 20-minute periods, with expansion to longer periods of time only where clearly found to be desirable:

Wages and Wage Systems
Fringe Benefits
Working Conditions
Communications
Leadership and the answering conflicts
Employee recreational and social programs
General morale
Organization, departmentation and lines of authority
Hiring, training and Career Development
Directing the Work Force
Delegation of Authority
Long range - and - short range planning
Management controls and Feedback

When the interviews are completed, they are reported in great detail under Supervisory and Non-Supervisory sections; a quantified summary is added; and an evaluation and a series of recommendations for action on a priority basis are appended.

Following study by a management team, a dinner is then held with all participants sitting at tables in carefully mixed groups, where they receive a report on Management findings and intended action, discussing at their tables their viewpoints and priorities for further improvements, reporting through their own selected chairman their findings before the entire group and receiving further comments and clarifications from top management in attendance.

As the Manufacturing Director of a major Southern California cooperation, then going through the difficulties of a major reorganization, commented following such a final meeting: "As of four o'clock this afternoon, I was totally convinced that we could not possibly solve the problems attendant to our reorganization program. Seeing the spirit and the positive, creative thinking demonstrated here this evening. I am now convinced that we cannot possibly help but solve these problems."

The findings from these many "Bubbling Up of Ideas" programs have been that significant changes do occur, both in attitudes and in material corrections, as a result of such a program's influence. And these results arise, not so much from an outsider telling a company what it should do, but through passing on the recommendations for improvements made by responsible persons within the firm itself. It is believed that here lies a sound and broadly usable way to accelerate management's and every person's gain, from both the creative thinking and the detailed knowledge of those who perform the company's specific functional jobs.

If those people are worthy of their jobs at all, they can be inspired to communicate valuable information and recommendations, if the company will demonstrate its interest, produce a creative environment for easy communication, assure the anonymity of the persons interviewed, and take the time to study suggestions, decide specific actions, and report fully on resulting plans, moves, and results to all those who have given their thoughts through the interview program.

VIII - Conclusion

In conclusion, it can be stated:

1. The laws against featherbedding in this country are inadequate and should be strengthened, to deal with serious hindrances to American productivity.

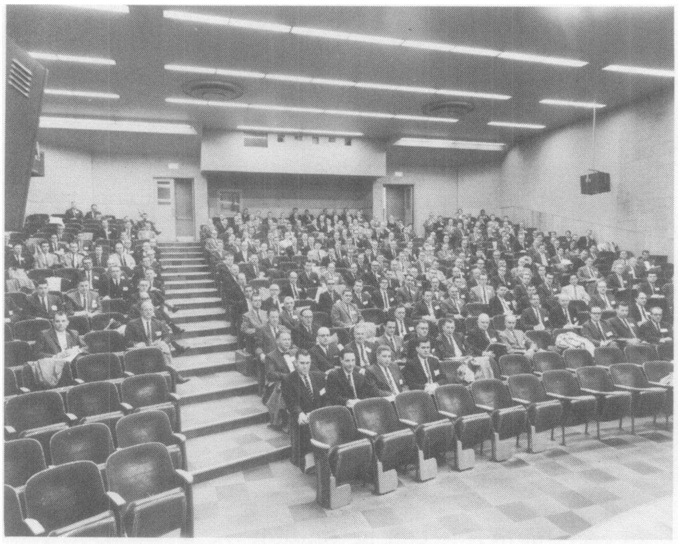
2. By firmness and moral courage, management, and the government itself, could often avoid featherbedding activities under existing laws to a far greater extent than is presently accomplished.

3. Yet labor unions have a proper role to play in protecting the interests of employees in the course of technological change.

4. Exciting, voluntary programs are being worked out by management and by management in cooperation with labor unions across the land, to develop an understanding of the economics of production and to protect proper employee interests, while accelerating the rate of technological and productivity improvements.

5. Such improvements can benefit labor in general, management, the stockholders, the consuming public, and our posture of national strength. Current experimentation should therefore be studied carefully for possible expanded application, by the private sector of our economy.

INFORMALS

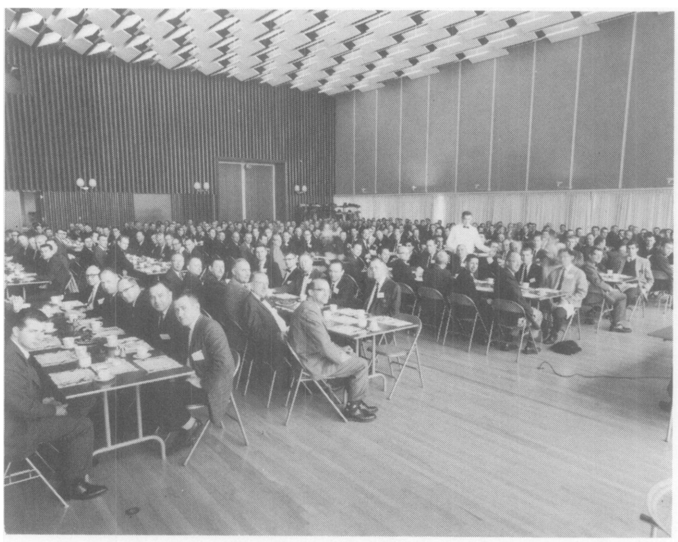


General Session
Dwinelle Hall

Chancellor Edward W. Strong
Welcome Address

BERKELEY

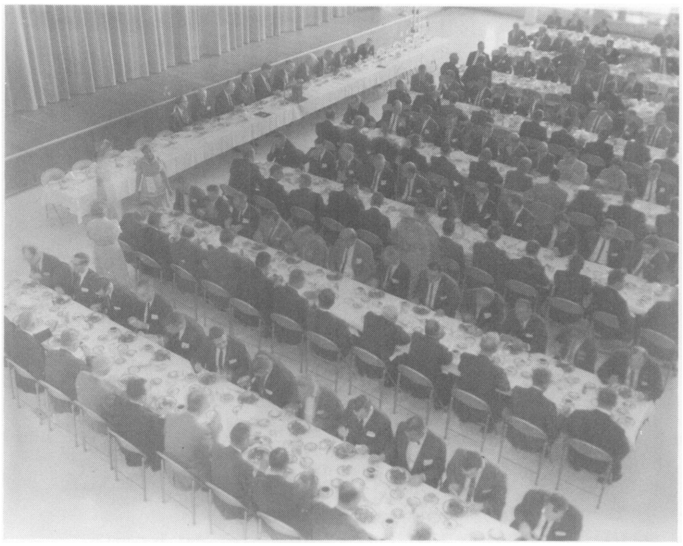
Luncheon Session
Student Union Building



Luncheon Session
Student Union Building

INFORMALS

Demonstration
Production Management Laboratories



Luncheon Session
Student Union Building

LOS ANGELES

General Sessions
William B. McLean

Luncheon Session
Student Union Building

ROSTER OF ATTENDANCE

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BONZO, Cecil
Johns Manville
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CRAWFORD, William
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2	1950 Jan. 27-28	D. G. Malcolm	M. P. O'Brien, Dean, College of Engineering, Berkeley
3	1951 Feb. 2-3	D. G. Malcolm	George A. Pettitt, Assistant to President Berkeley
4	1952 Feb. 1-2 Feb. 4-5	D. G. Malcolm	H. A. Schade, Director, Institute of Engineering Research, Berkeley Wesley L. Orr, Assistant Dean, College of Engineering, Los Angeles
5	1953 Jan. 30-31 Feb. 2-3	D. G. Malcolm	E. Paul DeGarmo, Assistant Dean, College of Engineering, Berkeley L. M. K. Boelter, Dean, College of Engineering, Los Angeles
6	1954 Jan. 29-30 Feb. 1-2	Bruce G. McCauley	M. P. O'Brien, Dean, College of Engineering, Berkeley Raymond B. Allen, Chancellor, Los Angeles
7	1955 Jan. 28-29 Jan. 31, Feb. 1	Joseph D. Carrabino (Gen.Ch.) Bruce G. McCauley (Ed.)	Paul H. Sheats, Associate Director, University Extension, Los Angeles Arthur M. Ross, Director, Institute of Industrial Relations, Berkeley
8	1956 Feb. 3-4	John R. Huffman	M. P. O'Brien, Dean, College of Engineering, Berkeley David F. Jackey, Dean, College of Applied Arts, Los Angeles
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14	1962 Feb. 2-3	Edward V. Sedgwick	Franklin D. Murphy, Chancellor, University of California, Los Angeles John R. Whinnery, Dean, College of Engineering, Berkeley
15	1963 Feb. 1-2	Thomas H. Hazlett (Gen. Ch.) George P. Redman (Ed.)	Foster H. Sherwood, Vice-Chancellor, University of California, Los Angeles Edward W. Strong, Chancellor, University of California, Berkeley

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