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THE IMPACT OF THE CHANGING ENVIRONMENT ON THE MANAGEMENT OF LARGE SCALE PUBLIC SCIENCE PROGRAMS

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THE IMPACT OF THE CHANGING ENVIRONMENT ON THE MANAGEMENT OF LARGE SCALE PUBLIC SCIENCE PROGRAMS

By

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B.S., University of Texas, 1957

THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of

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ABSTRACT OF THESIS

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ABSTRACT

Large scale public science programs, particularly those associated with the defense and space industries have grown more expensive, both in terms of dollars and in human assets since World War II. Many interacting variables have contributed to the environment which forced these costs to increase such as: each administration's perception of world events, sudden shifts in program emphasis, increasing technical sophistication, constant crises pressure, increasing costs, increasing government control and decreasing personnel morale.

In addition, emphasis in the social and economical environment of the Nation has shifted from defense and space to the biosphere and the well-being of the individual. Therefore, the objective of this paper is to propose a mechanism for reversing this trend toward ever increasing program costs. Specifically, the proposition is that government contracting agencies should become their own integrating contractor. The primary reason for this proposal is to avoid the huge, long-term contracts that have traditionally required the winning contractor to hire great numbers of additional personnel only to dismiss them again as their portion of the program is completed. Also, by contracting directly with subcontractors, the government can reduce the compounding of overhead charges and profit by each element of the program hierarchy.

Motivation for the project as well as some insights as to the nature of the problem were derived from the author's experience. Recent periodicals and management texts were the

primary sources of information. Research to confirm the basic causal factors also included a search of textbooks on recent American history. Computer technology was seen as a tool for assisting in the accomplishment of future programs without hiring massive, temporary staffs. Current status and suggestions for the utilization of these computers were obtained from recent trade journals and by interviewing key management personnel at the Manned Spacecraft Center, Houston Texas.

Course work for the Program for Advanced Study in Public Administration, plus additional research, suggested that gross disregard for basic human behavior characteristics has been one of the major contribution factors to high program costs. Consequently, a redefinition of the interface between the responsible government contracting agency and the contractor is proposed to help provide a working environment that is conducive to increasing the self-esteem of both government and contractor personnel.

In summary, this redefinition together with the proposition that government agencies become their own integrating contractor are seen as reasonable, realistic means for reducing the cost of future large scale public science programs.

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ABBREVIATIONS

CTR	Cathode ray tube
DOD	Department of Defense
ICBM	Intercontinental Ballistic Missile
MSC	Manual Spacecraft Center
NACA	National Advisory Committee on Aeronautics
NASA	National Aeronautics and Space Administration

CHAPTER I

DEVELOPMENT OF THE RESEARCH PROJECT

Purpose and Scope

Several forces have been developing in the last few years which are significantly changing the environment in which large scale public science programs are managed. These forces are the maturing of computer technology; the increasing tensions between the government and defense and space to the biosphere and the well-being of each individual; and the recent pressure to reduce federal spending to curb inflation.

It is not possible to single out conclusively the contribution that any one of these forces has made to the environment in which science policy makers now find themselves. Nor can the contributions of any single force on future policies and processes be anticipated without consideration of the other major factors involved. Therefore, each of the forces mentioned above will be described and its identifiable contributions woven into the recommended management policies.

The objective of this paper is to propose a mechanism in which computer technology and more attention to basic human motivational factors can be used to aid the administrators who are attempting to relieve the dysfunctional tensions and to accomplish the goals associated with their total environment.

Specifically, my proposition is:

> Recent advances in computer technology will permit large scale public science organizations to become their own integrating contractor with the attendant benefits of significant reduction

> in costs and improved personnel morale while maintaining the required quality of the end product.

Computer technology, like few other events in history, has such ubiquitous application and is inducing such fundamental changes in the way society will conduct its routine business that it must be considered to be one of the major factors.

> Today, we are dealing with machines that can change society much more rapidly and profoundly than the machines that accompanied the "Industrial Revolution" of the late eighteenth and nineteenth centuries because they deal with the stuff of which society is made - information and its communciation.[1]

One assumption upon which this paper is founded is that economic and social pressures will force all levels of federal program management, especially within the Department of Defense, The National Aeronautics and Space Administration, and their contractors to eventually learn to use these tools. The transition can be painful and very costly or with careful planning, discipline and a willingness to break with tradition, it can be one of the best things that has happened. The objective then is to make the transition as quickly, yet as painless and as smooth as practical.

This assumption seems well supported by recent literature. During the last year, the application of computer technology to management function has been the subject of numerous articles in the Harvard Business Review, articles in the American

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[1]Diebold, John, Man and the Computer, Frederick A. Praeger, Publishers, New York, 1969, p.4.

Management Association pamphlets and innumerable articles in the various trade journals. The following quotations, for example, were taken from recent issues of the Harvard Business Review:

> The companies that will survive and prosper will be the ones whose managers have mastered the techniques of generating and using perceptively the information that can be provided by data banks.[2]

> For their well-being, all institutions in our society, particularly industry and government, must anticipate radical technological changes that sweep aside existing practices and open new opportunities - or create new problems. The companies that neglect this task run a serious risk.[3]

Fortunately, the use of computers has been central to an increasing number of functions in the defense industry for the last twenty years. In the early 1950's, for example, computers were absolutely necessary to compute accurate missile trajectories. By the mid-1950's, a few complex hardware subsystem performance programs were being used in the larger companies. During the last few years, computers have been utilized for the technical aspects of nearly every large hardware program. However, their use as a management tool has just begun to become operational in a few companies. The historical development of computer technology and its utilization by defense

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[2] Vandell, Robert F. "Management Evaluation in the Quantitative World," Harvard Business Review, January-February, 1970, p.83.

[3] Bright, James R., "Evaluating Signals of Technological Change," Harvard Business Review, January-February, 1970, p. 62.

contractors is well documented and need not be comvered here.[4] Discussion relative to computer technology will therefore be limited to recent developments and to the applications proposed.

A frequently overlooked, yet essential variable related to the application of computer related devices is the human element.

> Industry's greatest interest has been in the direction of discovery, invention and mechanization, and will be even more so now with the advent of automation. However---even in the most advanced form of automation, people are necessary. And automation will demand increasingly more and more from the men who are to build and control the machine.[5]

Development engineers have traditionally been poorly satisfied, or self-actualized, by their work.[6] This dissatisfaction is particularly true in the defense industries. Government procurement practices and industrial employment practices have resulted in such job fragmentation that it is difficult for the individual to identify with, or claim any specific thing as his personal contribution to the program. The reward structure is depersonalized. Working conditions usually tend to further reduce individual identity by arranging large numbers of employees in what has traditionally been called a "bull pen" or "on the floor", therefore morale tends

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[4] For example, see Berkeley, Edward C., The Computer Revolution, Doubleday & Co., Garden City, New York, 1962.

[5] Shefferman, Nathan, The Shefferman Personnel Motivation Program, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1961, p. 1.

[6] Pelz, Donald C. and Andrews, Frank M., Scientists in Organizations, John Wiley and Sons, New York, 1966, p. 116.

to be low and turn-over high. These conditions, added to the feast-or-famine nature of the industry, present a formidable array of negative motivators.

Even without the use of computers, program costs could be reduced significantly and quality increased by providing conducive environment and by arranging assignments such that each employee would feel that he is important to the total operation.

> If we can solve the problem of human relations in industrial production, I believe we can make as much progress in the work cost as we made---through the development of mass production.[7]

Therefore, improvement in the job satisfaction and self-actualization of the individual worker is a major consideration in each argument supporting my hypothesis.

This study is limited to a macro-view of the policies and processes of a major development program as viewed from a scientific field center of the Federal government. Specific examples are used only to illustrate the concepts being presented. Although arbitrarily selected, these examples are hopefully realistic and reasonable.

Major Points in the Research Design

This paper is based primarily upon descriptive, sociological research dealing with the development of forces and with the interaction of groups; the impact of government in-

[7]Shefferman, p. 6.

stitutions on social and economic welfare of the defense industries and the search for a better way of doing things.[8]

The arrangement of the paper as well as the purpose and primary research data source for each chapter is contained in the following paragraphs.

Anguish in the Defense Industry[9] -- My interest began as a concern for the low employee morale and for the apparently exorbitant cost of aerospace programs observed during several years association with major government hardware programs. An academic year devoted to graduate work in the Program for Advanced Study of Science Policy and Administration at The University of New Mexico has provided an excellent opportunity to study all aspects of this situation. Regular course work covered such germain subjects as the formulation of Public Science Policy, Public Finance and the Budget Process as well as both the historical and current thinking on Human Behavior and Organization Theory. In addition, the academic environment and facilities provided a unique opportunity to conduct specific research on the forces discussed herein.

The research procedure chosen required first a verification that the low morale and high cost were widely recognized as real concerns; also, that the factors postulated as important were common to the industry and not just associated with a few specific programs.

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[8]Dawe, Jessamon, Writing Business and Economic Papers, Littlefield, Adams & Co., Totowa, New Jersey, 1965, pp. 9-13.

[9]Title taken from Richard M. Anderson, "Anguish in the Defense Industry," Harvard Business Review, November-December, 1969.

Periodicals were chosen as the primary source of data because they contain broader representation of opinions and much more current thinking than is possible for even the most recent books. Current data are considered to be important because the equation for a solution must be based on the existing status and the trends of the key variables. Findings and conclusions resulting from this phase of the research are contained in Chapter II.

Computer Technology -- Early in the research process, computer technology emerged as a mechanistic device having sufficient power and scope to serve as a means to improve the morale and cost picture. Research then shifted to determine the current status and trends of computer technology and utilization.

Since computers have been a basic tool for the defense industries for many years, research was also required to determine why computer technology had not already had the impact on the program cost and personnel morale postulated by the literature. The primary source for this data was recent periodicals dealing specifically with computer technology and its uses.

Personal interviews were also conducted with key personnel at one government field operation, several aerospace contractors and two major suppliers of computer hardware, software and utilization services. These interviews were conducted to calibrate, in a sense, the literature; that is, to determine if the impressions obtained from the literature was consistent with actual utilization. The results of these studies are contained in Chapter III.

<u>Application of Computer Technology to Specific Program Management Functions</u> -- After determining the root causes behind the high cost and low personnel morale of the defense industry, and that computer technology has become operational, the next step was to show that computer technology can be instrumental in the treatment of these concerns.

First, existing and potential applications of computer technology in specific hardware program management functions are presented to facilitate an understanding of these functions. Then, the effect that the use of computers will have on personnel requirements and policies is discussed. Data for the discussion of the management functions and the specific application of computer tools thereto come largely from the author's experience augmented by personal interviews with key personnel in these functions at the NASA Manned Spacecraft Center, Houston, Texas. This discussion is contained in Chapter IV.

<u>Impact on Personnel and Organizations</u> -- Research results on basic human motivation and on how computer technology has affected, is expected to affect and ought to affect personnel requirements, personnel policy and organizational structure is contained in Chapter V. Foundation knowledge for this selection was acquired in conjunction with the Program for Advanced Study in Science Policy and Administration. Research

on specific points utilized both current periodicals and books containing historical and current thinking on human motivation and organization theory.

Government as its own Integrating Contractor -- Chapter VI contains a logical development of the arguments to support the hypothesis that the government should become its own integrating contractor. The model developed is highly normative in that emphasis is on what ought to happed with no adjustments for specific programs on specific government agencies. A hypothetical program is invested to enable the discussion of specific items thereby, hopefully, reducing the potential for semantic confusion. Particular emphasis is on the demarcation of roles between government agency and its contractors.

Conclusions and Summary -- The summary and conclusion chapter contains first a brief restatement of the main points discussed in each chapter, program management policies and practices. Then, a set of normative policies and practices are presented which are calculated to substantially reduce the cost of large government hardware programs and greatly improve the self esteem of the average employee involved with defense industry.

CHAPTER II

ANGUISH IN THE DEFENSE INDUSTRIES

The trend in the government's technique for managing large defense programs has been to respond to ever increasing costs with ever increasing control while at the same time requiring the contractor to accept an ever increasing proportion of the risk.[1] This detailed control and heavy pressure is forcing the defense industry, especially the prime aerospace hardware contractors, to consider whether or not the risk of bankruptcy, the health, home life and careers of many of its key personnel and the "feast or famine" nature of the industry is worth the reputed low average profit potential.[2]

This situation did not just happen. When viewed in context with major trends of the last twenty years, these conditions are more understandable.

Background

The following review of the major events, or phases through which the defense industry has passed during the last twenty or so years, is intentionally simplified to emphasize the prominent trends.

Prior to 1941 -- Prior to World War II, weapon system procurement was relatively simple and inexpensive. In the aero-

[1] Drake, Hudson B., "Major DOD Procurements at War with Reality," Harvard Business Review, January-February, 1970, p. 119.

[2] Ibid., p. 120.

space industry, for example, a company would build a few prototype aircraft designed to meet a particular need of the Armed Services. The service would test the aircraft and if it fit an existing need and was acceptable from an operations viewpoint, the service would place an order for a number of aircraft on essentially a fixed price basis. If the service decided that they did not want or need the aircraft, the company would try again. In this government/industry relationship, the government performed two basic, distinct functions. It provided several customers (each branch of the service) in the usual marketplace sense of the word. And it provided technical assistance to the entire industry at research centers such as the NACA aerodynamic research and testing center at Langely Field, Virginia. The government in its role as customer were different agencies than the government as technical advisor.

World War II: 1941 to 1945 -- During World War II, the industry began to change from a relatively small industry into a giant. In a real sense, the industry exploded in an environment of schedule pressure and tight labor. To get enough good people to do the job, the industry hired anyone they could who had even reasonable credentials in the hope of getting or developing enough good people to get the job done. This became a tradition.

Postwar: 1945 to 1948 -- After the surrender of Japan, September 2, 1945, the United States could hardly wait to demilitarize. Even though approximately one quarter of the work force (8 million veterans and 3 million defense workers) were layed off in a nine month period, the transition was smooth.[3] Primarily because the general economy developed so rapidly to satisfy the needs that had accumulated during the war. However, the defense industry had the first four-year period of famine.

> Except for temporary increases at two points of crisis, the gradual whittling of the armed forces continued, until by the spring of 1950 the army was down to 600,000 men and the ceiling on defense expenditure to $13 billion.[4]

Korean War: 1948 to 1953 -- During this period, aerospace spending alone quadrupled, jumping from approximately $3 billion per year to approximately $12 billion per year in 1953.[5] Cost was secondary to schedule and technical development. In addition, most defense contracts were of the cost plus fixed fee type in which profit was a fixed percentage of the total program cost. Therefore, each company was motivated to hire as many people as they could. In addition, schedule pressure was at crisis level. Engineers were in such great demand that any reasonably qualified person could find a job.

Postwar: 1953 to 1957 -- In 1953 a movement began to reduce military expenditures. A "new look" in defense policy was formulated in which it was decided that the United States would

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[3] Fishman, Leslie, Allen, Jay, Bunger, Byron and Eaton, Curt, Reemployment Experiences of Defense Workers, Report No. ACDA/E-113, United States Arms Control and Disarmament Agency, 1968.

[4] Williams, T. Harry, Current, Richard H., and Freidel, Frank, A History of the United States: Since 1865, Alfred A. Knopf, New York, 1965, p. 673.

[5] "Growth Trends: U. S. Aerospace Industry," Aviation Week and Space Technology, March 9, 1970, p. 22.

rely on thermonuclear weapons delivered by the Air Force. Army ground forces, unproven missile research and other basic scientific research were all greatly reduced. Overall defense expenditures were reduced by 10 percent.[6] The defense industry had its second four years of famine. Less than one-tenth the number of the veterans and defense contractors laid off after World War II were involved in the post Korean transition. However, there was no corresponding accumulation of civilian needs. Therefore, in spite of continued defense spending, intensive use of the GI bill, and a healthy economy, the personal income loss from production was more than double the post World War II loss.[7]

<u>Arms Race: 1957 to 1961</u> -- In August 1957 Russia launched its first successful ICBM. In October, 1957, it placed its first satellite into orbit. President Eisenhower devoted almost the entire 1958 annual State of the Union address to Congress to the armament crisis. He called for heavy additional expenditures for missiles and for submarines and cruisers that could carry these missiles.[8] Although it was a feast period for the missile and ship building industries, it was extended famine for the aircraft manufacturers. The prevailing attitude at the time was that military aircraft would be totally replaced by missiles. Even so, by 1961, defense was really big business directly employing 3-1/2 million people and requiring half of the Federal Budget.[9]

[6] Williams, p. 749

[7] Fishman, p. 229.

[8] <u>Ibid.</u>, p. 762

[9] <u>Ibid</u>, p. 787

Defense contractors became notorious for exceeding contract costs. Mr. Richard M. Anderson suggested that Congress, the contracting agencies and the private contractors each contributed to an environment within which cost excesses were inevitable.[10] Both the contractors and the agencies for which they were preparing cost and schedule estimates tended to be optimistic. They were afraid that if they told Congress what they really thought the program would cost, Congress would not approve the funds.[11] The problem was further complicated because the contractors did not maintain realistic PERT and other trend charts considered to be essential for good management to avoid revealing the true situation too soon. By the time the problems became obvious, sunk costs were so great that the program would probably not be cancelled.[12] This lack of sound management practices, of course, caused even further cost increase and schedule slippage.

The Kennedy Years: 1961 to 1963 -- President Kennedy and Secretary McNamara built their defense plans upon the theory that the strength of thermonuclear weapons on the part of both the United States and Russia was sufficiently great to constitute a mutual deterrent against war. They also favored a broad range of options as opposed to President Eisenhower's reliance on an all-out nuclear attack.[13] Again the distribution of defense funds shifted. Again hundreds of thousands of families had to move to follow the business.

[10] Anderson, p. 168.
[11] Drake, p. 125.
[12] Ibid.
[13] Williams, p. 787.

In addition, President Kennedy asked Congress to set a goal of landing men on the moon and returning them safely before the end of the decade.[14] The newly created NASA and its contractors began urgent staffing. Again there was little time and little incentive to be overly concerned with selecting the best people, or with saving money. Total employment by the NASA and its contractors grew from approximately 50,000 in 1961 to over 400,000 in 1965.[15]

Problems of another kind began for the industry in 1961 when Secretary of Defense Robert McNamara began to try to get the defense industry on a more business-like financial posture. Much of the defense spending during the Korean War and the Cold War arms race was for new technology on a tight schedule. Therefore, cost plus fixed fee contracts were used. Secretary McNamara was convinced that this type of contract for large military hardware procurements was much too expensive. He initiated several changes; greater emphasis on planning prior to contract award, the Total System Concept and incentive contracts.[16] After decades of operating in an environment in which money, for all practical purposes was no object, these changes ran into considerable difficulty. Unfortunately, the remainder of the Department of Defense and the contractors could not change old habits and procedures that quickly.[17] The only real

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[14] Ibid., p. 788.

[15] Normyle, William J., "Limited Funds Defer Manned Programs," Aviation Week and Space Technology, March 9, 1970, p. 67.

[16] Williams, p. 788.

[17] Drake, pp. 123-124.

change was a tremendous increase in cost and paper work. The contractors still responded with what they thought the agencies wanted to hear rather than with realistic estimates.

In addition, the "total system" plan was initiated in an attempt to make the prime, or integrating contractor do a better job of planning by making him responsible for every aspect of the system being procured from initial design to operational support. This concept has proven to have several disadvantages.

a) The incentive contracts required implicitly that the contractors be able to predict the cost of solving unknowns many years in advance. This has proven to be unrealistic because of the unanticipated unknowns that always arise early in testing phases. Nor was the implementation of this concept realistic. Several of these "total system" contracts are so large that if the contractor guessed wrong, or managed poorly, penalties could bankrupt the company several times over.[18]

b) Another difficulty has been the government's desire to make changes. Schedule pressure and rapid technological

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[18] Ibid., p. 124. One particularly significant example is Lockheed Aircraft Corporation. According to Barry Miller, "Complex Problems Hit Lockheed," Aviation Week and Space Technology, March 30, 1970, pp. 56-57, "If one single factor could be isolated and identified as the root cause of the companies financial woes, it would be the concept of total-package procurement and the controversial interpretation and administration it allowed." Although Lockheed has a backlog of over five billion dollars, three of its large defense programs are total-package, fixed price contracts that are in trouble. Lockheed's net worth is reported to be approximately $340 million and the loss from these programs could exceed $600 million.

developments forced the armed services and the NASA to combine the role of "customer" with the role of "technical advisor" to do everything possible to get the systems operational as soon as possible. Unfortunately, by combining the roles of customer and technical advisor, the government essentially removed technical responsibility from the contractor. Informal "suggestions" as well as formal directions were issued by the government specialists on virtually every element of the system being developed. Thus, if the contractor so chose, he could claim that he had been directed to do almost everything. These changes were very expensive in both dollar cost and personal morale.

This tendency to change the contractor's design is particularly onerous in the early development phase before formal configuration control has become effective. Any government design engineer could write a letter of technical direction to the contractor changing requirements or telling him how to design a particular part. Of course, these letters were not official until signed by the appropriate contracting officer. However, it was very difficult for these contracting officers to know if these changes were really needed, or simply a different way of doing the same thing. Since the engineer working for the government represents the customer, he usually got the benefit of the doubt.[19]

c) Cost is significantly increased by the compounding of profits and overhead charges for tiers and tiers of subcontractors

[19] This observation is based on several years experience in the Apollo Program Office and verified by explicit conversation with NASA contracting officers.

and vendors. Each level's profit and overhead charges include a percentage of the total cost of the tiers below. For example, the following case was noted by the March 31, 1964, McClellan Report prepared by the Senate Committee on Government Operations:

> One instance they noted involved pyramiding through three tiers; (1) the producer of the article; (2) the subcontractor, and (3) the prime contractor to the government. They found that the original producer's bill was $53.8M, including 9.2% profit. The subcontractor tacked on a modest profit of 6.8% and billed the prime $57.5M. The prime tacked on G&A of $2.1 and a modest profit of 5.9% and billed the Government $62.9M - the difference in cost from producer to the user over $9M, and total profits over $11M. One might logically suggest that this profit pyramiding was appropriate because of the effort input by the succeeding tiers. However, the costs for any such effort is not included here. These costs were reimbursed separately and profits added.[20]

Vietnam and Apollo: 1963 to 1969 -- As the urgency of the Cold War began to subside, Vietnam, the Apollo program and pressure for domestic needs began to increase. Demand gradually increased for conventional weapons; i.e., rifles and bombs as well as new weapons especially designed for the non-structured, jungle environment of Vietnam action. Aircraft orders doubled from approximately 1.3 billion to 2.5 billion between 1964 and 1966, then began decreasing almost as rapidly as it had grown. Missile orders dropped from 1.6 billion to approximately 1.0 billion in 1965, then increased gradually to 1.3 billion in

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[20] Lang, Dave, "Profits," NASA Procurement Countdown, Vol. 25, December 1969.

1968 before starting down again.[21] Again, countless thousands of people were hired only to be fired a few years later.

Summary of Historical Influence

When viewed from the taxpayers point of reference, the defense industry has been an ever-increasing monster. Except for brief post-war periods, expenditures have climbed from the beginning of the Korean War until 1969. Each major increase was forced by a specific world event that required crisis response. For the most part, anyone could get a high paying job whether they were good workers or not. However, a very large percentage had to plan to move every four or five years as emphasis shifted on the type of weapons needed. These moves are very expensive for the government and for the employee. As a rough estimate, the personal economic loss averaged one half of one year's salary per move per family.[22] For the individual it also meant leaving friends, uprooting families and starting over in another house or another job with no seniority. It was not unusual for an employee having several years experience to move, as he had done before, when business began to decline. This technique in the late 1960's, however, frequently resulted in the employee finding himself without a job in a few months

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[21] Aviation Week and Space Technology, March 9, 1970, p. 23.

[22] Fishman, p. 226.

as the new job began to cut back and he no longer had the protection of seniority.[23]

Individual companies were in a constant crisis environment. They were either urgently preparing proposals for new business, staffing and working under great schedule pressure when the winds of fortune turned their way or regrouping and reducing staff under great financial pressure when the wind turned away.

The Current Environment

The environment in which the defense industry operates is changing again. The nation's top priority is shifting from defense and space to the biosphere and the well being of the individual. These changes are, in turn, causing the emphasis within the aerospace industry to shift from schedule considerations to cost considerations.

Financial

Since 1968, procurement obligations for military aircraft and NASA spacecraft have decreased by more than five billion dollars.[24] This is equivalent to 400,000 employees that were forced to leave the aerospace industry alone, not counting other defense industries.[25] In addition, contractors are spending

[23] One of the author's personal acquaintances working at North American Rockwell was laid off in spite of the fact that his management considered him to be one of their better engineers. It had been his fourth job in two years simply because he had no seniority in a declining economy. He went into the grocery business.

[24] Aviation Week and Space Technology, Mary 9, 1970, pp. 25, 65.

[25] Fishman, p. 234.

hugh amounts of money on commercial aircraft development and preparation for new DOD and NASA contract proposals. As a result, aerospace contractor debt is skyrocketing. Total debt has risen from approximately $1.2 billion in early 1966 to approximately $5 billion in early 1970.[26] Many contractors are finding it increasingly difficult to obtain operating capital.

Several articles have appeared in leading financial and management periodicals suggesting that the government change its contracting policies and become more generous with the maximum profit it permits defense contractors to earn. For example, Hudson Drake, Director of the President's Commission on White House Fellows and consultant to the President's advisory council on executive organization for science and technology (from North American Rockwell Corporation) writes:

> According to the Federal Trade Commission's financial report for Manufacturing companies [1968], the average profit on sales for all manufacturing companies is 5.1% and the same average for aerospace companies is only 3.2%. . . Given the actual 3.2% profit level, it is not surprising to see companies that have hitherto relied heavily [or almost exclusively] on advanced system contract work moving toward the greener pastures of the commerical market place.[27]

Profit as a percentage of sales is not a particularly meaningful parameter for comparing the average aerospace companies profit to the average profit earned by the majority of manufacturing companies because of the differences in capital

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[26] Aviation Week and Space Technology, March 9, 1970, p. 32.

[27] Drake, p. 120.

investment. Most manufacturing companies operating in the commercial market place own their facilities, machinery, and other equipment. Defense contractors, on the other hand, utilize government owned buildings, tools, test equipment and even office furniture for most of their defense work.

Defense profit on total capital investment has declined during the last ten years from approximately 11% in 1958 to 6.8% in 1968. During the same time period, profit on this same basis for non-defense oriented firms increased from 7.5% in 1958 to 10.2% in 1968. For the last several years:

> Defense-oriented companies reporting high probitability have been considerably less profitable than high-profit non-defense firms. At the same time, those defense-oriented firms reporting low profitability have also been less profitable than low-profit non-defense firms.[28]

Personnel

As in the past when a particular company's business began to decrease, the company would quickly cut back personnel. This time, however, the business slowdown is industry wide. Deescalation in Vietnam and strong public pressure have reduced military spending. Completion of the initial lunar landing mission and the usual pause between major programs have reduced space spending. Anti-inflation policies and pressure from a cooling economy have reduced commercial aircraft spending. Consequently there is no place for employees that have been laid off to go.

[28] Aviation Week and Space Technology, May 4, 1970, p. 55.

Although statistics are not available for the entire defense industry, the decline in manpower for the NASA programs alone indicate the magnitude of the problem. Between early 1966 and 1970, NASA total employment fell from over 400,000 to approximately 175,000.[29]

A recent newspaper article showed that between 30,000 and 40,000 aerospace industry employees were laid off in the city of Los Angeles, California, alone during 1969.[30]

These figures are presented for two purposes. First, as explicit examples of how even a mild economic dip affects personnel employment in the aerospace industry. The second reason is to introduce the suggestion that future lay-offs of this magnitude can be significantly reduced by utilizing computer technology to conduct the routine, detailed work and thereby avoid the overstaffing that has become so characteristic of the industry.

Bigness vs. Profitability[31]

A new dimension is entering the environment in which the giant defense contractors operate. In a recent analysis of the relative profitability of large and small companies, Mr. Fred R. Wittnebert found that rapidly changing markets, the technological explosion, public and employee attitudes,

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[29] *Ibid.*, p. 67

[30] "Aerospace Industry Layoffs Hit Skilled," Albuquerque Journal March 15, 1970.

[31] Wittnebert, Fred R., "Bigness vs. Profitability," *Harvard Business Review*, January-February, 1970, p. 158.

competition and other factors are making it increasingly difficult for big business to compete with smaller, more flexible organizations. "Contrary to popular opinion, big business is no longer much more profitable than small business."[32] Since 1960, big companies have been losing ground rapidly. In fact, many have already fallen behind smaller competition in some respects.

Many factors are involved in this equalization:

<u>Working Capital</u> -- Smaller companies find working capital more readily available. This is partly because they do not require the hugh amounts sought by the industrial giants and partly because the United States has a tradition of helping smaller businesses.

<u>Response Time</u> -- Smaller companies can respond much more rapidly to new knowledge. Large organizations tend to be much slower because there are so many more people to inform. So many more levels of approval are required and frequently so many more ponderous organizational elements must analyze the situation before new knowledge can be utilized.

Research by Dr. Rensis Likert verified the considerable time required for policy changes to become fully operational and to become effective throughout an organization. Two time related changes are shown by Dr. Likert. The first is the time delay from the time top management starts a new policy until the subsequent levels start. The other is the gradual

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

increase (or decrease) in skill after initiation of the change. The changes for which the following figures were derived were for implementation of new management techniques which might require somewhat longer to absorb than other technical changes. However, they do suggest the time lag between levels and the time between generation of an idea and its incorporation into hardware.

	Time after initiation, months
Management's knowledge	0
Management's skills	3
Management's behavior	6
Attitudes, performance goals, motivation, communication	9
Turnover, absence	15
End results: productivity	12
End items quality	15

Steady gains in each category were also shown for over two years after the initiation of the changes.[33]

Computer Utilization -- Time sharing of computer facilities has also eliminated one of the previous advantages held by large companies. During the 1960's only large companies could afford to use computers.[34] Not only because small firms lacked enough business to fully utilize a computer, but even more important,

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[33] Likert, Rensis, The Human Organization, McGraw-Hill Book Company, New York, 1967, p. 92.

[34] Wittnebert, p. 160.

they could not afford to maintain one staff to do business the old way and another staff of computer specialists to develop the programs needed for their specific applications.

Now many time sharing networks have been established by enterprising companies to provide computer facilities to small users at greatly reduced cost per client. Firms offering participation in these time-sharing networks also frequently provide a library of programs to meet the needs of their clients.

Public Hostility -- One factor discovered by Mr. Wittnebert is the increasing effects of public hostility toward business in general. According to Mr. Wittnebert, the "have-nots" possess a warped perspective of the role payed by industry and profit in the well-being of the individual. The "haves" possess a disdain for the tools of abundance and even for industry's increasing awareness of their social responsibility.[35]

These objections are aimed at industry in general. However, small companies have the advantage of showing a low profile. They are therefore much less susceptible to moralistic objection, negative propaganda, labor coercion, political pressure, economic boycott and trade restraint.[36]

Personnel -- As computer systems use increases the average level of personnel intelligence increases as technicians and other personnel who were involved in routine operations are

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[35]Ibid.

[36]Ibid.

replaced by more highly trained professionals. Intelligent people tend to have a broader view and want greater participation and self-actualization. The long, tortuous ladders of large organizations make it very difficult for the ambitious young manager to reach the levels where he has sufficient control over his functions to feel effective. Therefore, many of the best minds prefer to work for small companies where they have greater influence.[37]

Development engineers have long disliked their treatment by large companies. A recent survey showed that development engineers are second only to production line workers in lack of self esteem and consequently low morale.[38] They are usually in "bull pens," given dull, routine work for years before given significant responsibility and frequently receive the same raises as their peers whether they work hard or do nothing. Small companies usually cannot afford such gross under-utilization of their skilled personnel. However, small firms are frequently not even considered by job hunting defense engineers because the small firms also show a low profile to perspective employees. They cannot afford the extensive advertising campaigns, so commonly conducted by the giants during periods of rapid personnel build-up.

[37] Ibid, p. 163.

[38] Pelz, Donald C. and Andrews, Frank M., Scientists in Organizations, John Wiley and Sons, New York, 1966, p. 116.

SUMMARY

Conditions causing the anguish in the defense industry have been building since World War II and therefore have become traditional. The primary cause seems to have been the inability of the Federal Government to maintain a uniform defense plan in which changing world situations are anticipated in time to permit gradual transitions. As a result, the government induced management by crisis. An international event would occur, or a new administration would interpret the country's needs differently and a sudden, major change of policy would result. One faction of the defense industry would be turning every rock to find personnel. Another faction would be laying off employees by the thousands.

Government agencies assigned the responsibility for implementation of these programs were also under heavy schedule pressure. Therefore, they in turn responded by increasing pressure and control over their contractors. This interference increased schedule pressure and frequent program changes directed by the government increased the cost, in both dollars and personnel well being, to the point that several of the industrial giants were beginning to deemphasize the government research and development business.

These practices also resulted in a greatly inflated manpower supply because every incentive (schedule pressure, profits, ability to respond to proposals and the development of computer technology) favored increasing technical staff.

Fluctuations in the industry were hard on personnel in that many were forced to move every four or five years. Most could usually find jobs but at an average cost of half a year's salary per move.

In 1969, however, several of the forces driving the defense industries' fourtunes began to turn down at the same time; the Apollo program, the Vietnam War, total government spending to combat inflation as well as the increase in the cost of working capital. As before, defense industry contractors began to unload their surplus technical staffs. This time, however, there is no place for these people to go.

Aerospace industry giants that have ample business are having a very difficult time with a new set of problems. The "total package" concept introduced by Robert S. McNamara required an accurate long range anticipation of costs that these companies were not capable of performing. As a result, many are locked into fixed price, incentive fee contracts for which both the extent of inflation and technical problems were badly underestimated. Incentive penalties are enough to bankrupt the companies. In addition, the general economy slowdown has seriously affected their commercial business.

Another new factor in an increasing unfavorable environment for industrial giants; public attitude agains industrial profits, industrial contamination of the biosphere, tight money and the equalization effects (vis-a-vis small businesses) of computer time sharing and rapid response to changes.

It is much too late for new policies and processes made possible by maturing computer technology to aid in the crisis that is now developing. However, this crisis will probably force more than a million people out of the industry (approximately 400,000 were forced out in 1969 alone). The objective now is to develop a mechanism for keeping the number of people in the industry down to reduce the susceptibility of the industry to these feast or famine cycles in the future.

CHAPTER III

COMPUTER TECHNOLOGY

Utilization of technological developments frequently proceeds in a series of jerks and leaps. Early in the innovation period, exaggerated claims are followed by disillusionment, general pessimism and skepticism. Then, after a reasonable period of development and learning, many, if not all, of the early "ridiculous" exaggerations and expectations are greatly exceeded.[1]

For many managers their last serious contact with computers was during the period of disillusionment, general pessimism and skepticism when computer utilization was limited to a few routine administrative bookkeeping functions and engineering computations. Business and management periodicals are now predicting that these managers will soon be unable to compete with companies that have been aggressively adapting these tools to their business needs. In January-February, 1970, Harvard Business Review, for example, Robert F. Vandell argues that the long promised wonders of the computer for management purposes has finally established a firm base and is now forcing a management revolution:

> The quantitative revolution is already under way in some leading industries. Its first fruits are beginning to exert broad effects on competition

[1]Kahn, Herbert and Wiener, Anthony J., The Year 2000; A Framework for Speculation on the Next Thirty-Three Years, The MacMillan Co., London, 1967, p. 93.

that will force other companies to adapt the new methods rapidly.[2]

The objective of this chapter is to give the reader an indication of the immense capability now available to program managers and to explain why computer technology is now ready to support industrial management when it was not just a few years ago.

Computer Utilization

The idea for an automatic machine that would add, subtract, multiply and divide in a sequence of steps automatically was conceived in 1812 by Charles Babbage, a professor of mathematics at Cambride University, England. He intended to use the machine to compute mathematical tables. Unfortunately, the precision tooling, mechanical and electrical devices necessary to make the machine were not available until nearly a hundred years later.[3]

And so it has always been. A resourceful, imaginative man had a routine task to accomplish, each element of which was adequately understood, but the sheer bulk of work required was too great without tools that technology had yet to provide.

In 1886, statistician Dr. Herman Hollerith was still trying to summarize United States census data taken six years

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[2]Vandell, Robert F., "Management Evolution in the Quantitative World," Harvard Business Review, January-February, 1970, p.92.

[3]Berkeley, Edmund C., The Computer Revolution, Doubleday and Company, Inc., New York, 1962, p. 32.

before. He decided to experiment with cards with punched holes in them and electrical devices to detect and count these holes. The idea came from the Jacquard loom that had been using punched cards for controlling the weaving pattern for at least eighty years. Hollerith's experiments and machines were successful and led to a great development of punched card machines for business, accounting and statistical purposes.[4]

At the Bell Laboratories in New York in 1939, Dr. George R. Stibitz was bothered with a log of complex arithmetic calculations for analy ing alternating electrical circuits. So he wired up ordinary telephone relays, representing each decimal digit by a code of ones and zeroes. Stibitz's "Complex Computer" performed computational chores for many years until replaced by more powerful equipment.[5]

Numerical computations required for the Atomic Bomb in the mid 1940's, and missile trajectories in the early 1950's would have been impossible without these computational tools. Even with these tools, years were required to develop sufficient computer software to permit the accurate simulations required.

During the next decade, the computer became recognized as the tool for taks in which:

> Large amounts of information needed to be stored, added or processed.

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[4] Ibid., p. 35.

[5] Ibid.

- A large number of interacting variables must be related or analyzed before a problem can be solved.

- Repetitive activities exist for which the decisions can be made more or less automatically by a computer model.

- Accuracy is important or useful.

- Cost per unit of data output should be low.[6]

For many managers in the defense industry, the last decade has been maddening. As personnel at all levels became aware of the computer's ability to do their routine and tedious work for them, resourceful, imaginative men would want to drop everything and develop a program to do this work. But technology had been unable to keep up with the demand. As amazing as the development of computer technology has been, it was not good enough. Computers were too slow, too expensive and too small to satisfy what the users wanted to do.

Even if computer facilities were available, it took longer to develop a program to use the computer to solve a complex problem than to divide the problem into steps for which programs were available and have them computed separately. This technique frequently required weeks before the total problem was solved. Programs had to be modified slightly. Runs could only be made at night because of low priority. Frequently, programs would not run because of a slight programming or data

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[6] Steiner, George A., Top Management Planning, Collier-Macmillan Canada, Ltd., Toronto, Ontario, 1969, p. 495.

error. Results from previous runs had to be analyzed before the next step could be taken. Forms had to be filled out and cards punched and checked.

Many of the people that were doing work which required computer use found themselves with very little to do except wait for the next set of numbers to come back from the computer. For managers, the computer came to represent trouble. Computers were (and are) expensive, required special facilities as well as special staffs of operations, programmers and key punch operators. As is so frequently the case with humans, the good got buried under the bad. "Computer trouble" became a standard excuse for not having work completed. These difficulties arose from trying to make operations use of computer tools that were not yet prepared to meet the need and with personnel that did not quite know how to best use the tools available.

Paradoxically, computers made many of the developments in the defense industry possible. But they also contributed significantly to its problems, especially the problems of cost and personnel morale. Costs increased because of computer facilities and the special staffs required to operate them in addition to the double requirement for technical personnel; one to get the program needs accomplished and another to make the computer useful. Morale decreased because so many people were simply gathering and preparing data for the computer or waiting around for answers to come back. The people were almost, but not quite replaced by the machine.

Now, just as the industry is getting accustomed to using the third generation computer equipment as technical and operational tools, a new revolution is upon us. Computer technology has reached the point that new developments are keeping pace with and exceeding our ability to make use of them.

Hardware and software developments that have become operational in the last year or two enable the technical personnel to work directly with the computer in real-time. Information storage and retrieval systems have essentially infinite capacity enabling both management and technical personnel to have all necessary data literally at their finger tips. These technological developments will require that personnel at all levels become "thinkers" and planners instead of primarily "doers."

> The main difference between the increasing pressure from the quantitative areas and other forces for change lies in the magnitude and pervasiveness of its impact. It will affect every facet of business organization. No executive can afford to ignore the new demands it will make on management and still expect to be successful beyond the next five to ten years. These demands, I believe, will prove personally more onerous to many executives than they have any reason to expect from their past experiences.[7]

Nor will it be sufficient for these executives to instruct their staffs to implement a system. The most prevalent reason for failure, or at least marginally satisfactory performance from the application of the computer to management problems has been attributed to inadequate planning.[8] Specifically,

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[7] Vandell, p. 92

[8] Lack of adequate planning has been mentioned in at least a dozen articles reviewed by the author. A few of these are: Vandell, pp. 90-91; Steiner, p. 6; John Diebold, "Bad Decisions on Computer Use," <u>Harvard Business Review</u>, January-February, 1969, p. 15.

the planners failed to consider implementation of computer hardware as a system to serve managers. John Diebold states in the Harvard Business Review that the prime reason for the failure of management information systems to realize their potential is because computer technicians, not managers have set the goals.[9] Unfortunately, most technicians are inclined to be primarily interested in the hardware and software per se without adequate concern for the rest of the system.

Planning at all levels is becoming more important than ever before. Primarily because computer aided design and computer controlled manufacturing can be so much faster than previous experience would indicate that the margin for error will be greatly reduced.

Intuitive and reactive managerial styles are already on the wane. Increased emphasis is being placed on "scientific" analysis and planning. Experience is still invaluable (if it is up-to-date), but it must be used with greater discipline.

> Analysis is now more vigorous, and computer techniques permit more alternatives to be analyzed in greater depth. But most important, formal planning is being used as a basis for action, not nearly for pro forma exercises. Ten years ago this sort of planning was a rarity.[10]

Computer Related Hardware

Computer technology, like so many other technological developments, has increased at a logarithmic rate. Starting

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[9]Diebold, p. 14.

[10]Vandell, p. 87.

slowly, accelerated in mid growth until development occur at an incredible rate as the system matures. Addition speed has long been a basic index of computer development. A few specific data points on how this index has changed over the years provides an accurate context for evaluating the impact of computer technology on industry in general and program management in particular. In 1944, Professor H. Aiden of Harvard, working with IBM, developed one of the first automatic general-purpose digital computers. It used relays as had Dr. George Stibitz of Bell Telephone Laboratories when in 1939, he used standard telephone relays, to make a digital computer for simple calculations. Professor Aiden's computer ground out urgent military computations for many years at the rate of three additions per second. In 1946, Dr. John W. Mauchly of the University of Pennsylvania School of Electrical Engineering completed Eniac (Electron Numerical Integrator and Calculator) which had been designed for speed by using standard radio parts instead of relays. Eniac could add at the rate of 5000 additions per second. During the next ten to fifteen years, the speed had increased to approximately 500,000 additions per second.[11] Computer speed is now on the order of one billion additions per second, (a manosecond). "A manosecond has the same relationship to a second that a second has to thirty years."[12]

[11]Berkeley, pp. 34-35.

[12]Diebold, John, Man and the Computer, Frederick A Praeger, Publishers, New York, 1969, p. 9.

The next big steps will be large scale integration techniques with metal-oxide semiconductors and the utilization of micrologic circuits in which thousands of active electronic elements are contained on a single silicon chip.[13]

> By 1975 central computer processing speeds may be increased by a factor of 200, central processing units reduced in size by a factor of 1000, costs cut by a factor of 500 and total U. S. computing power raised by a factor of 1,000.[14]

In addition to greatly increased speed, additional advances in the last few years stand out as the leading contributors to the quantitative revolution. These are the ability to time-share access to computer facilities through remote terminals and practically unlimited computer storage capacity. These advances, with the great increase in computer processing speed, and the appropriate software, permit each manager, engineer, or whatever, to have the data they need stored in the computer's data bank and to work directly with the computer in real-time.[15] However, these tools are still expensive. They are profitable only if their use is carefully planned and they are fully utilized. Fortunately, there are many sizes and types of equipment and many computer utility services available to choose from. There are so many, in fact, that even listing

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[14]Steiner, p. 498.

[15]Real-time means in this application that the user will get the data "as fast as I want the answer." For most uses, this is within a few seconds. The quote is from Edward J. Menkhaus, "Time Sharing is Everybody's Thin," <u>Business Automation</u>, September 1969, p. 27.

the kinds of hardware now available is beyond the scope of this paper. A few specific types will be discussed, however to suggest the current state-of-the-art.

Computers -- Almost unlimited variety of computers are on the market from desk top calculators to the immense IBM System 360 Model 195, expected to be available in early 1971. This system is being made to be the central control point for a complex airline reservation system; a coast to coast time sharing network, or massive scientific studies such as global weather forecasting and space exploration. It has an internal processing speed nearly twice that of the next most powerful machine and can run most programs developed for other IBM System 360 models without modification. The main core storage capacity is from 1 to 4 million bytes[16] of data - "enough to handle, for example, all the computer instructions for a space mission from launch to recovery." Its internal organization permits it to perform multiple tasks in parallel. For example, it can be doing two additional and a multiplication simultaneously and can process fifteen different jobs concurrently.[17]

Data Display Equipment -- Data display equipment provides one of the most flexible means for communicating with the

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[16] A byte is defined as a group of bits required to represent a single legitimate character of information. (Many digital processors use six bit byte, newer ones use eight.) Seymour V. Pollack, A Guide to Fortran IV, Columbia University Press, New York, 1965, p. 243.

[17] "IBM Announces Super Scale Computers," Business Automation, September 1969, p. 44.

computer from remote terminals. As with the computers, there are a large variety to choose from. The most common in current use is the teletype machine. The operator types in the instructions and the computer types the answer. Although the teletype is slow, it is by far the cheapest. On the other end of the spectrum are consoles containing Cathode Ray Tubes (CTR) for data display, light pens for modifying or manipulating the data, as well as alpha-numeric keyboards with keys for special functions. Several of these consoles also contain a hard copy printer to provide the user with a permanent copy of the data desired. Business Automation Annual Reference Guide, September 1969, lists 25 different manufacturers of CTR display units alone. Most of these manufacturers offer several different models to choose from.

Until recently only large companies could afford computers. Time-sharing is making the computer available to everyone. The term time-sharing refers to the simultaneous sharing of a computer by numerous persons who communicate with the machine by means of a terminal with a typewriter type keyboard at some remote site. Computers are currently available, such as Scientific Data Systems' Sigma 7, that can accommodate up to 100 users simultaneously.[18] In 1964 time-sharing was rare. By 1967 there were approximately 200 time-sharing systems in operation. The results of a recent study conducted by Honeywell predicts that by 1975, 50 percent of all computers will be

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[18] "Annual Reference Guide," Business Automation, September 1969.

utilized on a time-sharing basis.[19]

Optical Character Readers -- One of the awkward features of computer use in the mid '60's was the requirement to key punch all work before it could be run on the computer. Optical scanners are now available that can "read" instructions and data typed on an ordinary typewriter. For example, Recognition Equipment Incorporated's Input 2 System reads hand printed, typed and printed information in ordinary type styles from two lines at once. Its reading speed is 600 documents a minute. The information is recorded on magnetic tape. Systems 2 can recognize 40 machine printed characters in several type faces.[20]

Scan Data Corporation's model 300 reads all optical character reader fonts, all standard typewriter and typeset fonts at the rate of approximately 800 characters/second.[21]

As with most computer related equipment, flexibility and speed cost more. An optical character reader designed to read all styles of type as well as printed characters and special symbols will be considerably more complex, therefore much more expensive than a machine designed to "read" U.S. Standard Character Set for Optical Character Recognition on one size sheets. Again there are many varieties to choose from. These machines will become increasingly important because they can already reduce data input costs by a factor of 10.[22]

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[19] Ibid., p. 28.

[20] Ibid, p. 89.

[21] Ibid, p. 93.

[22] "Supersonic Seventies," Business Automation, January 1970, p.44.

Microfilm Systems -- One of the basic difficulties in the operation of an effective management information system has been the ability to store and retrieve large quantities of data rapidly and inexpensively. Even without the advances in computer technology, the increased speed, storage densities and retrievability of microfilm handling systems alone is enough to revolutionize information systems. One major step that has yet to be made is the ability to convert from microfilm back to tape for general applications. Several companies are working on this ability. When it is completed, it will complete a major system capability. Machines are available microfilm computer output directly, on a very high density microforms. For example, the Mindex Flash 370 by Microform Data Systems, Inc., uses 35 mm ultra strips upon which the images have been reduced by 250:1. Each ultra strip contains 2000 8-1/2 inch documents. A standard unit can store between 20,000 and 120,000 records with a maximum retrieval time of six seconds.[23]

The TISAR (Total Information Storage & Retrieval System) by Foto-Mem, Inc., can store pictoral, textual, audio, analog and digital information on microforms randomly or in sequence. The unit is the size of an executive desk yet can store the equivalent of 7 million documents (over a trillion bits). It will display stored information page by page, print dry hard

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[23] "Annual Reference Guide," Business Automation, p. 127.

copies and permits a user to interrogate, review and update displayed information over the telephone.[24]

The 3M Company makes an Electron Beam Recorder capable of transferring data from magnetic tape to microfilm at the rate at 60,000 characters/second.[25]

Graphic displays such as engineering drawings, forms and charts, can be prepared, stored and modified by machines such as the Information International. Inc., III FR-80. This machine has a resolution of 16,384 programmable points on 16 mm and 35 mm film. It can produce lines at the rate of 20,000 lines/minute, has 8 programmable line widths, 8 line densities, 8 spot densities, 5 character rotations and a variety of character styles. In addition, the user can select standard form overlays or draw directly on microfilm via a cathode ray tube screen with a light pen.[26]

These are just a few of the types of data processing equipment now available. Another indication of the variety available is the number of manufacturers in the field. Business Automation Annual Reference Guide, September 1969, lists 25 manufacturers of Cathode Ray Tube display units, 16 manufacturers of optical scanners, and 34 manufacturers of microfilm readers and reader-printers.

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[24] "Annual Reference Guide," Business Automation, p. 125.

[25] Menkhaus, Edward J., "Microfilm Captures More of the Action," Business Automation, May 1969, p. 40.

[26] "Annual Reference Guide," Business Automation, p. 127.

Computer Related Software

The term, "software," refers to the computer languages and to the programs written in these languages. The key to software utility is the ease with which the computer can be directed to perform the desired function. Early in the software development history, basic programmer languages were written to enable the programmer to direct the computer to perform frequently used functions by using one word rather than hundreds or even thousands of individual machine language instructions. As the use of computers grew, many companies developed special programs containing millions of machine language instructions for their unique needs.

Many of these special programs required years to design, debug and make efficient. Then the company would change computers and the old programs would have to be rewritten for the new machines. This time consuming, tedious, expensive and frustrating need to develop and modify programs has been a major deterrent to the utility of computers in the past.

This situation has finally been greatly relieved. Three languages are widely used - Algol, Fortran and Cobol - and a great many special languages have been developed for specific disciplines.

The next major classification of programs are made to direct the computer to complete the computation of an entire problem with one command such as computer trajectory, design gear, calculate thermal balance. Basic programs exist for nearly every routine function. Hundreds of companies are in the business of developing even larger, more specialized programs that can be purchased for a small fraction of its development costs. And the new generation general purpose computers are being designed to be compatible with programs developed for the last computer generation.[27]

So many computer programs are now available that even a listing of the disciplines for which programs are available would require a sizeable document. A few specific examples are described below to suggest the capabilities that have become operational in the last two or three years.

Graphic analysis of three-dimensional data developed by IBM permits raw data to be edited and the results displayed in the form of contour maps, perspective views, cross sections and fence diagrams.[28]

IBM has also developed a program to get around the problems associated with trying to use several problem languages. Problem languages are usually written for one specific group, business or disciplines using terminology that is usually not consistent with standard programming languages. The IBM Program Language Analyzer (PLAN) permits a user to combine and

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[27]"Supersonic Seventies," p. 47.

[28]"Graphic Analysis of Three-Dimensional Data (GATD) Application Description Manual," H20-0539-0, IBM Technical Publications, White Plains, New York, 1968.

even to modify each part of a given program language so that it can be utilized rapidly for his application. In addition, PLAN will permit the user to arrange the problem language programs that he needs in an automatic sequence so that he can proceed step by step through his problem with PLAN pulling in each special program as he needs it.[29]

Therefore, hardware and software modules are now available to perform most routine managment information, design and control functions with a minimum of specific adaptation.

[29] "Problem Language Analyzer (PLAN) Application Description Manual," H20-0490-1, IBM Technical Publications, White Plains, New York, 1969.

CHAPTER IV

APPLICATION OF COMPUTER TECHNOLOGY TO SPECIFIC PROGRAM MANAGEMENT FUNCTIONS

As discussed in Chapter II, the defense industry is now in a transition period. Application of computer technology to the program management function in the defense industry is also in a transition period. The last series of major programs were begun approximately ten years ago. At that time, computer technology had not developed much beyond a few specific technical and routine administrative applications for which its speed and accuracy were necessary.

Although computer technology increased tremendously during the subsequent years, most of the managers of those programs simply did not have the time, nor the inclination, to make the transition to computerized management tools. In addition, many of the applications that were tried were not particularly useful because they were developed by technicians instead of by the managers for whom the tools were intended.[1]

Only during the last few years have the managers of nearly every major aerospace company begun to give much greater emphasis to the utilization of these tools for management planning and control as well as for engineering and administrative tasks. The Boeing Company, for example, maintained tight computerized control of the manufacturing, assembly and ground

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[1]Failure of each manager to become involved in the development of computer applications being designed to serve his needs is, along with inadequate planning, the most frequently mentioned reason for failure of a newly implemented computer system to perform its intended function.

test of its giant 747 jet transport.[2]

Therefore, the major impact of computer technology on the policies and processes of major hardware programs is yet to come. Many of the trends, however, are clearly established and are presented in this chapter. Then in Chapters V and VI discussion will turn to policies and processes that ought to exist. That is, to make trends, not follow them to utilize computer technology to improve the well being of the defense contractors and their personnel.[3]

For this normative application, primary emphasis is given to the functions of a government agency field unit having direct responsibility for a major program and its direct contractors. The functions of other field units, agency headquarters or the contractor's subcontractors and vendors is specifically excluded to simplify the presentation. This presents no serious omission because similar application of computer tools will apply to these functions as well.

Although based primarily on the Apollo Program structure, the apportionment of tasks in the following discussion is somewhat arbitrary and does not represent any specific government agency or contractor.

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[2] Silveira, Milton A., Engineering and Development Directorate, National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas.

[3] Steiner, George A., and Ryan, William G., Industrial Project Management, Collier-Macmillan Canada, Inc., Toronto, 1968, p.12.

Computer utilization chosen for each task is based on existing trends and assumes that top management is dedicated to making maximum utilization of these tools to reduce the overall cost of the program and that the organization has developed and operational computer system. That is, that computer related hardware and software have been installed and are operating, that an organizational element exists for developing and maintaining the data banks and that all personnel have been selected and trained to utilize these capabilities. It is also assumed that a major program will have just completed conceptual planning and is beginning the hardware definition phase.

No allowances are made for any of the limitations required for a real organizational arrangement such as availability of the right kinds of people and the optimum type and location of computer hardware. In this sense, the discussion is intended to be normative, that is, to provide a target of what ought to be, toward which future personnel actions and organizational changes should aim.

For this discussion, the program management role was divided into five major functions plus the program manager. They are:

Program Manager	Responsible for all aspects of the design, manufacture, ground and flight tests and operation of all systems required for the program.
Program Control	Responsible for all business and administrative aspects of the program.

System Engineering	Responsible for the technical integration of all subsystems required for the program.
Design & Development Engineering	Responsible for the design of each subsystem required for the program.
Industrial Engineering	Responsible for manufacturing and ground testing all hardware and software required for the program.
Operations	Responsible for the technical performance of all systems, planning and conducting the flight test program and for the long term operation of the system.

To simplify the scenario, assume that each of the above are existing organizational elements and that time-sharing computer facilities were installed and all key personnel given a remote terminal complete with graphic display unit, light pen and hard copy printer. In addition, each of the major functions has its own, unlimited data bank. Access to each data bank is controlled by the manager of the function, subject to being over-ruled only by the program manager.

The same format is used for the following discussion of each functional area. First, the overall function is described in more detail. Then, two or three specific tasks are defined and the impact of the new computer tools is explored for each.

The Program Manager[4]

Since this discussion is somewhat idealistic, assume that the program manager has been given a specification for the total

[4] The Program Manager tasks for which computer technology would be particularly helpful, therefore were included in this paper and were suggested by Col. James A. McDivitt, Manager of Apollo Spacecraft Program Office.

system, a set of general agency policies and standards, a total budget and a schedule for having the first vehicle operational. In addition, assume that he has complete autonomy within these limits including the right to select contractors and to hire, or transfer out of the program, anyone he chooses. The manager's policy is that each of the subordinate managers and supervisors have explicitly defined responsibilities, budgets and schedules and they have control over and are held accountable for each.[5]

Program Status -- As a matter of policy, the program manager meets briefly with all of the programs functional managers and supervisors each morning in the Program Status Room maintained by Program Control. Each morning upcoming events and past accomplishments of program-wide interest are announced and general status is received with specific emphasis on a different area each morning.

In the past, computer systems had no direct function in the status report. A special staff contacted each supervisor daily to ascertain the status of each item for which that supervisor was responsible, then modified the status boards accordingly. For special presentations, the responsible supervisor would prepare view graphs and copies of charts and drawings he wished to discuss for distribution at the meeting.

With the computer systems, the program manager will be able to have the status of any aspect of the program displayed on

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[5] Steiner, Chapter 2.

his remote terminal scope. The morning meetings will still be held. However, the manager will already know the status of each area and discussion will deal primarily with problem areas. Major accomplishments and upcoming events might be covered, but since they will be available to all at any time via their own remote terminal scopes, they probably will not be discussed except for items of particular significance.

The special staff that had maintained the status room will be eliminated. Each supervisor will maintain his own status displays simply by calling them up on his scope and making the necessary modifications using the typewriter keyboard and light pencil on his remote console. Each of these will be coded such that only the person responsible can change it. However, anyone on the program can call up the display for his information any time he chooses. For special presentations, the person making the presentation can call up any chart, drawing, figure or any other data in his data bank from the presentation room remote terminal. Questions requiring computation or data manipulation can be answered in real time. If a hard copy of any of the material is desired, it can be printed on the spot.

<u>Trade Off Studies</u> -- In the past, if the program manager wanted to find out "what if," he would explain what he wanted to his staff or one of the function managers, then wait for the answer. Hopefully, the answer that came back was for the questions he had intended, but it frequently was not. In addition, getting the final answer he desired was usually an iterative process requiring days or even week. With a remote

terminal and access to all of the programs data banks, he could work out the answers himself in less time than it would take to explain the question to someone else.

Correspondence -- Perhaps the most onerous task faced by any program manager of a large program is keeping up with the correspondence. The extent to which computer technology could reduce this task is a function of the particular manager. Since all reports and memoranda can be prepared with the aid of a computer and stored in a data bank with all incoming mail, it would be a simple matter for the manager to simply call up the titles and authors for each item written within the organization or received from outside the organization within a given time period. He could then have the front page of those he was interested in displayed so that he could scan it. If desired, he could either read it all on the scope or he could request that a hard copy be printed for his retention.

Such a system would save considerable time and expense as well as making the information available much sooner. The majority of the paper that crosses a manager's desk, except for correspondence he must sign or explicitly approve, is for general information and a quick scan is all that is necessary. It would be a simple matter to arrange the display sequence so that the manager would simply have to touch the "next" key when ready to change to the next page or the next document.[6]

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[6] Several remote terminal models are equipped with special function keys that can be used to initiate a frequently used computer function to eliminate the need to type in specific instructions each time.

The cost of correspondence would be reduced in several ways. By using computer aided correspondence preparation, editing, corrections, updating periodic form memoranda or reports would be greatly simplified with the attendent savings of both the author's and the secretary's time. In addition, little or no reproduction would be required. Each piece of correspondence will contain a distribution list, as always. However, instead of mailing a hard copy, as soon as the correspondence is released, it is stored in the data bank and its title, author and date are added automatically to each addressee's incoming coresspondence list to be read at the addressee's leisure. And finally, hard copies need not be filed anywhere because it would be stored in a computer data bank, or a microfilm file or both. It would be accessible any time to anyone authorized to have the information. The savings in both paper and file cabinets should be impressive.

Program Control

Program control is responsible for the integration of all program costs and schedules, the administration of all contracts and for controlling the use of all computer systems charged to the program. Control usually implies authority by sanction. In this application, however, it implies authority by knowledge. Program control cannot direct the functional managers or their respective line supervisors to do anything. Their function is to assure that everything required for the program has been explicitly assigned to someone and to pull together and integrate all cost and schedule related information. When they find trends or forecasts that are inconsistent with the needs of another element of the program or with the overall program plan, they point out the conflict to the cognizant functional managers or supervisors and help them work out a solution.

Program control is required to enforce policy related to budgets and correspondence to contractors. If, for example, a supervisor wants to award a small study contract, but the amount exceeds his discretionary fund limit, Program Control cannot authorize the contract. Or if a group exceeds its computer budget, every subsequent use must be explicitly approved by the program manager until they get back within their budget. These are not really sanctions; rather they are strict enforcement of policy. Each supervisor and each functional manager has his own discretionary cost and schedule flexibility. These limits can only be exceeded by explicit approval of his immediate supervisor, subject to appeal to the program manager.

Three specific tasks which illustrate the impact of computer technology on Program Control are the development and maintenance of the Program Plan, control of correspondence to contractors and control of computer utilization.

Program Plan[7] -- Program planning personnel work with each organizational element to determine the activities that must be performed, the approximate time required to perform these activities and their relationship to other activities in the program.

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[7] Discussion of the Program Plan and control of correspondence is based on the author's experience as confirmed by Mr. James Shannon, Lunar Module Project Officer for the Apollo Program Office, NASA, MSC, Houston, Texas.

Then these activities are arranged by need sequence.

A large program has thousands of interdependent activities even when the level of activity considered for the planning charts is limited to key events. When done "by hand," that is, a computer is not used, only major events can be successfully coordinated. The same limitations exist for each level in the hierarchy. By the time planning gets to the detail required for daily activities, hundreds of people are involved and the coordination and integration of interacting need dates is very difficult. Mismatches are frequently missed.

Perhaps the biggest problem is caused by program changes. For example, a hardware change might increase schedule pressure for one string of events, but relax the pressure for another string. Each element in the string of events for which the pressure is increased is nearly always notified of the change. However, it is not unusual for many of those for whom pressure has been relaxed to never get the word. They will continue at the previous pace, frequently using overtime, special handling and other expensive extras to meet deadlines that are no longer valid.

Another difficulty is that the program plan is not an "action" document, that is, it is not used for day to day decisions. It is usually out of date even the day it is printed because preparation time is slower than change activity. Even in organizations employing planning tools such as computerized PERT find that all too often it becomes a pro forma exercise because it is usually out of date. The critical path shown today was really the critical path two or three weeks ago because of the delay in collecting data, getting it transcribed into a form suitable for the computer and waining for a block of computer time long enough to permit computation of the network.

With the new computer system, as each supervisor updates his daily planning chart, utilizing his remote computer terminal, his element of the PERT network would be automatically updated. With the greatly increased computer speed, portions of the network could be run any time. However, network will probably be run every night so that all of the day's program changes would be included and so that these changes could be noted during the next morning's status meetings (at the Government agency and the contractor's plants).

Two general types of changes are involved, those that change the program plan and those that only change status relative to the program plan. By maintaining the program plan in the same data bank as other planning tools, each unit's status could be presented relative to the appropriate position of the program plan. Since each would be updated daily the program plan would become the viable tool it was intended to be.

Contractor Correspondence Control[8] -- One particular aspect of correspondence control that has been difficult for Program Control to deal with adequately is technical direction to the contractors. Since letters of direction can influence contract

[8] Ibid.

costs, schedules and contractor's profit, all such correspondence must be signed by the contracting officer or his representative. The difficulty is that the contracting officer usually lacks sufficient information to make a meaningful decision.

It was not uncommon to find that several elements of the government had sent contradictory direction to the contractor over a period of a few weeks. The only way for the contracting officer to prevent this was to have a superhuman memory, check his files and hold a meeting on each piece of questionable correspondence. The flood of correspondence renders all of these methods useless except for the most obviously inappropriate.

By having the contract, specification, policies and previous correspondence in the data bank, and with the powerful document retrieval software that have been developed recently, the contracting officer need only insert his specific question and the computer will search the files for all information on that specific subject for his review. By carefully planning the display format, questions can be answered in a few seconds each.

Computer Utilization Control -- Computer application must be controlled carefully if costs are important. Several authors have mentioned that people quickly become dependent upon the computer as a substitute for thinking. "Every formal system, if taken too seriously and rigidly will become more of a hinderance than a help."[9] Computer systems frequently lead to

[9] "Putting Judgment back into Decisions," Harvard Business Review, March-April, 1970, p. 67.

many statistical reports, larger staffs and larger amounts of data that are never used.[10] This tendency to over-use the computer can become prevalent so easily that when multiplied by all users in the government and at the contractors, it can increase the cost of the program considerably. The objective behind constant attention to computer utilization, then, is to force a constant reminder that computer time is money. This task is included in Program Control because of the importance of coordination with management needs on a program wide basis.[11]

<u>System Engineering</u>

System Engineering serves very much the same function for the technical effort that program control serves for the business and administrative efforts. Early in a program, System Engineering apportions hardware performance requirements among the various subsystems. The objective is to attain an optimum total performance solution considering the high cost of unique hardware, mission objectives for which the optimum hardware performance are contradictory and components for which high performance requirements are incompatible with high reliability. As the design progresses and hardware is being developed, system analysis personnel assure that the various elements of the system are mutually compatible. In addition, occasionally one element will be unable to attain its performance or reliability

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[10] <u>Ibid</u>, p. 66.

[11] Steiner, George A., <u>Top Management Planning</u>, Collier-Macmillan Canada, Inc., Toronto, 1969, p. 480.

requirements. System analysts will examine the other elements of the system to determine if performance requirements can be shifted or modified to alleviate the difficulty.

Computer technology can greatly improve the quality of the systems analysts function by permitting the performance interaction between each element to be simulated to assure overall compatibility as well as assuring that the system can meet its overall performance requirements. This type of model is particularly useful for evaluating the effects of changing one element of the system or the environment in which the system must operate.

Another classic system analysis function is determining how to modify an existing system to meet new requirements, to improve its overall realiability or some aspect of its performance. Again a computerized vehicle performance model is a very useful tool. Alternative solutions can be tried to determine which provides the greatest increment in performance with the fewest complications for the rest of the system.

Vehicle Integration -- System Engineering also includes those engineering disciplines that affect and are affected by every other element of the system. For example, materials, vehicle dynamics, vehicle thermal control, design integration, weight and balance and interface control. These tasks have traditionally been seriously hampered because they are dependent upon each of the other engineering functions for input and because the analysis and calculation of the overall systems response in their area of interest is very tedious, complex and frought with uncertainty. Hence, these functions have been most important yet are poorly equipped to perform their role. Computer technology provides an ideal tool for these applications. By using preliminary design estimates of the characteristics, weight, etc., for each vehicle element, these groups can develop a systems model for their area of interest. These models are used to quickly balance the system performance, identify areas in which performance is inadequate or more than adequate and, most important, can identify incompatibles while they are easily modified. All too frequently such incompatibles are not discovered until the vehicle was being assembled or tested. Changes this late in the program are obviously very expensive.

Design and Development Engineering

Detailed design and analysis of specific subsystems such as structures, propulsion, guidance, navigation, electric power, communication, environmental control and crew equipment collectively comprise the design engineering function. Similar tasks are conducted in each area during the course of a program. Each maintains a current knowledge of the state-of-the-art and a file on component suppliers. Each conducts subsystem design and performance analysis, engineering tests, and coordinates with the manufacturing and support equipment functions.

Design groups have been using computer programs for the analysis of an increasing number of subsystem characteristics for several years. However, the use of a data bank and computer graphs are beginning to have great impact on engineering function.

The Search for Information -- In the past a large percentage of a design engineer's time was required to find suppliers for the components needed for his design. He would search catalogs, call suppliers, ask friends and negotiate special orders because he could not find existing components to fit his needs.

Optical character readers and microfilm recording, storage and retrieval systems and computer programs which can search for, compare and display words as well as their context provide all members of the team easy access to information that previously was unavailable or required considerable effort to find. The computer can select the appropriate catalogs, drawings, specification paragraphs and statements in any other applicable documents such as design standards so that the responsible engineer can quickly find the information he needs. He would simply query the computer or microfilm information system for the component having the particular characteristics he desired and a list of these components most nearly matching his specifications would be available in a few seconds. Data banks also greatly facilitate checking specifications, design standards and interface drawings during the course of the design to assure compliance.

Computer Aided Design -- Computer graphics represents a particularly powerful tool for the designer. Suppose, for example, that a designer had the task of arranging twenty electronic assemblies on an equipment rack subject to a series of contraints, they must be packaged such that they would fit within an existing irregular volume. They must be arranged so that each receives a specific amount of cooling. In addition, sufficient space must be allotted for assembly and for the shortest practical path for wiring these assemblies to a given junction box. Countless man hours of trial and error, sketches and drawing projections from various directions had to be carefully constructed to determine whether or not physical interference existed. This task typically requires no great creativity or knowledge, but does require a tremendous amount of tedious, routine work. It is the perfect assignment for a computer system. Utilizing his computer driven remote terminal scope, the designer would first feed the dimensions of each assembly and the volume available into the computer. Then he would call for a list of the assemblies and the "planform" view of the volume available to be displayed on his scope. To arrange the assemblies he would first touch the assembly he wanted to place, punch in the code, telling the computer to select the dimensions of that assembly and move it to the next spot he touched on the scope. Assembly by assembly, the computer would sketch in the outlines of each assembly wherever the designer indicated. After adjusting the locations of each assembly in one view to his satisfaction, the designer would check for interference in other views by simply directing the computer to rotate the picture so that he could check all dimensions. When satisfied with a particular arrangement, he would direct to computer to calculate the thermal balance to assure that each assembly would be cooled adequately. After making any necessary corrections, the designer would request the computer to print several selected views of the arrangement as well as the results of the thermal analysis. One man working directly with the computer can thus accomplish in a few hours what has frequently required several designers, engineers and draftsmen days and even weeks to complete.[12]

Industrial Engineering[13]

Industrial engineering includes all functions required to manufacture, assemble and check out the completed assembly such as analysis of the manufacturing sequence, configuration control and ground testing.

Manufacturing Analysis -- Manufacturing analysis includes planning the step by step processes, tools, support equipment and labor required to convert the basic raw materials into the finished vehicle in accordance to the manufacturing drawings prepared by the design groups. Computer tools have the same application in the manufacturing analysis as in the system or design analysis. By using a mechanized scheduling scheme such as PERT, scheduling each event from ordering material through

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[12] Milton A. Silveira.

[13] The following grouping of tasks and major uses of computer tools resulted from a communication with Martin Raines, Director of Reliability and Quality Assurance, NASA, MSC.

the assembly and testing of each component, assembly and subsystem. Utilization of resources can be optimized and alternatives worked around plans can be similated to select the least overall impact for unexpected delays.

By including the costs of all elements in the manufacturing process such as manpower, storage, extra equipment and additional facilities, decisions can be based on their impact on the total manufacturing cost and schedule picture as opposed to only one particular segment at a time. For example, it might be cheaper in the long run to pay a premium to have extra equipment installed at a critical point in the manufacturing flow than to add a week to the manufacturing period. Conversely, it might be less expensive to allow final assembly schedule to slip a month rather than force several subcontractors to expend premium pay and extra equipment to maintain the original schedule. Computer analysis of the overall manufacturing process including cost estimates will permit the program managers to make better overall decisions by providing mroe precise and current information.

Configuration and Process Control -- Configuration and process control are of utmost importance for maintaining high reliability and quality of the end item. Quality materials, sound design and manufacturing standards and practices as well as skilled, careful employees are, of course, of fundamental importance. The classic difficult is how to obtain and maintain these high standards. Computer technology can help by maintaining a current record of the location and status of every piece of material that enters the plant. One technique is to attach a coded card to every batch of material as it passes through receiving inspection. Then, at every step in which a portion of that batch is used, the card (or one like it, as the batch is subdivided) is simply inserted into a timeclock type data input device which records the parts code, time and date as well as the code for the process that is just beginning. The data input device sends this information to the computer data bank. As the components are assembled, new codes are used to represent a collection of specific items into a higher level assembly to keep down the volume of numbers. However, each individual part's total history is readily available in the data bank. The reason for maintaining such a complete file is to permit rapid location of any material, work from a particular machine at a particular time or other processes which might have produced a "bad batch" for some reason. Occasionally, an inadequate product is not discovered until the assembly is complete enough to be tested, weeks or even months later. By this time the other defective parts of the "bad batch" have been dispersed in other assemblies, in parts bins or elsewhere. Without a computer system to isolate these defective parts quickly, additional weeks could go by before all defective parts had been located. By that time, complete assemblies would require expensive rework to replace the defective component. Since this data can be stored in a data bank, it can also be used for manufacturing schedule control as well as for determining exactly which parts are in each vehicle.

Automation of many of the routine manufacturing functions is another rapidly increasing application of computer technology. Several electronic firms now, for example, design, manufacture and test many of their special electronic micro-logic circuits completely automatically. Not only is this automated production cheaper and faster, but the end product has much greater uniformity and reliability.[14]

Testing -- One application of these computer designed and manufactured micro-logic circuits is to continuously monitor the health and performance of every electronics assembly.[15] These micro-logic circuits are so small, their weight and volume are so negligible that they can be designed as an internal part of each assembly. In fact, the total weight added will usually be considerably less than the wires previously required to connect the sensors located through the vehicle system to various warning lights, controls and displays for ascertaining the health of the system.

On the Apollo spacecraft, the status of each subsystem is monitored by sensors located on each of a limited number of critical components. Some of this information can be displayed directly for flight crew information. However, most of the data are transmitted to the remote ground station that happens

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[14]Kugle, Don, Director of Computer Applications, TRW Houston Operations.

[15]Mueller, George E., "Applications of Computers to Manned Spacecraft," Computer Group News, September 1969, pp. 42-46.

to be in direct contact with the spacecraft at that time. A computer at the remote ground station processes the data and sends one of several preselected data formats to the Mission Control Center at Houston, Texas, via a limited capacity ground line or via a communication satellite. At the Mission Control Center, other computers process the information into prearranged formats to be displayed to the various flight controllers. Each flight controller monitors the data for which he is responsible to detect any abnormality that might indicate a problem.

By designing diagnostic micro-logic circuits into each active spacecraft assembly, then connecting each of these diagnostic circuits to an onboard computer, the need for ground monitoring will be essentially eliminated. One onboard computer can replace many computers on the ground as well as the large staff of technical experts that has been assembled for each of the previous flights.

These same diagnostic micro-logic circuits can also be used to checkout and test each assembly as the spacecraft is being assembled and during preflight checkout. This will save a great deal of time and money by eliminating the requirement for special test and checkout equipment.

Operations

In a sense, operations is both the beginning and the end of the hardware development process. Since they are responsible for the operation of this system after it has become operational, they are also the source of the overall system performance requirements necessary to accomplish the program objectives. In addition, they are usually responsible for conducting the flight test program to assure that the vehicle is ready for operational status. Specific functions include systems operation, flight crew training, ground crew training, maintenance and the operation of ground support facilities.

Operations has long been one of the leading users of computer technology for crew training, data processing and mission planning. However, there are still many areas in which an unlimited data bank and the reduced cost and increased speed of new time shared computers will be most beneficial. Two particular tasks for which this is true are the development, storage and retrieval of "what-if" data and automatic vehicle performance monitoring and data processing.

"What-If" Data[16] -- In order to cope with emergencies, operations personnel, especially flight and ground support teams, need to have as much data as possible on the actual performance limits of each vehicle subsystem and what happens when that limit is exceeded. Engineering analysis, ground test and flight test programs have long been the best source for this data. However, most of the data were "lost" to the operations personnel because the data were not stored in a useable or retrievable form. For example, the results of an

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[16] Author's personal experience.

engineer's file but the assumptions or input conditions would be missing. Although ground test output data are usually taped, the input conditions might not be and the data is therefor rarely useable.

To make this data useful, a special task would be required to organize and correlate the raw data so that it could be stored and retrieved in a useable form. Microfilm provides an ideal tool for storing this type of data because it is much cheaper and requires must less volume than magnetic tape.

Automatic Vehicle Performance Monitoring[18] -- One of the major uses of computer technology for the NASA manned space flights has been preparation for and real time monitoring of vehicle performance. The greatly increased speed and reduced weight and volume of computers has enabled system designers to move the primary vehicle monitory function on board the spacecraft as described in the last section. Caution signals will be sent directly to the flight crew if tolerances are exceeded. Data that must be transmitted to the mission control center can be greatly reduced and simplified. Not only because much less data is required with the emphasis on onboard monitoring, but also by utilizing a "change only" concept. That is, the remote computer would only transmit data for those functions that changed by some predetermined amount since the last time that particular function had been checked.

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[19]The following are based on the author's experience modified somewhat by a discussion with Sigurd Sjoberg, Director, Flight Operations Directorate, NASA, MSC.

As a result, far fewer flight control equipment and personnel will be required for real time monitoring.

Conclusion

The foregoing applications of computer technology were included to provide specific and tangible evidence that computer technology can force a great variety of changes on a single program. After such a computer system is in operation, a much better job can be done much faster by far fewer people. However, many new operational and management techniques will be required and considerable retraining will be necessary. Such a transition will require years to complete.

CHAPTER V

LIBERATION FROM BONDAGE: THE HUMAN ELEMENT

The high cost of existing policies and practices to defense industry personnel was discussed in Chapter II (Anguish in the Defense Industry). Specifically mentioned were the generally poor morale due to the feast or famine nature of the industry, the underutilization of employees capabilities and the frequen lack of correlation between performance and rewards.

This chapter is devoted to an examination of the research in human behavior and motivation to explicitly define the basic concepts and variables that significantly influence individual morale and productivity. Then, the specific implications that computer utilization has had, and is expected to have, on these personnel problems is discussed. These human relations considerations are of fundamental importance to the successful accomplishment of the objective of this paper. Costs cannot be reduced significantly, nor can quality be increased, unless the work required for a given program can be accomplished by fewer, highly motivated and well managed personnel.

Research in Human Behavior

Considerable research has been conducted during the last two decades from the industrial management point of reference to determine how to make workers more productive. In addition, considerable research and analysis has been aimed from the psychological point of view at how a human would develop and function if left to his own resources and not constrained to fit into an organizational mold. Happily, regardless of their original intent, both approaches have reached essentially the same conclusions. In our society, an individual will be positively motivated to perform at the level of his ability and will feel much greater self esteem if he can work in a cooperative environment on a task that presents a challenge and enough freedom for him to exercise initiative and choice in its execution.

Many author's have written on this subject. The basic concepts, however, have been adequately described in concepts prepared by: A. H. Maslow, Chris Argyris, Frederick Hertzberg, Douglas McGregor and Rensis Likert.

Generic Human Characteristics -- In "A Theory of Human Motivation: the Basic Needs," A. H. Maslow presented his hierarchy of human needs:[1]

Survival	The physiological needs for food, shelter, rest and exercise.
Safety	Protection against danger, threat or deprivation.
Social	A sense of belonging, acceptance by peers.
Egoistic	Self-confidence, independence, achievement, competence and knowledge, in short, one's self esteem.
Self-Fulfillment	Realizing one's own potential, creativity, self development.

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[1]Maslow, A. H., "A Theory of Human Motivation: The Basic Needs," from David R. Hampton, Charles E. Summer and Ross A. Webber, Organizational Behavior and the Practice of Management, Scott, Foresman and Company, Glenview, Illinois, 1968, pp. 27-39.

According to Mr. Maslow, these needs are independent and overlapping. Although one cannot be concerned with self-fulfillment if basic survival or safety needs are of primary importance, one can devote some energy to egoistic needs even though social and safety needs are not completely satisfied.

In other words, a human being will not be motivated by self-fulfillment goals if his basic survival needs have not been met. On the other hand, offering more salary is not effective as a motivator for an individual that already has more than enough to satisfy all of his basic needs except for self-fulfillment.

Another useful concept, developed by Chris Argyris in The Individual and the Organization, claims that "the self, in this culture, tends to develop along specific trends which are operationally definable and emperically observable."[2] These basic developmental trends are that the human being:

1. tends to develop from a state of being passive as an infant to a state of increasing activity as an adult.

2. tends to develop from a state of dependence upon others as an infant to a state of relative independence as an adult.

3. tends to develop from being capable of behaving in only a few ways as an infant to being capable of behaving in many different ways as an adult.

4. tends to develop from being erratic, casual, shallow, quickly dropping interests as an infant to possessing a deepening of interests as an adult.

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[2] Argyris, Chris, "The Individual and the Organization," from Michael D. Reagan, The Administration of Public Policy, Scott, Foresman and Company, Glenview, Illinois, 1969, p. 72.

5. tends to develop from having a short time perspective (i.e., the present largely determines behavior) of an infant to having a much longer time perspective as an adult (i.e., the individual's behavior is more affected by the past and the future).

6. tends to develop from being in a subordinate position in the family and society as an infant to aspiring to occupy at least and equal and/or superordinate position relative to his peers.

7. tends to develop from having a lack of awareness of the self as an infant to having an awareness of and control over the self as an adult.

These concepts help explain why the industrial revolution brought with it the tradition that the job is only a place to earn money. Two historical factors are particularly significant. The first is the concept of scientific management presented by Frederick W. Taylor in the 1940's. In this concept, the worker is considered to be a machine. The best production rate can be achieved if each and every action required for the job is carefully planned and each employee is taught exactly how to perform his assigned task. Instead of developing the greater independence, deepening interest, longer time perspective and greater control over his activities needed for normal human development, scientific management forced just the opposite. In addition, many of these workers had been forced by economic need (safety and survival) from the farm where they had enjoyed a positive environment for human development. Therefore, it is not difficult to understand the negative progression faced by these individuals that have so strongly influenced our societies attitude toward industry in general. Nor have we progressed very far in many industries. The typical development engineer, for example, is just another white shirt in a huge room filled with white shirts, each being told exactly what he should do, when he should to it and receiving essentially the same pay and rewards as the other workers regardless of his contribution. Also, most programs or projects have been so fragmented by specialization and the program hierarchies contain so many levels that even promotion to the next level provides very little and temporary improvement in the workers' basic need structure.

Motivation -- These concepts help explain Frederick Hertzberg's and Rensis Lebert's findings on human motivation. In an extensive and highly sophisticated study conducted during the 1950's, Hertzberg and his researchers interviewed a large number of workers several times over a five-year period to determine the short-range and long-range effects of various job attitude factors.[3]

Most of these factors turned out to be what he has called "hygiene" factors. That is, they are necessary for a healthy work environment, but cannot by themselves increase the motivation to work. Hygiene factors include supervision, interpersonal relations, physical working conditions, salary, company policies, administrative practices, benefits and job security.

The real motivators were factors which increased self-

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[3]Hertzberg, Frederick, Mausner, Bernard, and Snyderman, Bock Barbara, The Motivation to Work, John Wiley and Sons, Inc., New York, 1959.

actualization or self-realization; a real sense of achievement, recognition for these achievements, interesting and challenging work, a real sense of responsibility and the knowledge that good work will lead to advancement. These factors were shown to be the most powerful positive motivators. The study also showed that these same factors were not as strong on reducing motivation. The strongest long-term negative motivators included adverse company policies, incompetent technical supervision, inadequate salary and lack of recognition.

Authoritarian vs. Participative Management -- Douglas McGregor defined a set of management characteristics that have come to be known as participative management and labeled it "theory Y" as opposed to the usual authoritarian concept of management which he labeled "theory X". The following are his definitions of both theory X and theory Y:[4]

> "Theory X leads naturally to an emphasis on the tactics of control-to proceedures and techniques for telling people what to do, for determining whether they are doing it and for administering rewards and punishments. People must be made to do what is necessary."

> "Theory Y... leads to a preoccupation with the nature of relationships, with the creation of an environment which will encourage committment to organizational objectives and which will provide opportunities for maximum exercise of initiative, ingenuity and self-direction in achieving them."

In a theory Y environment, each worker has much greater opportunity to exercise intuition, judgment, and skill in the

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[4] McGregor, Douglas, The Human Side of Enterprise, McGraw-Hill Book Company, New York, 1960.

performance of his task. His task is large enough and identifiable enough so that he can take direct credit, or blame, for his performance and that he can feel a real sense of belonging to the team and that his contribution is important to the well-being of his fellow workers and of the company.

More recently, Dr. Rensis Likert coordinated and compiled very extensive studies over extended period of time to develop a stable body of knowledge for management's use on how to organize and run an enterprise.

The variables considered and the questions asked were much too extensive to reproduce here. However, the results were found to form consistent sets of characteristics. Dr. Likert arranged these characteristics into systems:[5]

System 1,	Exploitative authoritative
System 2,	Benevolent authoritative
System 3,	Consultive
System 4,	Participative.

With very few exceptions, high producing departments are seen as using management systems toward system four and lower producing companies as more toward system one.

In addition, these studies showed that most managers rely on pressure to meet production goals and have the attitude that an interest in their employees is a luxury.

> Most managers report (and these studies proved) that, when top management seeks to reduce costs, it shifts its system more toward System one, i.e., toward a

[5]Likert, Rensis, The Human Organization, McGraw-Hill Book Company, New York, 1967.

> system which they know from their own observations and experience yields poorer productivity and higher costs, on the average and over the long run, than does the existing management system of the company.[6]

This is exactly what the government agencies have done in their attempts to reduce the costs of defense and aero-space programs.

As he had anticipated, companies that really implemented participative techniques, or more accurately a participative environment (his system 4) showed significant improvement in labor relations, end item quality, reduced costs, reduced employee turn-over and several other factors. Conversely, adverse or dictatorial policies, such as extensive cost control, explicit task definitions, having little or no room for initiative and excessive schedule pressure (his system 1) resulted in a marked degradation in these factors.

Another significant contribution to the management field resulting from these studies was the amount of time required for policy changes to become effective (either positively or adversely). A full year was often required, for example, for a top management policy change to begin to effect the end product.[7]

The general environment in which defense industry employees must work violates many of these basic characteristics. In the author's experience, management emphasis has been on production

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[6]Likert, p. 11

[7]Refer to page for a representative time table.

through job fragmentation and management pressure. The majority of personnel involved with design and development activities are not challenged by their jobs. They do not feel that they are recognized as important members of the product team. And, experience has taught them that their monetary rewards are much more strongly influenced by the environmental factors beyond their control, than by the amount or quality of work they perform. These are classic Theory X, or in Dr. Libert's terms, systems one or systems two management characteristics. That is, the authoritarian approach in which personnel are considered to be machines that do what they are told to do as efficiently as they can.

A shift in management emphasis toward McGregor's Theory Y or Libert's System three and four, would help. However, so many people are employed in the industry that if the program is divided such that one task is assigned to each, little challenge or room for innovation and initiative would exist. Computer technology will greatly aggravate this situation unless the number of people assigned to a given program is greatly reduced. As suggested in references 2 and 6, one capable, motivated and trained individual working with the computer can do much more work, much more accurately and much faster than several workers have been able to accomplish without the computer. In addition, this one employee or small group of employees working as a team, would feel greater self-satisfaction, hence would, in the proper environment, become even more motivated. In fact, George Steiner and William Ryan have found that the few really effective program managers in the defense industries have such highly motivated employees that they work too hard.[9]

The Steiner/Ryan study also indicates the importance of selecting good personnel, defining their responsibility as broadly as possible, then giving them maximum possible freedom to accomplish their tasks. However, since their study deals primarily with the interface between the government contracting agency and the contractor's project manager, it will be referenced in more detail in the next chapter.

The Effect of Computer Utilization on Personnel and Organization Structure

> "The cybernation revolution has been brought about by the combination of the computer and the automated self-regulating machine. This results in a system of almost unlimited productive capacity which requires progressively less human labor. Cybernation is already reorganizing the economy and social system to meet its own needs."[10]

These words were taken from a memorandum sent to President Johnson in March 1964 by a group of west coast civic, academic and industrial leaders who called themselves the Ad Hoc Committee on the Triple Revolution. In 1964, computer utilization was limited to fewer applications and the critical factors for extensive utilization (computer speed, cost and available software) were appreciably less attractive than they are now (see

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[9] Steiner, George A, and Ryan, William G., Industrial Project Management, The Macmillan Company, Toronto, 1968, p. 161.

[10] The Ad Hoc Committee on the Triple Revolution, "Triple Revolution," Advertising Age Magazine, April 6, 1964.

Chapter III). Therefore, the concern expressed by the committee on the Triple Revolution are even more evident today. The economic and social system has been reorganized even further toward meeting the needs of the cybernation revolution.[11]

No such thing as "the effect" exists because each industry and each organization has reacted differently to the tools available. The subject has received sufficient attention in recent literature, however, to provide a reasonably accurate feel for the trends. Whether or not a particular organization has yet to achieve a particular level of implementation is not particularly important. The main argument is that implementation of computer tools is inevitable. "By 1985 the computer will have become central to the nervous system of the corporation."[12] Therefore, its effects must be understood and its utilization carefully planned.

In a recent study of the effects electronic data processing has had on a "typical" user of computers, Charles W. Hofer found a marked distinction in the consequences of computer use levels of the organization. Top, or general management was hardly effected, primarily because their function envolved working with and evaluating people, not machines or products. Middle, or functional management found their role to be

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[11]One current study that indicates the extent to which one industry has been affected is Charles W. Hofer, "Emergency EDP Pattern, Harvard Business Review, March-April 1970.

[12]Diebold, John, "Bad Decisions on Computer Use," Harvard Business Review, January-February 1969, p. 15.

somewhat modified. Greater need and a greater freedom to plan ahead, as well as better data to work with, were the main changes. The workers, or operational level personnel, especially in quantitative areas, felt the greatest changes. The improved efficiency resulted in several of these groups being combined, their scope of activity increased and the number of people required for a given task reduced as much as 40%.[13]

Emphasis on the great effect computer systems eventually have on personnel engaged in routine functions occurs very frequently in the literature. The following example illustrates the point:

> "While the computer extends the capabilities of the creative person, ... it reduces or removes the need for the engineer or designer who merely carries out routine design activities using handbook-type data according to preset rules. Of course, most of what is 'designed' is done by this sort of 'skilled' activity."[14]

By the same token these computer tools provide the greatest opportunity for liberating mankind from the bondage of routine labor that has ever occurred.[15]

In a very comprehensive article dealing with the effects of computer on organizations and management, Rober F. Vandell

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[13] Hofer, p. 16.

[14] Michael, Donald N., "The Unprepared Society: Planning for a Precareous Future"

[15] Diebold, John, Man and the Computer, Frederick A. Praeger, New York, 1969, p. 137.

presents his analysis of the basic areas of change. The following is an abbreviated summary of his observations:[16]

1) Implementation of computer systems has two main phases: First, a short term set-up phase, dominated by technical specialists, which is very expensive. This is followed by the long operational phase conducted by line personnel for which costs have been reduced substantially before preimplementation levels.

2) Decision making is much more rapid. More problems are solved, faster and with much less error. Most operational decisions are delegated to the "front line" because they can be more responsive and to free higher management for its increased pressure to plan more carefully and in more detail.

3) Formal planning becomes the basis for action instead of the pro forma exercise it has traditionally become. In addition, management's skill, or art, for prediciting changes is becoming increasingly important.

4) Strong pressures exist to reduce the size of the company. Mr. Vandell stressed the need for responsiveness. For a comprehensive analysis of other factors influencing the trends in company size see Wittnebert's "Bigness vs Profitability."[17]

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[16]Vandell, Robert F., "Management Evolution in the Quantitative World," Harvard Business Review, January-February 1970, pp. 83-92.

[17]Wittenbert, Fred R., "Bigness vs. Profitability," Harvard Business Review, January-February 1970, p. 158.

5) Top Management planning emphasis is shifting from tactics to strategy.

As computer systems become cheaper and management becomes more accustomed to its use, each manager's personal interaction with the computer is expected to increase. The American Management Association has sponsored a continuing seminar on this subject since 1964. The participants in this seminar expect each manager to eventually work directly with the computer as a real-time extension of his brain. Mental processes specifically named include postulating, judgement, analysis, logical deduction, planning, forecasting, computing, interpalation, interpretation and remembering.[18] The argument is that the computer can do many of these processes faster and more accurately.[19]

Obviously, the authors of the last study mentioned believe that even top management will eventually be greatly effected by computer tools. For this paper, however, direct interaction between top management and the computer to the extent described above is not considered. Major emphasis in the remainder of the paper is limited to middle management and the working level personnel where the greatest impact is currently being felt.

[18] Diebold, p. 15

[19] Sprague, Richard E., "Personalized Data Systems," Business Automation, October 1969, pp. 43-51.

Conclusion

Both of the forces discussed in this chapter (participative management and computer utilization) have proven to be very effective in reducing costs, improving the quality of the end item and improving personnel morale and motivation. Applied together they complement each other very well and promise revolutionary changes. Many years of understanding, dedicated and patient leadership will be required at all levels of management both within the governmental agencies and with contractor organizations before these tools and techniques will be understood and implemented effectively. However, the research that has been conducted and the experience of companies that have been utilizing these techniques provide a sound basis to confirm that the end results are worth every effort.

Chapter VI suggests a few policies and practices designed to provide a better working environment and to initiate the trend toward a system four type management.

CHAPTER VI

THE PROGRAM INTEGRATION FUNCTION

The foregoing emphasis in this paper has been directed toward the identification of the factors that have resulted in the familiar feast or famine nature of the industry, the high cost of each program and the low employee morale. Key factors that have been identified by a search of the literature include the size and duration of major contracts, crisis schedule pressure, overcontrol by the responsible government agencies, the basic disregard of human behavioral characteristics and the development of computer technology.

Emphasis in this chapter is on the recommendation of policies and practices to reverse these undesirable trends. Particular emphasis is on the interface between the contracting agency and the contractors.

Both the NASA and the DOD have taken positive steps to relieve many of the problems attributable to contractural responsibility for unanticipated technical difficulties.[1] However, in the author's opinion, additional emphasis is required on the optimum size of each contract and on providing a favorable environment for positive personnel motivation and pride in their work.

Extensive research has been conducted by several teams

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[1]National Aeronautics and Space Administration, Phased Project Planning Guidelines, U. S. Government Printing Office, Washington, D. C., NHB 7121.2, 1968, p. 2-1.

to identify the specific variables that consistently contribute to successful programs. Success in this case, pertains to completing the program successfully on schedule and within the prescribed budget. Many of these variables have been included elsewhere in this paper. However, a few have particular significance and are worth repeating as rationale, or basic underlying reasons for the definition of the government's role, the contractor's role and the demarkations between them. These variables, or factors, are:

> Holding the number of people having any connection with the program to the fewest required to complete the program.[2]
>
> Mutual trust must exist between the government and the contractors.[3]
>
> Huge, long-term contracts should be avoided.

The reasons for the latter has been a major theme throughout this paper and is implicit in the proposition. One specific technique for accomplishing this goal is described later in the chapter.

Emphasis on holding the number of people associated with the program to a minimum has also been a basic theme throughout this paper. The following discussion, borrowed from Mr. William B. McLean, expresses the reasons for this special emphasis very well.

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[2] Steiner, George A., and Ryan, William G., Industrial Project Management, The Macmillan Company, Toronto, Ontario, 1968, p. 33.

[3] Ibid, p. 64.

As the working force passes the minimum number required and the rate of progress slows down, the perceived need for more people and more liaison increases rapidly. More engineers on the project can emient more avenues of approach and more techniques to try. The maintenance of coördination between all of these different possibilities becomes a function which again requires more people and more paper work. Competition for the available jobs becomes keen. Communications begin to fall off. The understanding of what is to be accomplished becomes more remote. And, finally, the ability of each engineer to participate in setting up the goals toward which he is working, and his contribution to the total design becomes less, with a resulting loss of interest.

Tension within such an overstaffed organization grows, mistakes become more common, the trying of new things which might lead to significant shortcuts becomes entirely too risky, and the designer eventually loses control of the organization. On the other hand, the closeness of a small organization stimulates continuous and rapid feedback between all stages of the design process. Such feedback, provided by direct and rapid communication, is essential if we are to achieve integrated and functional designs. A small, effectife organization can probably produce designs that are simpler and more reliable by factors of from 10 to 100 over the kind of equipment that results from the straight-line process of starting with the military requirement, building up a big organization and wading through countless, detailed specifications.[4]

In the preceeding discussion, Mr. McLean stressed the importance of maintaining the engineers' interest in the program. Extensive research, discussed specifically in Chapter V, has shown that program cost and quality are tied directly to each individual's pride in his work supported by a participative or cooperative environment.

This research has also shown that the benefits of changes in policies and practices toward a participative environment come slowly. The attitudes and practices of many managers at all levels must be changed before the individual workers can be expected to change. This will require years of careful training and disciplined leadership by top management.

One way to get such a trend started is to carefully define and then monitor and discipline the distinction between the government's role and the contractor's role as defined below. The following definitions of these respective roles also contains the specific rationale, supported by the earlier chapters, for my hypothesis that the government should become its own integrating contractor.

The Government's Role

Only the government has sufficient knowledge and authority to define program objectives and to properly weigh the benefits

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[4]McLean, William B., "The Art of Simple and Reliable Design," U. S. Naval Ordnance Test Station, China Lake, California, 1963, p. 6. Taken from Steiner, p. 34.

to be derived from each of the major hardware alternatives tha always arise during the definition and development phases of a large scale program.

In order to reduce the potential for misunderstanding, the question will be posed in terms of a specific, yet hypothetical program. Assume the program in question is to design, manufacture, test and operate a large, manned space station. It is to operate in the near earth region, support an operational crew of 200 for at least 3 months without resupply and have an operational life of at least 10 years.

Such a space station would be useful for many things that can be defined in terms of specific objectives ranging from the development and testing of subsystems and techniques suitable for extended space flights to neighboring planets to the improvement of the biosphere by spotting and monitoring contamination sources and trends.

An exact list of possible objectives is not important to this argument. The important consideration is that the list will always be changing. If a contract were awarded to optimize the design of a spacecraft for a specific set of objectives as they exist today, many of these objectives have been replaced by a new set before the hardware could be manufactured, thereby, inducing hardware changes. It is also important to assure that all hardware required is within the state-of-the-art.[5] Specific sensors, computer facilities, maneuvering capability, life

[5]NASA, NHB 7121.2, p. 5-1.

support systems, communication systems, crew mix, everything except perhaps the basic structure could be expected to change during the spacecraft's operation life as new needs and new technological capabilities develop.

Attempting to anticipate this entire sequence with sufficient accuracy to permit selection of one prime or integrating contractor for the entire 15 or 20 year span of the program would be unrealistic. A realistic contract could be awarded for the development and integration of the first complement of equipment required to meet known objectives with certain provisos. For example, the vehicle should be maintainable by onboard field level personnel (non-astronauts)[6] and the basic structure must be designed such tat all subsystems could be replaced as modular units, including all wiring and plumbing. Then, the government could award separate contracts later for new sensor packages, engines, environmental control systems or whatever required to meet the changing needs.

In order for the responsible government agency to intelligently award these follow-on contracts, it must be able to conduct thorough operations analysis to determine which areas to change and how each should be changed to meet a new set of objectives. They must have current knowledge of the state-of-the-art. They must have qualified program control, systems

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[6]Donald K. Slayton, Director of Flight Crew Operations, Manned Spacecraft Center, Houston, Texas, suggested to the author on February 12, 1970, that a large space station would probably be manned by technicians and scientists, not astronauts.

analysis, design engineering, industrial engineering and operations groups to prepare specifications, award and administer contracts, provide technical assistance, operate and maintain the new subsystems.

Now the question becomes when should the government begin to award separate contracts for each subsystem module.

When should the government become its own integrating contractor?

As discussed in previous chapters, in order to save the cost of compounding profits through tiers of subcontractors, to reduce the manpower fluctuations that normally accompany the awarding of a major contract and to scale the financial risks associated with inadequate management on the part of the contractor to levels that would hurt, but not bankrupt the company suggest that the government should assume the role of integrating contractor as soon as practical. Obviously, it is not that simple. First the government agencies must prepare by staffing and training personnel for new disciplines; by developing computer data banks and the mechanism for keeping the data complete and current; by developing policies, processes and procedures for operating in this new mode and by educating the industry and the public on the agencies intentions and the reasons behind these intentions.

The Contractor's Role

Implicit in the foregoing section on the government's role was the assumption that the government would not want to manufacture any of the spacecraft hardware with the exception of a few unique, minor items. Hardware contractors have an expertise in the whole field of industrial engineering that is almost totally lacking in most government agencies. In addition, the magnitude of the manufacturing task for any given large program is much greater than the government could accommodate inhouse, even with computer tools, without imposing the tremendous surge of manpower that this paper is explicitly trying to reduce.

Hardware contractors have another advantage not shared by the contracting agency. It can intersperse jobs from other government programs or from the commercial market and thereby maintain stable employment, providing that none of these contracts is too large. By awarding hugh prime contracts, the government destroys this stable balance because massive hiring campaigns are required to meet the tremendous program scope within the schedule commitments.

Effective utilization of each contractor's manufacturing expertise implies that he should select hiw own vendors, prepare his own manufacturing drawings, and employ his own techniques for obtaining maximum reliability and quality for minimum weight and volume. In addition to the technical and economic sense of making maximum advantage of each contractor's special skills, there is the human motivation goal of providing each worker with sufficient "elbow room" to exercise his creativity, to feel like a real member of the team and to enjoy the discipline of specific personal responsibility. These arguments suggest that most contracts should be for at least complete assemblies and preferably for complete subsystems, but not for complete programs.

Demarcations between the Government and Contractor's Role

One of the points mentioned in Chapter II was the separation of the government's role as a customer and its role as a technical advisor. With the crisis schedule pressures of World War II, the Korean War, the Vietnam War, the Cold War and the Space Race, this distinction was greatly reduced. Government contracting agencies felt that they must assure technical success by monitoring and advising the contractor on every step during the program. Much of this assistance performed its intended function and did result in a better product. However, the cost in dollars and human motivation was very high.

The main theme of this chapter is that the desired benefits that caused such close control by the government can be achieved for much smaller cost by not only separating the government and the contractors roles but also by separating the government's role into three separate and distinct functions: planning, program management and technical assistance.

Program Planning -- Program planning is absolutely essential. As mentioned earlier, several authors have stressed that the increased complexity and faster pace imposed on industrial society by the "quantitative revolution" has forced a premium on serious, thorough, viable planning as never before. Many organizations have had long range planning groups for some time. For many organizations, however, these groups have been, in fact, pro forma units staffed frequently by high level personnel no one else wanted and which had essentially no effect on the real future of the organization.[7]

The real action planning was done by each line manager independent of a central planning group. The pace of most programs was such that these managers could implement their plans incrementally toward some poorly defined goal. If one of these incremental decisions proved to be inadequate, and if the inadequacy was discovered before too long, it could be corrected with relatively little impact. If it was not discovered until after the hardware had been built, correction was required on a crisis basis to prevent the entire program from slipping schedule.

Computer technology can greatly help avoid these problems by facilitating the planning itself and the integration of each line manager's plans into an overall program plan. These tools can also, however, result in much greater cost penalties for a given time to find and correct errors because the equipment design and manufacturing phases will be so much shorter. For example, a few years ago, a one month delay in discovering an error would have been relatively inexpensive because the design would not have progressed very much farther. The error could be corrected with only a paper change. In a few more years, however, the equipment will have been designed and manufactured in a month.

Another important aspect of planning related to the objec-

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[7]Steiner, George A., Top Management Planning, The Macmillian Company, Toronto, Ontario, 1969, p. 8.

tive of this paper is to provide a uniform flow of contracts, as opposed to the current tendency to award several hugh contracts at nearly the same time, then to wait another eight to ten years before awarding another series. To do this, the government will need a long range integrated plan so that needed technological developments can be anticipated, and development contracts awarded prior to the need for the hardware.

Opinions vary as to the length of lead time required for this planning. One prominent author suggests that five years is too short for the aerospace industry.[8] Other argue that computer technology combined with the solid base of knowledge now existing in most disciplines permit new developments to be achieved almost on demand. In any event, we tend to be too limited in that we only consider the state-of-technology at the moment of review. Long range planners need to monitor the signals to anticipate and lead developments so that they will be ready when needed.[9]

These arguments pertain primarily to the technical problems involved. However, increasing evidence indicates that the problem is now philosophical, not technical. Long lead times are required to obtain the required public, political and administrative support in time to allow hardware contracts to be awarded.

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[8] Ibid, p. 26.

[9] Bright, James R., "Evaluating Signals of Technological Change," Harvard Business Review, January-February 1970, p. 70.

Program Management -- The intent of both the NASA and the DOD procurement and program management manuals is to free the contractor to make decisions without undue interference.[10] This implies control by specification, standards as well as schedule and cost budgets. It is not intended that contracting agencies permit their technical experts to tell, or even advise, the contractor how to accomplish these requirements.

The main reasons given in the literature for tightening government program management control of contractors are:

1) A desire of government personnel to participate in all program decisions, hence they desire ever increasing quantities of data.

2) A desire to stimulate a competitive environment.

3) A desire to reduce cost without schedule or performance loss.[11]

Unfortunately, no counterbalancing forces exist other than the limited protests by the contractor. Therefore, an artificial counterforce must be provided. Perhaps the best and most straight forward method is a clear statement and strict enforcement of policy in which the respective responsibilities are defined.

The program management function was described in greater detail in Chapter IV. The primary difference between the government program manager's function and that of his industrial counterparts can be implied by their respective interpretations

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[10]Steiner and Ryan, p. 79.

[11]*Ibid*, pp. 71-72

of the term "system." To the government program manager, the system refers to all vehicles, ground facilities and other equipment and personnel required to accomplish the program objective. To a given contractor program manager, the system usually refers to his particular end item.

Technical Advisors -- All technical direction to contractors ought to be through changes in the specifications (hence the contract). A strong governmental technical staff is crucial to intelligent specification of specific performance requirements for each contract. These specialists are also needed to assist the contractors in areas where they are having technical difficulties and ask for assistance, or in areas where special facilities are required that are impractical for each contractor to procure and maintain (large thermo-vacuum chambers for example).

Government technical specialists should not be permitted to tell the contractor how to design the equipment he has contracted to build. Several problems result if this is allowed. Costs increase because these directions frequently require redesign or rework. Whether the cost is borne by the government or by the contractor is irrelevent. The argument is simply that these are unnecessary costs. If the contractor's design does not meet the specification for which it was contracted it might be necessary to formally direct a change. However, this is a default of contract items that must be decided by the government's program manager.

Another argument against permitting government technical people from directing, or even suggesting how a design should be implemented is that even government technical specialists that have no direct connection with the program management function represent the customer to the contractor, that is, the contractor's employees will tend to fear sanctions of some sort if he does not do as the government technical specialist implies. This could cause the contractor's designer to change or compromise his design even though he is not in technical agreement. The result is a frustrated designer and perhaps a suboptimal design.

Preventing government technical specialists from telling the contractors how to design will be increasingly difficult with computer aided design and well-supplied data banks. He might very well be totally capable of designing a better product than the contractor's design engineer. Occasionally, however, a technically optimum design might require modification to permit practical manufacturing, or to achieve greater reliability. Since the government's design engineer is usually not intimately familiar with the contractor's manufacturing techniques and capabilities he cannot accurately second guess his contractor counterpart.

One technique to prevent this potential conflict would be to implicitly define policy against it. Then, conduct an extensive training program to make all government personnel aware of the financial and personnel morale implications of their interference.

CHAPTER VII

SUMMARY AND CONCLUSIONS

The defense industry has been notorious for its feast-or-famine nature. This tradition began during World War II and increased in intensity with each of several abrupt changes in defense policy. These changes resulted in shifting contractor requirements such that activity in portions of the industry would decrease rapidly and other portions would accelerate under heavy schedule pressure to meet the highly sophisticated technological needs of the newest crisis. Each of these factor contributed to greatly increased program costs. High costs, in turn, tended to cause increased government control which also added to both pressure and cost.

To break this divergent series, Robert S. McNamara introduced the "total package" concept in the early 1960's in which one contractor is responsible for all aspects of a given program from inception to operational support on essentially a fixed-price contract. Unfortunately neither the Department of Defense nor the contractors knew how to manage such an arrangement. Proposal costs became prohibitive for all but the largest companies and the risks associated with the hugh, long duration, fixed price contracts were potentially greater than any one company could accommodate. As a result, many of the defense and space contractors find it increasingly difficult to continue as a research and development contractor exclusively for the government.

During the last few years, both the Department of Defense and the National Aeronautics and Space Administration have modified their procurement practices to reduce the contractor's risk. However, much still needs to be done to reduce the cost of these programs even further and to greatly improve the morale and self-esteem of the employees.

In his book entitled, Space Age Management, the former administrator of the NASA, James E. Webb wrote:

> There is no doubt that we have the technological tools to free our society of many of its burdens and to carry it to new levels of achievement. What we need is an operating concept that requires us to find ways to use these tools deliberately and purposefully to reform our society and to assure continued progress toward the greater goals we set for ourselves long ago.[1]

Two major technical tools having sufficient power and applicability to "free our society" are computer technology and human behavioral characteristics.

Computer Technology -- Computers, and the computers ability to generate, store, manipulate and communicate knowledge is producing a prodigious rate of change in almost every aspect of program management. Personnel at all levels are gaining real time access to an every increasing supply of information and an ever increasing variety of tools through the use of remote terminals and computer time sharing.

A real appreciation for the impact potential of these tools can be obtained by examining the increase in the

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[1] Webb, James E., Space Age Management, McGraw-Hill, Inc., New York, 1969, p. 25.

computer's fundamental variable, its central processing speed. In the mid 1940's, the first general purpose digital computer could add or subtract at the rate of 3 additions per second. The newest computers are capable of conducting several of these operations simultaneously, each at a rate of approximately a billion per second. A billionth of a second is to a second as a second is to thirty years.

This is not to say that additional advancements in computer technology will not be useful. However, the major needs now are for even greater speed and increased random access memory storage capacity to further reduce cost. One authority recognized by the authors of Business Automation (Frederic G. Withington of Arthur D. Little, Inc.) predicts that by 1975 there will be a five-fold increase in circuit speed with corresponding drops in cost ranging from 10 to 50 percent of the present costs. Memory storage capacity is expected to have an improvement in cost-performance of 10 fold, using rotating magnetic disks devices offering as many as one billion bytes of storage capacity, with 50 millisecond random access.

The existing capacity and speed of these devices is already transforming the computer from a tool for specific technical applications to a general purpose management tool with almost limitless application.

As a result, all levels of management are in a very difficult transition period. For many organizations, the competitive pressure from the market place, the zealous enthusiasm of the computer services companies and the lack of adequate training, planning and preparation of its personnel has lead, or will lead, to an expensive fiasco. However, the trends are clear. Many leading business consultants predict that in order to obtain the rapid response necessary to adapt to changing markets, new information and a changing economic and social environment, all levels of management must adapt to these tools to survive.

In companies that have begun serious use of computers, top management are devoting every increasing time and energy to strategic planning by combining their experience with the information stored in data banks. They are delegating the tactical planning that had required so much of their time to middle management.

Middle management is no longer required to devote the majority of his time to assuring that the operations level are doing their work because their output is readily available through computer processed production and status reports. Therefore, they have more time and greater need to plan, conduct trade-off studies, and integrate the work of their employees.

Operations level personnel, of course, have received the greatest impact from the utilization of computer tools. Nearly all of the routine functions that have required large numbers of personnel to perform can now be conducted much faster, cheaper and more accurately by the computer. Recent studies have shown that up to 40 percent fewer personnel are required to perform the same quantitative tasks.

Human Behavior Characteristics and Organizational Efficiency -- Thousands of employees are hired during the course of large defense and space programs that are not really needed. These people are hired in the rush to find enough qualified personnel to support the schedule requirements, to accommodate peak demands and to have a reserve for contingencies. The industry wide philosophy for meeting any contingency has been to assign a lot of people to solve the problem.

Since the government paid all expenses, plus a steep overhead charge for most of the advanced programs, contractors were motivated to hire as many people as they could. In fact, in the interest of meeting tight schedule requirements, the government frequently encouraged the contractors to hire even more personnel than they wanted.

As described in Chapter V, these excess personnel were worse than useless. They introduced unnecessary work, plugged communication channels and spread discontentment because they were frequently bored. Each employee was frequently faced with policies and practices that allowed little discretion, highly fragmented job assignments that provided little room for initiative and a reward structure based on longevity and favoritism instead of contribution to the organization's goals.

Excess personnel are not only expensive for the government. As the program nears completion and these people are laid-off, they must move to a new job. Research for the Department of Labor has shown that the average cost of such a move (for aerospace industry personnel) is half a years salary per move. This includes no allowance for the personal feelings associated with insecurity and uprooting his family every few years.

Contractor personnel problems have been further complicated by all the "help" they received from government personnel. Typically, government personnel implicitly assumed that schedule did not allow the luxury of permitting contractor personnel to make mistakes, that two (or more) heads are better than one, and that contractor personnel will not perform unless they are pushed.

These factors provide a discouraging work environment that destroys the job interest, motivation and self-esteem of contractor personnel at all levels. Substantial research on basic human characteristics and motivation factors in an industrial environment have shown conclusively that the cost and quality of a company's end items is a strong function of the morale and self-esteem of its personnel. Fortunately, the techniques that result in the most productive employee are consistent with the natural development and well being of the individual.

Therefore, the policies and practices proposed for the administration of future large science programs must consider management techniques to improve personnel motivation and to hold the total number of personnel (both government and contractor) allowed to have anything to do with the program to a minimum.

Hugh prime contracts also present a burden from the point of view of contractor personnel efficiency. The ideal contract load for a given company would provide steady growth and stable employment. Key personnel would know each other, communication channels would be well established, lines and levels of authority would be well understood and the organization would perform as an efficient team.

Hugh contracts destroy this balance by requiring the rapid addition of tens of thousands of new personnel to the organizational structure. The result is an inefficient organization for the first several years as competent management personnel are selected, lines of communication established and a working team developed. About this time the development phase for the program nears completion and the team begins to disperse. Then the cycle begins again on a new program for another company. Consequently, huge programs tend to result in an inefficient organizational structure for the most of the developmental phase of the program. This argument suggests that contracts should be within the individual companies' existing capability without requiring more than a small percentage of additional personnel.

Bigness vs. Profitability -- Industrial giants are finding it increasingly difficult to compete with smaller companies on items for which the demand and the price are determined by the commercial market place. The reasons for this shifting advantage can be grouped into two general categories; increasing public resentment of industry in general and the consequences of ponderous corporate hierarchies.

Large companies are more susceptible to general public resentment than smaller companies because they are so much more visible. This pressure is manifest in several ways such as government antitrust actions, trade embargoes and union demands.

Smaller companies are not only less susceptible to external interference, they are also much more responsive to change and permit greater individual freedom because they are not hampered by hugh hierarchies. Also, the advent of computer time-sharing, has not only given the small company the use of the computer that was for so long one of the advantages of size, the small company can make more effective use of the computer time it buys.

<u>The Program Integration Function</u> -- The unique role of the government in the management of large public science programs is to develop the program objectives and the performance capabilities required. The unique tasks for which contractors are needed include the detailed design, manufacture and test activities required for each end item. A major task in between these functions that could be performed by either is that of general program integration. Program integration includes the preparation of common design and manufacturing standards, the preparation of detailed performance and interface specification for each suplement that is to be contracted for separately, development of the overall program plan, integration of hardware development schedules, configuration and change control, and assuring that all elements of the program fit together mechanically and functionally.

The National Aeronautics and Space Administration has demonstrated that government agencies can perform most of the functions very well. In addition, increased utilization of computer technology could greatly enhance the quality of these efforts while reducing the total number of personnel and the time required. Equally important, computer use could greatly facilitate control and integration of the program as it progressed.

Conclusions

Without sacrificing the number of programs, or the quality of their respective hardware, government agencies can significantly reduce the cost of large scale public science programs to be consistent with the demands of the nation's changing social and economic environment. Computer technology and basic human motivation characteristics are the tools. The major deterrents to the utilization of these tools are phychological and philosophical, not technical.

Emphasis in defense and space contracts has been on technical superiority and schedule too long to enable a rapid transition to adequate hardware performance for the least cost. The transition will be particularly difficult for management personnel. It will require more explicit planning and persistent discipline in execution than any of these managers have experienced in previous programs.

The notions that large public hardware programs require massive numbers of people and that these people will only perform well under heavy external pressure are deeply ingrained in the minds of many managers both within the government and within the defense and space industry contractors. In addition, the notion that government personnel are not capable of performing as effectively as personnel in private industry is also widely held. These notions are no longer true, or at least they need not be. They are primarily a result of tradition, a general lack of appreciation for how to establish a truly creative, effective and efficient working environment and a lack of management courage and discipline at all levels.

Even if top management fully understood and agreed with the concepts presented herein and knew exactly how to implement these changes, research has shown that several years would probably be required for these policies and practices to become effective. Therefore, the author's recommendation is that the first step should be to provide a government/contractor interface that would be conducive to these ends. Then, capability for effective utilization of computer technology should be developed for each major program function. And finally, contracts should be limited to specific portions of the overall program such that each can be readily accomplished within the winning contractor's existing capability.

Recommendations

Management of large programs is, of course, a very complex task in which public policy, program objectives, technical complexity, size, organizational elements, quality of personnel and management personalities are all important variables. The

Nation's social and economic environment can be reflected in all of these areas. However, this paper is somewhat normative in that ways to reduce the cost of major programs and improve the well-being of the individual employee are presented without considering the effects of these variables.

The specific recommendations from this study are limited to the macroscopic policies and the governmental organization structure required to provide an environment that is conducive to low cost and high productivity. Although very important, the day-to-day operating policies and personnel relations are beyond the scope of this effort.

Three specific recommendations are offered:

- that the government separate its program management function and its function as technical advisor.
- that the government establish a strong, central organizational unit in the Program Control area to plan, coordinate and control the use of computer related equipment throughout the program.
- that the government become its own integrating contractor such that a continuing stream of smaller contracts can be awarded throughout the life of the program.

The major reasons for separating the technical advisor function from program management per se are to prevent government technical personnel from exerting too much influence over the contractors technical efforts and to provide an academic environment in which the government experts primary responsibility is to become the best in their respective specialties.

As such they would be able to assist private industry, or other government agencies, whenever their technical expertise was needed. This technique will permit (and require) each contractor to be totally responsible for the performance of its technical and its management teams. However, in the event that it really gets stuck technically, it can turn to the government technical advisors for aid.

The basic concept is to control each contractor by specification and contract rather than by close supervision.

A central unit to control computer use is important because of the great potential for misuse. These tools are simply too expensive to permit their use to be uncontrolled. Such a control unit must also be separated from the technical areas, especially from the computer use center where the computers tend to become ends rather than means. Program contol is suggested as the ideal location for this unit as it is the only area in which the relative cost (or savings) of a particular computer application can be assessed relative to its value to the overall program.

Several benefits could be derived by having the government agencies become their own integrating contractor. Obsiously the problems associated with huge, long term contracts would be avoided because no such contracts would be needed. Smaller contracts can be much more easily managed because the cost incentivies can be realistic and because the task to be performed can be more easily specified. In addition, the government would have the flexibility to award separate contracts for follow on subsystems as they are needed for new program objectives.

Additional Comments

This paper has defined only an overall policy objective and a few specific mechanisms for developing an environment in which these objectives have a chance to be accomplished.

Much more effort must be devoted to specific plans for implementing these mechanisms. Personnel must be trained and the entire concept reviewed, discussed and sold to management personnel within the government and within the industry before anything can be accomplished. These steps are being taken by those industries in which the commercial market place demands maximum efficiency and effectiveness for survival. Competition is becoming even less forgiving as computer technology and human motivation concepts become operational tools in the managers' kit.

Defense and space programs are now, for the first time since World War II, entering a competitive environment similar to that faced by private industry. One major difference is that agencies such as the Department of Defense and the National Aeronautics and Space Administration have but one customer - the Public. And this customer is served indirectly through the Executive and the Congress. Therefore, in a way, the managers of these agencies have a much more difficult task than their industrial counterparts. The only alternatives available in lieu of more money are to drastically reduce the number and scope of programs, or to become considerably more efficient. The fundamental theme for this paper has been that the latter would be the only acceptable course of action if it could be accomplished. Research on the basic reasons for inefficiency in defense and space programs; on the current status of comput technology and on basic human motivation characteristics has convinced the author that a great deal can be done to reduce program costs. However, the techniques for achieving these cost reductions require basic philosophical changes in the way the government has conducted its program management business in recent years.

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