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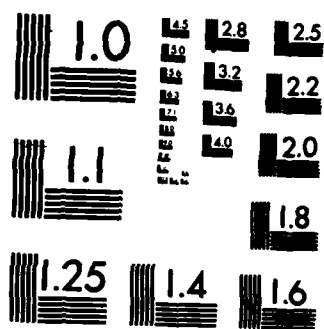
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THESIS

Gregory J.S. Eskesen, Major, USAF
Janet J. Hockersmith, First Lieutenant,
USAF

AFIT/GLM/LSM/84S-18

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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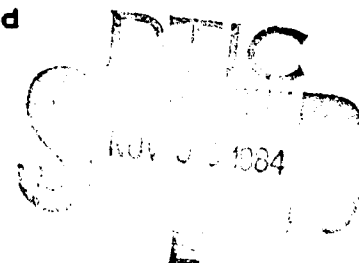
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AN APPRAISAL OF THE USAF TECHNOLOGY MODERNIZATION PROGRAM

THESIS

Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Logistics Management

Gregory J.S. Eskesen, B.A.
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September 1984

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Preface

The purpose of this study was to determine the management cost associated with a typical Technology Modernization Program and to compute a return on the government's investment using these additional costs. This study was conducted for HQ AFSC/PMI to see if 1) savings exist when personnel costs are considered, 2) a better utilization of manpower could be made, and 3) the payoff for future Tech Mod programs could be established when all costs, seed money and personnel, were considered.

We found that there is no "typical" Tech Mod program; the verification of the savings data is difficult; and with the reported savings, the return on investment is reduced from 2% - 25% when personnel costs are included. Future studies are needed to attempt to verify the purported savings.

We have had considerable help in conducting this study. We would like to express our appreciation to Dr. Richard Taliaferro, our advisor, and Captains Dave Odor and Brian Kochell, HQ AFSC/PMI, for steering us in the right direction; and to the ASD Tech Mod Program Managers in the SPOs for granting interviews necessary for the completion of this project. Finally, we would like to thank our spouses, Linda and Glenn, for their understanding and cooperation throughout this project.

Gregory J. S. Eskesen

Janet J. Hockersmith

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Abstract

Thesis
→ This investigation outlines the factors affecting the slowed productivity growth in the US with emphasis on DOD contractors. One of the primary causes of this phenomena is a reduction in investment for capital equipment.

The Technology Modernization Program was designed to assist defense contractors in capital investment decisions. The contractors and the government are reporting large savings as a result of the Tech Mod program.

The Aeronautical Systems Division's
X AGO's Tech Mod programs, the type of capital equipment being purchased by the contractors, and the government's management costs for the programs. The analysis of the government's investments, money and personnel, was made to determine the overall return on investment rate for a particular program. ↗

AN APPRAISAL OF THE USAF TECHNOLOGY MODERNIZATION PROGRAM

I. Introduction

During the last several years, the United States industrial base has received increased attention from agencies of the Federal Government including the Congressional Committee on Armed Services and the Department of Defense (45:5). Of particular interest is the problem of slowed productivity growth. The Defense industry has received particular interest from Congress in the area of productivity. This is evidenced in its publication of The Ailing Defense Industrial Base: Unready for Crisis. This study indicated that one of the main problems with the Defense industry is the use of equipment and facilities that are, in some cases, 20 years old (45:17).

As part of the military attempt to improve industrial productivity in the aerospace sector, the Aeronautical Systems Division (ASD) of Air Force Systems Command (AFSC), has selected two concepts as the foundation for its productivity enhancement efforts - contracting for productivity and modernizing contractor facilities through their Technology Modernization (Tech Mod) program (2:i). Contracting for productivity involves such things as the issuance of multiyear contracts and contracts based on

"Should Cost" studies conducted at the contractors facilities. Tech Mod differs from contracting for productivity in that the latter involves the contractor using his existing facilities and equipment for the production of weapon systems. The Department of Defense (DOD) expects that these contracting procedures will induce the contractor to make capital investments, but any investments designed to increase productivity and lower cost would be of the contractor's own initiative. Whereas, Tech Mod is a form of contracting that enables the contractor to make these capital investments with financial aid and encouragement from the Government. This study will focus on the Technology Modernization aspect of the productivity enhancement efforts.

The proponents of Tech Mod believe it offers an alternative to piecemeal productivity improvement by systematically performing a top-down factory analysis of defense contractors facilities. Tech Mod focuses on capital investment and technology through a business deal centered on cost and risk sharing by DOD and industry with the goal to improve contractor productivity. Specifically, the developers of Tech Mod hope it will provide for reduced acquisition costs, reduced lead times through investment in modern plant and equipment, and the application of new technology in manufacturing. The desired net result of implementing a Tech Mod program is a "sharing in the savings" between the contractor and the government (2:21). The savings from the reduced acquisition costs are to be shared

by the Government and contractor so as to at least maintain, or possibly increase, the contractor's return on investment, thus acting as an incentive to modernize.

It has been postulated that Defense contractors may be reluctant to modernize their facilities on their own accord. This may be based on the contracting methods used by DOD; the indepth analysis of each element of cost with profits being based on these costs; and the spreading of investment cost over individual contracts through overhead accounts with no concrete assurance that follow-on contracts will be awarded. Modernization of facilities implies an increased return on investment. But, with the contracting methods and profit analysis undertaken by DOD, the current mix of return on investment and return on sales appears to present an adequate overall profitability balance for investors as well as the contractor. Any cost reduction measures taken by the contractor would result in lower profit dollars, not a lower profit rate, and a lower return on investment for any specific contract.

In reviewing the annual reports of eight major defense contractors, the return on investment (measured in terms of stockholder's equity) is as shown in Table I. The segregation of the commercial and defense returns could not be determined from these reports. But, in comparison with all manufacturing industries, as reported in the Statistical Abstract of the United States - 1982-83, the return on stockholder's equity is higher for those contractors

conducting business with the government. This higher return may be related to the lower amounts of capital equipment investments in the defense industry.

TABLE I

Average Return on Stockholder's Equity
for Major Aircraft Defense Contractors

Contractor	1983	1982	1981	1980
Boeing	12.1%	18.7%	19.8%	28.8%
Lockheed	42.3%	79.2%	-148.8%	9.5%
General Dynamics	23.6%	14.3%	14.2%	22.2%
LTV	-16.8%	-12.9%	38.9%	28.2%
McDonnell Douglas	14.1%	12.4%	11.2%	18.8%
Northrup	18.8%	1.8%	9.7%	19.1%
Rockwell	17.4%	16.5%	17.5%	17.1%
United Technology	16.9%	28.4%	21.2%	22.7%
Average Return on Stockholder's Equity	16.2%	17.7%	-1.8% ¹	18.7%
Average Return for All U.S. Manufacturing Firms	NA	NA	13.6%	13.9%

¹Includes a negative 148% return for Lockheed Corporation in 1981. Without Lockheed, the return was 18.8% for the seven remaining companies.

Source (Annual Reports and 12:546)

Problem Statement

Before investing in any capital equipment, a contractor determines his expected return on investment rate. This rate is calculated as an interest rate that equates the investment cost to the present value of the net income stream over the

life of the investment. This return is a major aspect involved in the negotiation of a Tech Mod program. It determines the amount a contractor may need to borrow from investors to finance capital improvements.

This study will use the same approach in determining the Government's return on investment to evaluate the merit of selected Tech Mod programs. A full-costing approach will be used to determine this return. The expenditures by the Government will include all costs identified with the Tech Mod program including the management costs, versus the current method in which management costs are funded through accounts which are not tied to any specific program. The cash inflows will include the projected or actual savings accruing to the Government from the implementation of a Tech Mod program. The return on investment rates for each program can be compared to the others to determine which programs offer a better return to the Government. This rate may also be used to ascertain the impact of management costs on the Government's return on investment.

The particular problem to be investigated is "what is the cost to the Air Force in terms of manpower in implementing Tech Mod (38)". Does the cost to the government of Tech Mod justify the benefits or savings in system acquisition costs? The method used by AFSC to determine savings does not take into account manhour costs of Air Force personnel who manage Tech Mod. It is this aspect that must be included to determine the "full-cost" of Tech Mod programs and is the focus of this study.

Research Objectives

Air Force Systems Command is currently involved in 49 different Tech Mod Programs, 34 of which are being conducted by Aeronautical Systems Division (ASD). Projected government investment in these programs is \$734.3 million of which \$670.2 million is to be spent by ASD alone. Projected savings from 21 of these ASD programs amounts to \$2025.2 million, the other seven program savings are yet to be determined (38).

This study will first identify those contractors involved in the ASD Technology Modernization programs along with their progress in the program. This identification will include the actual and projected costs and savings associated with each program.

The first objective of this research is to determine the "Air Force Management Cost" of each program.

Objective two is to determine the benefit/cost relationship of these programs taking into account the manpower expenditures of the Air Force.

The final objective is to determine the Government's return on investment for implementing each Tech Mod program under study.

Productivity Defined

Further discussion of productivity requires an understanding of what productivity actually is. In its simplest form, productivity may be expressed as a ratio of

the units of input required to create a given output. The input factors include land, labor (both direct and indirect), capital (in the form of equipment and facilities), monies, and management.

The Department of Defense (DOD) regulations define productivity as "the efficiency with which an organization utilizes its resources to provide final outputs." Air Force regulations provide a more expanded view of the term. Here productivity refers to both "efficiency" (the ratio of inputs to outputs) and "effectiveness" (to what extent the output satisfies mission objectives). According to the Air Force, it involves not only questions of quantity and cost, but also quality, timeliness, responsiveness, and readiness (8:403).

Improving productivity in DOD activities has become increasingly important to the Government Accounting Office and others because of (8:402):

an expanding defense budget that has brought louder and louder calls from members of Congress and the public for assurances that the additional defense funds be spent efficiently. Public announcements and comments by DOD officials on major efficiency and productivity initiatives they claim will save billions of dollars; and rising concern over the ability of the defense establishment to meet military needs.

Factors Affecting U.S. Productivity

In general, productivity growth is closely connected with the rate of capital formation. Capital investment forms a necessary part of increasing labor productivity since new plant and equipment often means newer, more productive

technology. As shown in Table II, the United States appears to have a low rate of gross investment as compared to the industrialized countries of Germany and Japan. (Of course, United States' industry was not devastated as were the industries of Germany and Japan at the close of World War II. In having to rebuild, Germany and Japan could be expected to increase productivity more rapidly than the United States with its already mature plants and facilities. As soon as Germany and Japan reach the level of maturity of the United States, one might also expect their productivity growth rate to slow.)

TABLE II

Gross Fixed Capital Formation
(as a percentage of gross domestic product)

	1960	1965	1970	1975	1980
United States	17.9	18.8	17.6	17.0	18.2
Japan	29.5	29.9	35.5	32.4	32.0
Germany	24.3	26.1	25.6	20.7	23.6

Source (10:27)

Firms may obtain funds for investment purposes from a variety of sources. These include retained earnings; depreciation expense (the recapture of previous investment for new investment); various types of borrowing, including

sale of bonds; and the sale of stock. Retained earnings and depreciation expense are sources of funds internal to the firm and the other sources are external to the firm (15:113). In 1982, the following were sources of capital investment funds for private non-financial firms (27:29):

- Individuals and Families - 28%
- Insurance Companies - 14%
- Foreign Investors - 14%
- Corporations - 12%
- Endowments and Foundations - 6%
- Pension Funds - 34%

Personal Savings.

According to Chase Econometrics, the percentage of personal disposable income devoted to savings in 1988 was 21 percent in Japan, 15.5 percent in France, 15 percent in Great Britain, 13 percent in West Germany, just over 10 percent in Canada and 5.6 percent in the United States (36:72,39:421).

A cause for the lower investment in capital in the U.S. may be that, as of 1979, the Commerce Department's estimate of the personal saving rate showed it had reached its lowest point in nearly three decades. At 3.3 cents for each dollar of after-tax income in the fourth quarter of 1979, the saving rate was less than half its average in the first half of the 1970s and well below the average of six cents of each dollar of income since World War II. Historically, the individual and family sector has been a major contributor to national savings available for capital formation (42:11).

In 1979, the lack of savings on the consumer side was not as much a concern for business as it might have been. Investment in plant and equipment as a share of GNP was fairly high due to the savings outside the private domestic sector. This increased money for investment was due to an over-all governmental surplus (with state and local surpluses more than exceeding the federal deficit) and funds from OPEC and other foreign investors accruing from their investment in private and U.S. Government securities. But since the federal government deficit has now become larger and in view also of the national objective of limiting oil imports, it may be more difficult for the business sector to find financing for its investment programs (42:14).

Inflation has pushed consumers into higher tax brackets so that the average citizen faces higher marginal tax rates than a decade ago. These higher marginal tax rates may have decreased the incentive to save and therefore, reduced the resources available for capital formation. The Economic Recovery Tax Act of 1981 is intended to decrease the severity of these problems. For example, starting in 1985, individual income tax brackets will be indexed to remove the effects of inflation that push taxpayers into higher tax brackets. This change should have an impact both on incentives to save and on productivity. The tax act has some specific incentive provisions aimed at increasing capital formation by business: the acceleration of their cost recovery allowances, the enhancement of the investment tax credit and an additional

tax credit for certain research and development costs (36:76).

Cost of Capital.

The cost of capital, which includes interest costs, has been blamed for lower investment rates. An increase in the cost of capital may be due to an overall lower savings rate. The "law of supply and demand" affects the monies available for investment; the lower amounts of monies available forces the interest rates charged for these monies to be higher. Therefore, companies find it more cost effective to use labor versus new capital equipment in the production of goods. This view is supported by the findings of Dr. George N. Hatsopoulos, the chairman and chief executive officer of Thermo Electron Corp. and a founding member of the American Business Conference, Inc.

Dr. Hatsopoulos' findings were that from 1961 to 1973, the cost of capital in the United States, which includes interest and related expenses, was about 15 percent a year adjusted for inflation. By 1983, the cost of capital rose to 20 percent. He believes the cost of capital has increased 20 percent more than the cost of labor since 1973, such that, "as capital becomes more costly relative to labor, firms tend to forego investments needed to boost labor productivity (41:86)."

Dr. Hatsopoulos suggests that a way to lower the cost of capital in the United States is to change tax policy by permitting corporations to make increased use of tax-favored

sources of financing. Examples are, treat dividends on preferred stock as tax-deductible interest payments so that corporations could issue stock in lieu of bank borrowing; or permit corporations to issue debt instruments with the rate of repayment based on the corporation's profitability (41:86).

Depreciation Expense.

The United States also appears to be at a disadvantage in the area of depreciation expense as a source of funds for capital investment. Governments in countries such as Canada, Japan, Great Britian, etc., allow up to 100 percent depreciation of new capital within the first two years. This, along with the price of capital may help to explain the high capital formation figures for Japan in Table II (48:31).

Theories on the Productivity Problem

As the following section will show, there are many theories as to the perceived productivity problem in the United States as well as many proposed solutions. A discussion of those that reflect the range of thought in productivity theory follows.

Even though United States productivity levels are still higher than those of other major industrial countries, the gap may be closing due to a decrease in United States productivity growth rates. In 1982-83, the Congressional Budget Office estimated that productivity in the United States was approximately ten percent ahead of productivity in

most European countries and even further ahead of the Japanese. The overall level of Japanese productivity in 1983 was about seventy percent of that in the United States. Three decades ago, United States productivity led that of its nearest European competitor by forty to fifty percent. But, that gap may be narrowing (36:69).

Japan has closed the productivity gap in key areas but the United States has the capability to regain its preeminence. Rates of productivity increases vary greatly in our economy and, in areas such as communications and agriculture, we continue to lead the world [39:421].

Benjamin B. Tregoe, Chairman of Kepner-Tregoe, Inc., specialists in organizational development and research, lists five causal factors for the decline in productivity. His first two factors deal with the relationship between management and the labor force as well as the cultural differences between U.S. and foreign firms. His third factor relates to the emergence of an immediate return on investment (ROI) as the main criterion of management. He believes that over the last 38 years, maximization of profit in the short term, with little thought to sustainability in the long run, has become the index by which organizations are judged (43:25).

His fourth factor was the advent of the business computer. Overnight, it was possible to obtain more numbers than had ever been available before. Managers spent more time with numerical reports than they did with the substance of the situation they were managing. The fifth factor is the

unprecedented good times that followed World War II. In the prosperity that followed the war, management practices that might otherwise have been questionable were adopted (43:26):

Responsibility for this (reduction in productivity) belongs not just to a set of external conditions but also to attitudes, preoccupations, and practices of American managers. By their preference for servicing existing markets rather than creating new ones and by their devotion to short-term returns and 'management by the numbers', many of them have effectively forsworn long-term technological superiority as a competitive weapon.

Capital Labor Ratio

While Mr. Tregoe contends that the decline in productivity growth is related to management practices, Mr. Roger B. Porter, a writer in the area of productivity, relates the decline to a lower capital to labor ratio. He states that from 1948 to 1968 the average annual rate of productivity growth in the United States was slightly over three percent. His studies indicate that this rate averaged slightly over two percent during the next five years and, since 1973, it has fallen to an average annual rate of increase of six-tenths of one percent. But, other industrial countries have also experienced declining productivity growth rates since 1973 (36:69). Mr. Porter feels that (36:70):

There is a general consensus among analysts that the single most important determinant of productivity per man hour is the quantity of capital per worker. Other things being equal, when the amount of capital grows more rapidly than the amount of labor, productivity increases.

According to Mr. Porter, during the last thirty years the ratio of the net stock of capital to labor, excluding capital

applied to environmental and pollution control, grew at an average rate of almost three percent during the 1948-68 period. This ratio declined during the next five-year period to 1.8 percent and since 1973 has declined even further to 0.7 of one percent. "Thus, an important cause in the slowdown in the rate of increase in productivity per man hour in the United States has been a dramatic decline in the rate of growth of capital per worker (36:69-70)."

While the capital to labor ratio is important, it is not the only determinant of productivity growth. Several features finding themselves on Mr. Porter's list include:

1. Lower investment in research and development;
2. Shifts in capital and labor from one sector of the economy to another (service sectors);
3. Increased natural resources costs, especially those related to energy;
4. The increased role of government, especially in the form of regulations such as those imposed by the Environmental Protection Agency and the Occupational Safety and Health Administration (36:71, 39:420).

Output Employee Ratio

Mr. Edward F. Denison's study of the causes for the decline in productivity growth, which follows, is lengthy; but covers a number of factors to explain the decline and is worthy of detailed discussion. Mr. Denison, who in 1979 was an Associate Director of the Bureau of Economic Analysis stated (11:1), "Growth of American productivity was rapid by

historical standards during most of the postwar period. But in the last half of the 1960's the rate began to slacken." He believes that prior to 1974, this slackening was partly due to short-term fluctuations in determinants of output that display irregular movements. A main determinant was a drop in the intensity of use of employed labor and capital from a peak reached in 1965-66. The transfer of surplus workers from farming to nonfarm jobs, in which they produced output of greater value, decreased as the supply of such labor decreased. Costs of regulations, that the Government felt had benefits greater than their costs, began to encroach upon productivity. According to Mr. Dennison, this characteristic of the productivity slowdown is not applicable to more recent years. The influences responsible for the productivity slowdown prior to 1974 were no longer sufficient to explain the shortfall from the earlier trend. The major productivity measurements - output per person employed, output per hour, and output per unit of input - showed much the same pattern of decreased growth (11:1).

Mr. Denison shows that the growth rate of output per person employed, in which productivity is measured, has declined from 1973 to 1979. He defines employment as the number of persons employed, full-time or part-time, during an average week.

In nonresidential business, national income per person employed (NIPPE) increased by an average of 2.4 percent a year from 1948 to 1973 - for a total increase of 82 percent.

TABLE III

National Income Per Person Employed in
Non-residential Business: Growth Rate and
Sources of Growth, 1948-73 and 1973-76

	1948-73	1973-76	Change
Growth Rate	2.78	-0.38	-3.16
Contributions to growth rate in percentage points			
Total factor input:			
Changes in workers' hours and attributes:			
Hours	-.24	-.54	-.30
Education	.52	.88	.36
Changes in capital and land per person employed:			
Inventories	.10	.02	-.08
Nonresidential structures and equipment	.29	.25	-.04
Land	-.04	-.03	.01
Output per unit of input: ¹			
Improved allocation of resources ²	.37	-.01	-.38
Changes in the legal and human environment ³	-.04	-.44	-.40
Economies of scale	.41	.24	-.17
Advances in knowledge and miscellaneous determinants ⁴	1.41	-.75	-2.16

¹Contributions to the growth rate shown in subsequent lines are restricted to effects upon output per unit of input.

²Includes only gains resulting from the reallocation of labor out of farming and out of self-employment and unpaid family labor in small nonfarm enterprises.

³Includes only the effects on output per unit of input of costs incurred to protect the physical environment and the safety and health of workers, and of costs of dishonesty and crime.

⁴Obtained as a residual.

Source (11:3)

It then dropped by a total of 5.6 percent from 1973 to 1975. From 1973-76 the growth rate was -0.5 percent a year. The analysis of growth sources upon which Mr. Denison drew was carried only to 1976. But he believes that slow productivity growth has characterized the entire period after 1973, continuing through, at least, 1979. In 1977 and 1978 NIPPE increased to its 1973 level, therefore, over the period from 1973 to 1978 its growth rate was zero. NIPPE in the first half of 1979 was below the 1973 and 1978 rate. From 1948 to 1973 the growth rate of NIPPE was 2.43 percent a year. The first column of Table III summarizes Mr. Denison's estimates of the sources of its growth in that period (11:1-2).

Per Mr. Denison's table, changes in average hours at work subtracted an estimated 0.24 percentage points from the growth rate in 1948-73. This is an estimate of the net effect of changes in average working hours upon the growth rate of output. It allows for the fact that labor is only one type of factor input, but it is the largest type. It also takes into account the probability that shorter hours for full-time workers have increased the work done in an hour by lessening fatigue and absenteeism, so that the percentage decline in labor input is less than that in hours (11:2).

Persons with different amounts of education are regarded as providing different amounts of labor input. Their work is weighted according to the average earning differential between persons who differ only with respect to amount of education. For example, a full-time worker with 4 years of

college is counted as 1.84 times as much labor as one with 8 years of elementary education. "The contribution of education measures the amount by which output per worker has been raised by the upswing in the educational background of employed persons (11:2)."

The contributions of capital and land do not reflect changes in their use. Instead, a single estimate is made of the effect upon output per unit of input of changes in the ways with which capital, land, and labor (as measured by hours at work) are utilized. Inventories and fixed capital both increased more than employment from 1948-73 as well as nonresidential structures and equipment. As employment increased, the land available per worker declined. Improved allocation of resources contributed an estimated 8.37 percentage points to the growth rate (11:3).

The legal and human environment in which business must operate has changed in several ways that may affect output per unit of input. Mr. Denison has estimated the effect of three of these changes. Governmental controls required business to divert from ordinary production to pollution control an increased share of the labor and capital that it employs, so that these resources are no longer available to produce measured output. OSHA has similarly diverted labor and capital to the protection of worker safety and health. Rising crime has forced business to divert resources to crime prevention, which has directly reduced measured output. According to Mr. Denison, these changes began towards the end

of the 1948-73 period. They are estimated to have subtracted only 0.04 percentage points from the growth rate over that entire period (11:3).

Gains from economies of scale refer to the rise in output per unit of input that is made by changes in the size of the markets that business serves. Economies of scale are estimated to have contributed 0.41 percentage points to the 1948-73 growth rate (11:3).

The contribution of advances in knowledge is a gage of the gains in measured output that result from the use of new knowledge applied to production - managerial and organizational as well as technological. The introduction of new final products provides the user with a greater range of choice or enables him to better meet his needs with the same use of resources, but it does not necessarily contribute to growth as measured; it results in "noneconomic" or "unmeasured" quality change. In general, only the advances in knowledge that reduce the unit costs of final products, already in existence, contribute to measured growth (11:4).

Mr. Denison concludes that (11:4) "important contributions to the growth of NIPPE in 1948-73 were made by advances in knowledge, increased education of employed persons, increased capital per worker, improved resource allocation, and economies of scale."

Technological Change

A small group of economists and engineers from the Massachusetts Institute of Technology, known as the "System

Dynamics Group", agree with Mr. Porter in that the lower investment in research and development has led to a decline in productivity growth. In 1982, they developed a theory that the driving force in the growth of an industrial society is technological change. They contend that innovations occur in groups and the economic growth that they start follows a long, cyclical path of 40 to 60 years. In their view, the industrialized countries are just entering the downside of that cycle (1:126).

These economists believe that the technologies of the traditional industries - autos, airplanes, steel, chemicals, and machinery - which produced the great boom of the 1950s and 1960s are now on the decline and that the new technologies that will generate the next boom are just beginning. These technologies - solar energy, biogenetics, the computer and electronics - have not shown their full impact on overall employment and economic growth (1:126).

To this group, the fact that new technologies have not yet created large new industries supports their conclusion that the U.S. has entered the downswing of a long technological wave. This downswing will end, they say, only when the U.S. reduces its dependence on today's smokestack industries and makes a major leap to the new ones (1:126).

The System Dynamics Group believes that long waves of economic growth are like a law of nature and cannot be changed by government intervention. Therefore, the government should leave the market alone, except for such

steps as cutting the capital gains tax to encourage new capital and using tax incentives to encourage labor to leave old industries and retrain for new ones (1:126).

The idea that an industrial economy goes through long waves of growth and decline was first advanced by the Russian economist Nikolai D. Kondratieff. He saw 40 to 60 year waves going as far back as 1790. When he proposed his long-wave theory in 1922, he said that the latest peak occurred around 1920. So, according to the Kondratieff idea, economic activity should have peaked again around 1970. Kondratieff, however, offered no theory to support his findings (1:126).

The System Dynamics Group believed that it could explain Kondratieff's waves. Their basic proposal is that industrial economies tend to overinvest in existing technologies, especially in capital goods industries, and that excessive investment leads to their decline when demand fades. They claimed that the latest wave of over-investment began in the 1960s. As evidence, they point to worldwide overcapacity in steel, autos, diesel engines, chemicals, shipbuilding, machine tools, and even semiconductors (1:126-127).

The nation has spent the past 25 years building up a huge investment in industries - steel, machine tools, cement, glass - needed to produce cars and the many other products they helped create. The group believes as the auto industry's economic influence diminishes, much of this investment will be unusable. The decline in capacity utilization is shown in Table IV. Capacity utilization

reached its peak in the late 1960s. Today, it is about 43% in steel and 63% in nonelectrical machinery (1:127).

TABLE IV

Factory Capacity Utilization and Investment
in Plant and Equipment

Capacity Utilization								
'65	'67	'69	'71	'73	'75	'77	'79	'81
89%	87%	86%	78%	87%	73%	82%	86%	78%
Investment in Plant and Equipment (Average Annual Rate of Growth)								
1958-59			1968-69		1978-79		1988-82	
+4.0%			+5.2%		+4.0%		-1.0%	

Source (1:126)

The System Dynamics Group says that the productivity of capital peaked by the mid-1960s and subsequent increases in output from additional capital investment have experienced diminishing returns. Jay W. Forrester, professor of management at MIT's Sloan School of Management and director of the group stated (1:127), "By the time the late stages of expansion have been reached, the folklore has taken firm root that more capital plant is expected to increase productivity. In fact, however, capital plant has reached the point of diminishing returns."

As the group sees it, the recent decline in capital investment is not a sign of a need for more capital. More capital investment is not going to bring large payoffs if this capital is invested in the wrong industries.

The MIT group has some critics. Harvard University's Dale W. Jorgenson contends that if there were excessive investment, it should show up in declining returns on investment. Dr. Jorgenson and Barbara M. Fraumeni, an economist at Tufts University, attempted to calculate the actual returns on U.S. investment in the postwar period. Their figures show that, overall, the financial return which increased investment has produced has generally been stable; therefore, growth has continued to increase. There was a higher return in the late 1960s, but Dr. Jorgenson explains this as the result of the Kennedy-Johnson tax cuts. Nobel Laureate Wassily Leontief stated (1:130), "It is most implausible that over 200 years a periodicity exists. The whole structure of the economy changes." Another problem with Kondratieff cycles is the vagueness of their dating. Even those who believe in the long wave theory differ in how they measure it (1:130).

Mr. John W. Kendrick believes that three new constraints have developed in the recent past which have affected production methods in manufacturing and thus, productivity growth: (1) increases in energy prices and interruptions in supplies of specific fuels; (2) fixed time schedules of requirements for water, air, and land pollution control; and

(3) fixed time schedules of requirements under the Occupational Safety and Health Act (OSHA). "While, constraints such as these are not entirely new, their strength, severity, and nearly simultaneous occurrence make the outcome on production patterns, and thus on productivity change, highly uncertain (29:463)."

One way in which productivity change can be affected is by a diversion of real investment from productivity-enhancing capital additions and replacements to uses that are neutral or even negative in their productivity effects. Examples are "add-on" investments to reduce heat loss, convert to other fuels, reduce discharge of pollutants, and reduce safety and health hazards to workers. But since the adjustment to these types of constraints may mean the adoption of new production technology, the result may be more rapid capital turnover with the possible net effect of accelerated productivity growth (29:463).

In Mr. Kendrick's view, a sudden and unexpected change in the relative price of energy may accelerate the obsolescence of existing plants, and their replacement with new plants might increase productivity. The requirements of pollution abatement and OSHA may also accelerate obsolescence for a similar reason. The new weighted price of outputs should be taken into account (29:502).

Technological Diffusion

Another theory to increase productivity was proposed by George R. Heaton of M.I.T. and J. Herbert Holloman of Boston

University. They believe there needs to be an increased diffusion of technology in the United States and Government policies have allowed R & D expenditures to overshadow diffusion-oriented programs. These gentlemen use U.S. Department of Labor statistics to show that during the 1960s, the "best" firms in various industries were about 2.4 times more productive than the "worst" firms and that recent data indicates the gap has widened (productivity being measured by the value added to products per employee). They feel that "while not a route to dramatic breakthroughs, technical diffusion is an important, relatively low-cost way for the U.S. to improve productivity (26:12)."

Heaton and Holloman believe the Government can play a role in technological diffusion. For example, Federal environmental standards are often based on the pollution-control procedures of "leading firms" which are spread through the industry by regulation. Even though the government can help, they feel diffusion of technology is essentially up to private enterprise. Their suggestion is to form groups comprised of personnel from different companies to discuss and share new technological processes (26:13-14).

GAO Findings on Productivity in the Defense Industry

A reduced productivity growth rate implies that the cost per unit of production may increase. In November of 1979, the General Accounting Office (GAO) presented a report to Congress on what they believed were the major effects on

costs of procuring Defense weapon systems. After several years of study, the GAO concluded that the major effects on costs, which are interrelated to the theories on the slowed productivity growth rate, have resulted from:

- Attempts to deploy systems with new technology and high performance;

- Low rates of production due to budget constraints;

- Absence of price competition between contractors;

- Lack of motivation on the part of contractors to reduce costs;

- Impact of socioeconomic programs, Government controls, and paperwork; and

A nationwide problem of reduced research and development expenditures (20:i).

Of the above list, the GAO feels the principal factors that tend to drive costs higher are the desire for high-technology systems and the budget constraints that lead to uneconomical procurement and production practices (20:ii).

GAO reported that some of the unidentified contractors they studied did not believe that an increase in profits, based on facilities employed, would provide the motivation necessary for contractors to make capital investments. The contractors felt that program stability (some guarantee that investments could be recovered) was more important than a slight increase in profits (20:iii).

The military places its emphasis on the procurement of technically superior weapons to ensure that they will

outperform the enemy's weapons in combat. DOD hopes that superior performance will counter the numerical advantage of the Soviets. Along with this is DOD's desire to bring improved weapons to operational status as quickly as possible to meet known or suspected enemy weapon's growth and advances.

Weapon operational performance and delivery performance seem to be paramount to DOD program managers and directors. If these DOD priorities are made clear to a contractor, and GAO believes they are, then the contractor may have reason to rank productivity improvement and cost reduction as subordinate objectives (20:7-8).

The high-technology policy is a major factor to cost. The perceived need for greater capability based upon the perceived threat, means complex electronics, avionics, fire control systems, etc., are needed to defend against that threat; and this, in turn, keeps driving up the cost of acquiring weapon systems (20:8).

Commercial production volume can be set at optimum rates by company management based on production efficiency and market analysis. However, production rates of military weapons are indirectly dictated by constraints set by Congress, Office of Management and Budget, or the Office of the Secretary of Defense. Major weapon systems are subject to annual review by Congress and may be revised several times. Also, Congress or DOD may dictate that production of an item be stretched out at a low rate to ensure that a surge

capability is available in the event or threat of war (20:11).

The production of new weapon systems may also be established at an uneconomical rate, because the item is undergoing concurrent development and production, which means that a limited production rate must be maintained until the item has been fully tested and proven effective. The weapon system may also be produced at a limited rate because there are not sufficient funds available in the DOD budget to produce a greater number in a given year. GAO believes that whatever the reason for producing below the optimum rate, the effect is a loss of productivity and an increase in the cost of the system (20:11).

Another factor GAO believes is affecting the cost of Government procurement is the information needs of the Government to plan and manage Federal programs. The Commission on Federal Paperwork found that all American business spends \$25 billion to \$32 billion each year on Federal paperwork; the 10,000 largest firms spend an average of over \$1,000,000 each on Federal paperwork; and five million small businesses spend an average of over \$3,000 each. These amounts are added to the contract costs that the Government must pay to obtain weapon systems (20:20-21).

II. Productivity and the Defense Industry

The defense industry encompasses an extensive network of prime contractors, subcontractors, suppliers, and vendors interwoven into a complex market structure (23:13). Companies within the defense industrial complex constantly face financial, technological, marketing and political barriers which hinder free entry and/or exit from the defense market place and sometimes drive smaller firms out of business (19:46).

Productivity problems and solutions in the different segments of industry vary. However, a significant portion of manufacturing done on defense programs occurs in a labor intensive, versus capital intensive, environment (37:135).

Overall, manufacturing represents the largest single segment of the nation's GNP - almost 38 percent. DOD is the largest buyer of goods and services in the nation; thus, DOD through its manufacturing technology program not only attempts to improve productivity and reduce the cost of its weapon systems, but also tries to make a major impact on the productivity of a large segment of the total U.S. economy (32:70).

In Defense, two problems have been cited most frequently as inhibiting modernization and progress in the productivity area. These are program uncertainties and a profit policy which is based on cost. In the first instance risks are

introduced which hinder the recapture of investment and inhibit long-term planning. In the case of our cost-based profit policy, a contractor may actually see his overall profit picture reduced as a result of efforts to improve productivity which lead to reduced costs (37:135). The percentage of profit obtained on a contract may remain intact but, the actual profit dollars are lowered before an adequate return on the investment can be realized.

Relationship of Profit to Productivity

All government contracts require some kind of analysis of pricing, whether the method employed be a price analysis or a cost analysis, to assure that the government pays a fair and reasonable price for timely delivery of the desired quantity of required supplies and services. A price analysis involves looking at the total price (cost plus profit) of an item without the analysis of individual elements of cost. This type of analysis is employed on the majority of firm fixed price contracts where there is adequate competition; catalog, market or regulated prices; prior quotations; rough yardstick and/or parametric relationships have been developed; and, independent estimates exists. These prices are compared to prices submitted by the contractor to determine the fairness and reasonableness of the contractor's quote.

A cost analysis involves looking at the individual elements of cost; labor, material, indirect costs and profit to determine whether the elements of cost are necessary and

then whether they are fair and reasonable. The analysis is conducted on the cost and pricing data submitted by the contractor. These data include (a) vendor quotations; (b) nonrecurring costs; (c) information on changes in production methods or purchasing volume; (d) data supporting projections of business prospects and objectives and related operations costs; (e) unit-cost trends such as those associated with labor efficiency; (f) make-or-buy decisions; (g) estimated resources to attain business goals; and (h) information on management decisions that could have a bearing on costs (46:sec 15.801). Submission of cost and pricing data is made in accordance with the provisions of the Defense Acquisition Regulation (DAR) and the new Federal Acquisition Regulation (FAR) (46:sec. 15.804-2).

Although the government considers profit to be an element of cost, it is not subject to the same scrutiny placed on the other elements of cost in the contract. After the analysis of the cost and pricing data, the contracting officer "shall use the Government prenegotiation cost objective amounts as the basis for calculating the profit or fee prenegotiation objective" using a "structured approach except as specifically exempted under the agency's procedures (46:sec 15.903)." One such structured approach is the Weighted Guidelines Method for computing the profit rate.

On 13 May 1975, the Deputy Secretary of Defense initiated a major DOD study of profit and its relationship to capital investment and increased productivity. This study, known as

Profit '76, focused on the difference between profit statistics of defense contractors and durable goods producers between the years of 1970 and 1974. The findings of this study identified a strong correlation between the then existing DOD profit policy and low levels of capital investment within the defense industry. During this time, durable goods producers realized a profit before taxes, based on sales, of 6.7 percent; whereas, defense contractors were realizing a 4.7 percent average (4:6). [While Profit '76 focused on the difference in profits between durable goods producers and defense contractors, the study used return on sales as its basis versus return on investment. However, return on investment is the true gage of profit earned from the use of capital and is typically the index used by investors as a basis for investment. Anticipated return on investment is used by firms in deciding whether to make further investment. Since the majority of defense contractors are publicly owned, return on investment is a more suitable method to determine the profitability and investment risk associated with a durable goods producer.]

As a result of Profit '76, DOD undertook several policy revisions with the long-range goal of achieving increased productivity. Some of the major revisions include (4:xii):

The emphasis on Contract Cost Risk was increased from 30 percent to 40 percent of profit. In general, the relative profit range on fixed-price type contracts was increased.

A new factor, contractor investment in facilities capital, was added to the Weighted

Guidelines and represented 10 percent of profit.

The implicit recognition of cost of money on facilities capital was removed as a contract cost under Cost Accounting Standard 414.

A Special Productivity Factor was added to the Weighted Guidelines to return the lost profit opportunity caused by productivity increases which lower the cost base.

In 1982, AFSC conducted a similar study to determine if the desired goals of the revised profit policy were achieved. The specific objectives of AFSC's Profit Study '82 were to determine if the profit policy had: 1) stimulated investment in contractor facilities, 2) rewarded productivity improvements, 3) fostered a reasonable level of interest in defense contracts, and 4) been understood by government and industry (4:xi).

The impetus behind the revised policy changes of 1976 was that an increased return on sales (profit) would stimulate capital investment (4:13). The 1982 study indicated that negotiated profits on AFSC contracts had risen from 8.8 percent in 1974 to an average of 10.6 percent in 1981 (4:15). But, the increase was not due to the change in profit policies. Instead, increased profits were traceable to a number of items: contract cost mix, contract type mix, applied Weighted Guideline factors, capital employed, Treasury Rate, and special profit (4:20).

To identify the relationship between profit and capital investment, the Profit '82 study revealed that capital investment within the defense industry had increased since

the 1976 study. Statistics published by the Aerospace Industries Association in the book Aerospace Facts and Figures 1982/1983 revealed that investment in new plant and equipment had increased in a number of industry segments. These increases are shown in Table V. But, in the Profit '82 study, a significant correlation was established between increased capital investment and the increased sales base of the contractors studied. As a percentage of sales in 1979 and 1981, capital expenditures of defense segments were four percent while the commercial segment approximated seven percent, thus raising doubts concerning the relationship between the revised profit policy and capital investment in the defense industry (4:35).

TABLE V
New Plant and Equipment Expenditures
1977-1982
(\$ billions)

	1977	1978	1979	1980	1981	Est. 1982
Nonfarm						
Business	\$198.1	\$231.2	\$270.5	\$295.6	\$321.5	\$345.1
All Manu-						
facturing	69.2	79.7	98.7	115.8	126.8	136.8
Durable Goods	34.8	40.4	51.1	58.9	61.8	67.2
Aerospace	2.0	3.2	5.3	7.0	6.4	7.3

Source (4:33)

An additional item, incorporated in the Weighted Guidelines Method of computing profit rates, was the "special productivity factor". This factor was intended to remove a major disincentive for productivity enhancements by the defense industry - lost profits. The Profit '82 study indicated that this factor was not used except in a few cases. The reason for its disuse is in its practical application, the problem being in the difficulty of measuring productivity. Other problems include the application of this factor in the instant contract, even though the productivity increase would provide benefits well into the future. Furthermore, based on answers received in the survey of industries, contractors do not perceive a genuine interest by the Government to use the factor (4:48).

Other indications from the above mentioned survey show that contractors perceive the Government profit/fee objective as being dictated by management, regardless of the Weighted Guidelines computation, and that the contracting officer assigns weights to "back into" that profit objective (4:51).

Profit and Capital Investment

A major finding reported in the Profit '82 study was that profit, by itself, will not induce capital investment. The greatest concern to industry is to fully recover capital investment, including a reasonable return, such that other programs with a direct stimulus on capital investment must be undertaken (4:53).

Perhaps the main reason profits, in and of themselves, do not induce capital investment is the emphasis the government, as well as the contractor, has put on one definition of profits - "the sum remaining after all costs, direct and indirect are deducted from an income of a business (25:1135)." In this sense, only one aspect of profitability - the return on sales - is being considered.

A second measure of profitability, more commonly used by lenders and investors, defines profits as a financial or monetary gain obtained from the use of capital in a series of transactions; the ratio of this to the amount of capital invested; and the proceeds from property or investments (25:1135).

Utilizing this definition, the profitability of a firm can be determined through its use of any aspect of capital assets - labor, equipment, etc. Therefore, the return on investment, the original investment plus gains realized over and above this investment, is a major indication of the profitability of a firm.

As shown in Table I (page 3), the return on stockholder's equity (investment) is appreciably higher than the 4.7 percent return on sales from the Profit '76 study. Return on investment for aerospace companies is relatively high due to the labor intensive methods used in producing aircraft and aircraft components. Since labor is part of total capital, capital turnover is faster, creating a higher return on investment. Other things being equal, investors (both public

and private) wish to maximize their return on investment; that is, receive the greatest future benefit for the least cost (40:912).

Alternatives for inducing capital investment, in the form of equipment versus labor, have been suggested and some implemented. These alternatives include multiyear contracting, improved contractor financing, capital investment indemnification, etc. Tech Mod has also been identified as a major inducement for capital investment. These programs are consistent with the opinions expressed in the Profit '82 survey where 73 percent of those surveyed believed that profit policy inducements are effective only if combined with other incentives versus 10 percent who did not (4:40).

Productivity and Cost Incentive Programs

Other than the Tech Mod program, procurement procedures and practices aimed at improving contractor productivity and reducing costs have been introduced. Three of these procedures; Multiyear Procurement, Should Cost and the Cost Accounting Standards will be discussed. This discussion provides further background information in the area of Government efforts to increase productivity and to reduce costs.

Multiyear Procurement is geared towards reducing the perceived contractors' fear of program cancellation before the investment is recaptured and an adequate return on investment is realized. Should Cost studies seek to point

out procedures that could be implemented by a contractor to reduce cost. This differs from Tech Mod in that the contractor, after the Should Cost analysis, receives recommendations for reducing cost and increasing efficiency, but, no monies are received by the contractor from the Government for investment purposes. Cost Accounting Standards have been introduced which are specifically aimed towards contractor investment in capital equipment.

Multiyear Procurement.

The nature of the weapon systems acquisition process tends to slow productivity advancements. The 7- to 12-year program acquisition cycle for major systems may appear to give a contractor time to make long-term plans for capital investment and improvement. Actually, the acquisition process has the opposite effect due to the instability created by the single-year contracting and funding methods used by the Government (23:12).

Multiyear procurement describes situations in which the Government initiates contracts, to some degree, for more than the current year's requirement. Multiyear contracts have been used to acquire specific items or services needed on a repetitive basis since the early 1960's (23:4-5).

Multiyear procurement for weapon systems was developed to counteract short-term planning and increase Government contractor's long-term investment planning. The 1982 DOD Authorization Act (Public Law 97-86, dated 1 December 1981) gave Congressional support for the use of multiyear

procurement. The Act provides for (1) use of multiyear procurement on major systems acquisitions; (2) use of advance procurements to obtain economic lot prices; and (3) an increase in the contract cancellation ceiling from \$5 million to \$100 million (23:19).

One proposed advantage of multiyear procurement is cost savings estimated to be between 10 and 20 percent of unit procurement costs, resulting from the contractor's ability to predict future program needs. This advantage should allow the contractor to plan material and component purchases to take advantage of economic order quantities (which they are reluctant to do under single-year procurement practices). A second anticipated advantage of multiyear procurement is to encourage the contractor to invest and then possibly to recoup start up and capital investment costs over a three- to five-year period versus a single year. The third advantage hoped for is that the program will create stability which would attract more businesses to the defense industry thus stimulating competition and reducing acquisition costs (23:21-23).

There appears to be a disadvantage to multiyear procurement; the commitment by the Government to purchase a specified number of end items over a three- to five-year period. This gives the contractor the authority to purchase materials and components in economic lots before they are actually needed. If the Government requirements change drastically during the life of the program (perhaps due to a

change in the perceived threat), the Government may be faced with increased costs, delays in delivery schedules, or cancellation costs associated with termination of the contract (23:24).

Should Cost. (13)

Another approach used in the efforts for controlling the rising cost of weapon systems is the "Should Cost" concept. Should Cost is directed more towards the analysis of contract costs versus increasing productivity. The implementation of the Should Cost team's findings are the contractor's responsibility.

The Should Cost concept for purchasing weapon systems at the best possible price was not a new idea; the analysis of each line item cost is an essential element in the overall negotiation of any Government contract. What was new was carrying out the concept by using special teams of highly qualified individuals to perform an indepth analysis of all phases of a contractors operations. The Air Force developed the following definition of Should Cost:

A technique of contract pricing that employs an integrated team of Government acquisition, contract administration, audit and engineering representatives to conduct a coordinated, indepth cost analysis at the contractor's or subcontractor's plants. The objective is to identify uneconomical or inefficient practices in the contractor's management and operations and to quantify the findings in terms of their impact on cost. The result is the development of a realistic price objective that reflects reasonably achievable economies and efficiencies.

Should Cost studies are directed mainly towards sole source contractors where the procurement value is in excess of \$10 million; histories of increasing costs exist; and the procurement action involves major, on-going programs. The objective of a Should Cost study is to identify and challenge uneconomical practices in the contractor's management and operations; to quantify the findings in terms of cost impact in establishing the Government negotiation objective; and to establish a program for eliminating such practices in the future.

Should cost studies generate meaningful results only in selected instances. The Air Force encourages that Should Cost be used only for contracts where the dollar value and other contracting factors are such that the payoff from an in-depth analysis, in terms of improved contractor operations and more realistic prices, is likely to significantly outweigh the time, effort and cost involved in conducting the review.

Cost Accounting Standards.

On 1 July 1968, the General Accounting Office (GAO) studied the feasibility of using uniform cost accounting standards (CAS) in the negotiation of defense procurements amounting to \$100,000 or more. The purpose was to lower contract costs.

The fact is that a contractor's cost estimate plays an important role in the establishment of the negotiated procurement price, and the cost of any specific order can

only be accurately measured through the operation of consistent cost accounting practices (14:1). On the basis of the GAO study, Congress passed Public Law 91-379 in August 1970 creating a board to promulgate uniform cost accounting standards applicable to negotiated defense contracts (14:3).

Two cost accounting standards that weigh heavily in any investment decision are CAS 409, "Depreciation of Tangible Capital Assets" and CAS 414, "Cost of Money as an Element of the Cost of Facilities Capital." The intention of these standards is to allow a contractor to obtain a fair rate of return for his investments, not necessarily to encourage capital investment. CAS 409, which became effective on 1 July 1975, allows recovery of depreciation expenses based on estimated actual service lives of capital equipment. It does not allow use of accelerated depreciation methods such as the Accelerated Cost Recovery System.

Depreciation Methods (CAS 409).

The intent behind rapid depreciation allowances is to encourage modernization of plants and equipment; the allowances are likely to do so, but not if interest rates remain high. Under the new law, both accelerated and straight line depreciation offer substantial encouragement to invest in plant and equipment. Moreover, rehabilitation credits offer companies the option of modernizing old plants, if that alternative seems more preferable (2:44).

One initiative designed to spur capital investment is the proposed reform of national policies on depreciation of

capital assets, deemed necessary because existing policies are believed to have discouraged the defense industry from modernizing manufacturing facilities and equipment. In support of such reforms, the Deputy Secretary of Defense instructed DOD's general council (48:49):

General Council should support legislative initiatives to permit more rapid capital equipment depreciation and to recognize replacement depreciation costs by amending or repealing Cost Accounting Standard 409, depreciation of tangible capital assets.

The Financial Accounting Standards Board (FASB), the Internal Revenue Service (IRS), and the Cost Accounting Standards (CAS) Board are the three principle regulators who establish depreciation rules (48:30). The CAS Boards requirements on depreciation, as stated in CAS 409, parallel those of the FASB in both principle and practice (48:31):

The method of depreciation used for financial accounting purposes shall be used for contract costing unless i) such method does not reasonably reflect the expected consumption of services for the tangible capital assets to which applied or; ii) the method is unacceptable for federal income tax purposes.

Over the years, the intent of various changes to the IRS code, such as optional depreciation methods and the investment tax credit, has been to encourage capital investment. Although the direction of these changes was appropriate, their relative impact on producing much needed capital investment has been minimal. Dr. Allen E. Puckett, Chairman of the Board, Hughes Aircraft Company, summarized his views on the problems of inflation and inadequate tax laws as

follows (48:31):

With inflation, current tax provisions no longer provide the incentives needed to spur economic growth. The tax benefits resulting from accelerated depreciation and tax credits now in effect are insufficient in terms of reinvestment.

Those countries which have shown increased capital investment and productivity have also pursued taxation policies designed to stimulate capital investment. Switzerland allows a depreciation rate of 50-80 percent in the first year for machinery; the United Kingdom allows 100 percent; Japan 95 percent; and Canada 100 percent over the first two years. Until recently, the United States had not come close to providing comparable incentives (48:31).

In an effort to improve incentives for capital investment in this country, lawmakers in the Congress have enacted a number of tax reforms. One such reform is the Economic Recovery Tax Act (ERTA) of 1981, known as the 10-5-3 Bill, which greatly increases the minimum depreciation life required by the Internal Revenue Code for tax purposes. The 10-5-3 refers to the bill's shortened depreciation periods for plant and facilities, equipment, and vehicles - 10, 5, and 3 years respectively. The ERTA of 1981 stipulates that assets qualifying for the 5 year write-off be depreciated as follows: 20 percent the first year, 32 percent the second year, 24 percent the third, 16 percent the fourth, and 8 percent the fifth year (48:32).

DOD has not supported the proposal for using 10-5-3 depreciation in pricing defense contracts. Instead, it has

proposed use of replacement cost depreciation, under which the annual charges are adjusted upward, based upon an index, to compensate for the amount of inflation incurred during the year (48:33).

Some in industry and government have criticized the CAS Board principally because they believe that its Standard 489 mandates use of straight line depreciation without regard to the impact of inflation or replacement costs. They argue that the board has inhibited capital investment by rigidly adhering to old, outmoded accounting conventions of the FASB (48:32).

Industry normally sets aside cash amounts equal to the annual depreciation charge on an asset in order to accumulate the funds needed for its eventual replacement. However, CAS 489 directly affects both the timing and the amount of DOD reimbursements to defense contractors for depreciation costs, and critics believe that it creates insufficient funds for replacing old assets. The shortfall in accumulated funds results because inflation erodes the value of total depreciation charges, which are actually worth much less in terms of real value than the amounts reflected under accounting procedures (48:33).

Of the 29 witnesses who testified before the Defense Industrial Base Panel, none addressed the underlying rationale for either standard 489 or the actions of the CAS Board in general. "Those who have objected to the standard have furnished little hard evidence of a direct cause effect

relationship between low capital investment and the board's regulations on depreciation (48:33)."

Industry and government have erroneously insisted that CAS 489 is a straight line depreciation policy. Most defense industries actually use accelerated depreciation rather than straight line depreciation for pricing defense contracts. A survey of the CAS disclosure statements filed by the top eight aerospace corporations revealed that all but one used some form of accelerated depreciation for cost, tax, and financial accounting purposes. "Contrary to some testimonies offered at the Defense Industrial Base Panel hearings, seven of these corporations use exactly the same method of depreciation for cost and financial accounting (48:33)."

Cost of Money (CAS 414).

CAS 414, which went into effect on October 1, 1976, results in reimbursement to a contractor on an interest-type basis for the undepreciated book value of his facilities. It is an imputed cost rather than an actual cost so as not to penalize a contractor who has financed purchases of facilities or equipment himself rather than obtaining loans for this purpose. Traditionally, costs of this nature have been recovered as an element of profit rather than as an element of cost. DOD profit policies were adjusted due to this allowance (37:141).

In promulgating its standard 414, "Cost of Money as an Element of the Cost of Facilities Capital", the CAS Board has provided a measure of relief from inflation. Under that

standard, defense contractors are annually reimbursed an amount equal to an asset's average undepreciated balance multiplied by the Treasury rate as published by the Secretary of the Treasury. The Board selected this approach for dealing with the problem of inflation because it found a strong correlation between interest rates and the rates of inflation; also, the board believed it was simple to administer (48:34).

Suggested Alternatives for CAS 409 and 414.

Coupled with depreciation reimbursements under CAS 409, the amounts contractors receive for cost of money under standard 414 provide nearly the same total result in real terms as would be obtained if the asset were written off in the first year of use (48:34).

Alternatives to revision or repeal of Standard 409 are available, however, and a program responsive to the problems of the defense industry might include the following measures. 1) A restructuring of DOD's profit policy to give more profit to those contractors who actually make capital investments that are used in the performance of defense contracts. The profit increment should be significantly tangible and visible to establish a direct relationship between reward and investment. 2) Adopting a cost accounting policy which insures that contractors are not forced by government auditors and contracting officers to use straight line depreciation on the basis of an overly narrow interpretation of CAS 409. Greater leeway should be given to defense

contractors who want to use generally accepted methods of accelerated depreciation. 3) Encouraging defense industries to make greater use of loans provided for under Title III of the Defense Production Act. More loan funds should be made available for use in making the capital investments needed to modernize the defense industry (48:34).

Profitability and Productivity

While the stated goals of Multiyear Procurement, Should Cost and CAS are reducing costs and increasing productivity; the underlying attempt of these programs is to expand the definition of profits to that espoused by investors and lenders - the ability of a firm to realize a return on all aspects of capital. Profit, in the form of monies remaining after all expenses have been paid, is one indication of a firm's well being. Profit in the form of experienced gains over original capital investments is another. Without consideration of this aspect of the profitability picture, the productivity of any industry cannot be increased. Investors and lenders will discontinue their practices with a firm if they cannot realize an adequate return on their investment.

The need to increase national productivity has justifiably been proclaimed the challenge of the 80s. In recent years we have witnessed the eclipse of the once dominant U.S. automotive, steel and consumer electronics industries by their more productive foreign counterparts. Those industries where the U.S. still retains an edge--aerospace, semiconductors, computers--have become the new targets of foreign competition [5:1].

Solving the productivity problem extends beyond the reach of AFSC, the Air Force and the Department of Defense. But, being a major buyer of goods and services within the U.S., DOD believes the productivity problem has received enough attention to warrant the establishment of an organization to work this problem, The Office for Industrial Productivity.

Office for Industrial Productivity

In 1982, Under Secretary of Defense for Research and Engineering Dr. Richard D. Delauer established an Office for Industrial Productivity in the Pentagon to stimulate increased efficiencies and productivity throughout the defense industry. The Directorate is composed of Director, Industrial Resources; Director, Standardization and Acquisition Support; and Director, Industrial Productivity; all under the Assistant Deputy Under Secretary of Defense (3:119-120).

The primary role of the Industrial Productivity Directorate is to foster increased production efficiencies and productivity of the defense sector of U.S. industry. The Directorate serves as an advocate of tax policies, capital investment incentives, government regulations, and legislative initiatives to promote productivity or reduce impediments to a more productive defense industry (3:121). Emphasis in the policy area will be on Department of Defense acquisition strategies, source selection criteria, and contract incentives. The Directorate will also examine

acquisition strategies, source selection criteria, and contract incentives employed on particular programs from the standpoint of assessing overall policy implementation by the Military Services relating to productivity.

To enable the Office of Industrial Productivity to carry out its role, the Industrial Modernization Incentives Program was initiated.

The objective of the Industrial Modernization Incentives Program (IMIP), is to develop, test, and refine contract incentives encouraging industry to make productivity enhancing capital investments. Incentives include shared savings rewards and contractor investment protection. Other incentives, such as award fees, are permissible but have as yet received less attention (38:135). A major aspect of IMIP is Technology Modernization (Tech Mod).

III. Technology Modernization Program

A General Approach

Tech Mod was accepted by the Air Force in 1977 when General Dynamics developed a long-range plan for technology and facility modernization to produce the F-16. It formed the framework for future cooperation between the Air Force and contractors to improve productivity and lower acquisition costs. As the idea matured, investments and incentives were defined and shared risk/benefit goals were developed. Currently, each Product Division in AFSC is involved in some form of Tech Mod with their respective contractors (5:3).

There are three phases to a Tech Mod Program; factory analysis, development of technologies, and implementation of the approved technologies. The conclusion of a "business deal" provides the transition from Phase I to Phases II and III (5:1).

The factory analysis is conducted to determine the needs of the facility and the modernization programs that might apply to the systems being produced in the facility. Phase I identifies two areas for productivity improvement. The first is investment in off-the-shelf, state-of-the-art improvements that create immediate productivity advances. The second is technology advances that require additional development and investment. These areas, with their required investments, are weighed during the business deal.

The business deal is a transition mechanism between Phase I and Phases II and III. It determines the ground rules for the Phase II and III contract. During the business deal, the Air Force and the contractor define what they hope to achieve and evaluate opportunities for technical and economic value. Items considered during the business deal include:

Scope of the Tech Mod - Whether the factory as a whole or select areas will be upgraded, the ultimate goal is to upgrade the entire factory.

Business Base - The Tech Mod will include one large program or more than one program.

Mutual Investments - The levels of investment by the Government and the contractor are determined by the needs and objectives of each Tech Mod.

Technology Selection - Of the technologies identified during Phase I, select the ones offering better alternatives in terms of feasibility, return on investment, and risk.

Hurdle Rates - Define an acceptable return on investment rate. These rates are negotiable, but must be defined upfront.

Schedules - Define the technologies needing development and their implementation date.

Incentives and Other Provisions - Negotiate awards or penalties for scheduled implementation progress and how the "savings" from the new technologies will be shared.

Phase II of the Tech Mod Program is concerned with the development of the technologies, design, and building of the

factory modernization improvements. Phase II also identifies implementation plans, hardware/software requirements and confirms specific applications through method demonstrations.

Actual implementation of the technologies occurs during Phase III of the program. This phase includes the purchase and set-up of the equipment identified as having the greatest potential payback.

Typical funding for a Tech Mod is a joint Air Force/contractor venture. The Air Force supports the majority of the Phase I and II funds ("seed money") and the contractor funds capital equipment for Phase III. Some contractors have completed Phase I on their own; others, the entire Tech Mod in return for incentive contracts to obtain an acceptable return on investment (5:4).

A major factor in a Tech Mod Program is the creation of an arrangement that supports an acceptable payback to the Air Force and the contractor. Any savings over and above the initial investment is justification for a Tech Mod on a known program. Also to be considered would be benefits to other programs the contractor is working on and future benefits to new programs (5:6).

New Technologies Being Employed

Of the new technologies available, there are only a few of which the defense industry has taken advantage. Many of these technologies were developed by the Air Force in conjunction with the work being conducted at the Air Force

Materials Laboratory under the guise of the ManTech (Manufacturing Technology) Program. These technologies were begun with the advent of Numeric Control in the late 1950s.

Numeric Control.

Numeric Control (NC) is a form of programable automation in which the manufacturing process is controlled by numbers, letters, and symbols. With NC, the numbers, letters, and symbols form a program of instructions designed for a particular process. When the process or job changes, the program of instructions is changed since it is usually easier to write new programs than to make major changes in the production equipment. NC equipment makes up approximately 15 percent of the modern machine tools in industry today. Equipment using numerical control has been designed to perform operations such as drilling, milling, turning, grinding, sheetmetal pressworking, spot welding, arc welding, riveting, assembly, drafting, inspection, and parts handling (24:164).

Numeric Control has led to further extensions in improving technology. Four of these extensions are Direct Numeric Control (DNC), Computer Numeric Control (CNC), adaptive control, and industrial robots.

Direct Numeric Control uses a large computer to control different and separate NC machine tools. The program is sent to the machine tool directly from the computer memory. One computer can be used to control more than 100 different machines. The DNC computer provides instructions to each

machine tool immediately on demand (24:233-235).

Computer Numeric Control is an NC system that uses a mini- or micro-computer to perform the basic numerical control functions. They control only one or a small number of machines and collect data to serve as part of a management information system (24:239).

Adaptive control reduces the in-process time. Where NC guides the sequence of tool positions of the tool, adaptive control determines the correct speeds and feeds during the machining process. Adaptive control responds to and compensates for variations such as material hardness, width or depth of cut, air gaps in the part, etc. This results in more efficient operation and longer tool life (24:241).

Computer-Aided Design.

Computer-aided design (CAD), another technology being adopted by the defense industry, is any "design activity that involves the effective use of the computer to create or modify an engineering design (24:262)." There are basically two reasons for using CAD. The first is to increase the productivity of the designer. The computer helps the designer to visualize the product and its subassemblies. This helps the engineer reduce the time to develop, analyze, and document the design. The second reason is to create a data base for the manufacturing of the product. The computer not only aids in the design of the product but also the development of the process plan or "route sheets" used by manufacturing engineers to create the actual product (24:262,269).

Hypothesis and Research Questions

The bottom line objective of IMIP is to make it practical for industry to implement modern equipment and management techniques in order to produce DOD weapon systems at lower cost. Tech Mod is concerned with the implementation of modern equipment and better management techniques throughout the factory in order to reduce costs. Neither the Government nor the contractor do this on a "no-cost" basis. This study examines the government's cost (including management) to determine if this portion of the IMIP is cost effective. The following hypothesis and research questions to support or refute the hypothesis, are the guidelines used in the conduct of this study.

Hypothesis.

The cost to the Air Force of ASD Tech Mods, when management costs are accounted for, does not justify the benefits or savings accrued from Tech Mod in those programs. The 34 Tech Mod programs in ASD will be the focus of this study. Although this is not a "scientific" random sample, it does relate to the aerospace and propulsion sectors of the aerospace industrial base. The findings relate to the industrial base analysis currently being conducted by the Air Force.

Research Questions.

1. What are the projected costs for each Tech Mod Program in ASD?
2. What are the projected savings from these programs?

3. How much time has been expended or is projected to be spent on each ASD Tech Mod Program?

4. What is the dollar value of this time?

5. What is the Air Force's Return on Investment when all costs are considered?

IV. Methodology

Introduction

Chapter one presented the factors affecting productivity in the United States. Chapter two emphasized the Defense Industry and addressed ways in which the DOD is attempting to correct the problems of productivity and costs facing Defense Industry contractors. Chapter three defined the concept of Technology Modernization and some basic technologies recently adopted by manufacturing firms.

The developers of the Tech Mod program were looking for ways to increase productivity while, in turn, reducing costs of government acquisitions. One of the elements used to motivate contractors to invest in facility and capital improvements is the sharing of the resultant savings between the contractor and the government. These savings are based on the difference between the proposed cost of a weapon system before and after Tech Mod implementation while taking into account the investments required by both parties.

The Government investment, or expenditure, includes the seed money for a Tech Mod program. This money does not include management costs because of the differing funding programs within DOD; personnel costs are not associated with any particular program, they are funded in and of themselves.

This funding profile differs entirely from defense as well as commercial contractors who tie personnel costs, as

closely as possible, to a particular program in order to estimate the total cost of a program.

It has been estimated that Government personnel expend 33 manyears of effort on a typical Tech Mod program (30). With the inclusion of the cost of this effort, will savings reported on a Tech Mod program still result?

This chapter defines the techniques used to quantify personnel expenditures. With the quantification, costs will be assigned and the return on investment for the Government can be determined.

Air Force Systems Command (AFSC) has been designated as the acquisition command of the Air Force for all newly developed weapon systems and their components. AFSC is comprised of five principal divisions that maintain responsibility for these components until they are transferred to Air Force Logistics Command. The divisions and their responsibilities are as follows:

Aeronautical Systems Division - responsible for the development and initial deployment of aircraft and their propulsion systems;

Electronics Systems Division - responsible for the development of command, control and communication systems;

Armament Division - responsible for the development of missiles and munitions;

Space Division - responsible for the development and implementation of space technologies; and,

Air Force Contract Management Division - responsible for

overseeing all contractual activities at a contractors' facility involving AFSC contracts.

The emphasis of this research project is focused on the Aeronautical Systems Division (ASD). This focus is in line with the current Defense Industrial Base Sector Analysis being conducted throughout the Department of Defense. Of the eight sectors being studied, ASD is the lead Product Division/Organization for the aircraft and propulsion sectors (47).

Data Collection Procedures

There were five categories of data collection used in the conduct of this study. Each category was used to support the research questions, stated earlier, for all types of Tech Mod programs planned and being implemented at ASD.

Contract Review.

A review of existing Tech Mod contracts determined the government investment to date, persons involved, the expected savings generated during the conduct of the program, and the technologies to be developed or implemented.

Manhour Accounting Summaries.

A review of the Manhour Accounting Summary (MAS) statistics was conducted. For FY 1983 and beyond, the manufacturing personnel in each Program Office have been directed to report manhour expenditures, on Tech Mod, for that particular program, by using a 70500 functional code on the MAS sheet. These statistics are filed by the program

offices on a bi-monthly basis. Prior to 1983, efforts pertaining to Tech Mod were reported through the MAS on an ad hoc basis. The negotiation of Tech Mod contracts is not included in this functional code summary.

Management Plans.

To determine the projected manpower requirements, a review of the management plans for each organization was conducted. This review determined the number of personnel expected to be involved in the Tech Mod Program. This number was compared to other programs of a similar nature to see if a correlation existed and, if so, was this a realistic projection of manpower needs.

Personal Interviews.

To determine the negotiation times as well as any other times not reported under the MAS system, personal interviews were conducted. The persons interviewed were those government personnel directly involved in the management and implementation of each Tech Mod program within the different System Program Offices.

This process determined direct manhour expenditures. To determine the indirect or overhead manhour expenditures involved, a review of all organizations at higher headquarters directly involved in Tech Mod was conducted.

The above methods were used to determine the number of manhours expended or projected to be spent on a Tech Mod program. To assign costs to these manhours, the average rank and/or grade of the personnel involved was established.

Using existing pay scales, the dollar value was computed by multiplying the percentage of time expended on the program by this average. This procedure allowed for any under or over estimations of time expenditures. To compute Temporary Duty assignment costs, the number of assignments, their length of time, and location were aggregated and again, multiplied by the same factors applicable in the computation of personnel costs.

Determination of Actual Savings and Return on Investment

Total direct and indirect management costs to the Government for each Tech Mod under study was included with the monetary investments. This total was then subtracted from the actual or estimated future savings of the specific Tech Mod to which they applied. The Return on Investment (ROI), with and without personnel costs, on each of these programs was computed using tables of interest factors for discrete compounding periods. Compounding periods used were the actual or estimated time periods for the applicable Tech Mod program to be completed. Due to the budgeting cycles within the DOD, it should be noted that all data beyond FY 84 are based on estimates. Only those investments with a high probability of occurrence were utilized. Military and civilian pay data for FY 85 and beyond was estimated at a four percent annual increase. This estimate is in line with the current rate of pay raises experienced over the past two years. No determination was made on whether a specific ROI

was acceptable or not - this should be left up to higher authority, such as those who approve or disapprove individual Tech Mods.

V. Savings and Investment Data

The savings reported for each of the following Tech Mod programs was determined through the contractor's cost estimating techniques. These savings were then verified by the government's audit personnel.

Savings Determination

The original program estimates use the existing equipment and manufacturing techniques currently employed by the contractor. By use of parametric analysis and knowledge expected to be reaped from the Tech Mod projects; a new estimate is then made for the overall program cost. The difference between the two estimates is what the government and the contractor term the savings. For each of the Tech Mod programs, the contractor is allowed to make an adequate return on his investment before the sharing in the savings occurs.

In all but one of the Tech Mod programs studied, the verification of these savings is difficult to accomplish. For the B-1B program, once the technologies have been implemented, the dollar amount assigned to the current contract will be reduced by the savings amount; the contractors have agreed to return that amount to the government. The government, in turn, will issue a new check to the contractor to meet their negotiated return on investment rate; 35% for Rockwell, 30% for AIL. These rates were based on the amount

of technical risk associated with the projects undertaken by the two contractors.

In many instances, the savings are, in reality, cost avoidances. The budgets for the weapon systems are not reduced by these savings; the monies are funneled into other aspects of the program. The B-1B savings approach is being considered by other programs who have yet to negotiate their Tech Mod business deals. This approach is preferred due to the actual savings that are realized. It alleviates many of the GAO's inquiries as to where these savings are going.

Incentive Provisions.

For the Tech Mod program with Lockheed, Georgia Division, a share ratio of 50/50 was established. Two incentive provisions were negotiated with this contract. The first incentive was designed to insure the technologies would be implemented in a timely manner. For each month the contractor had the new equipment working ahead of schedule, a bonus was to be paid. The second incentive was designed to encourage the contractor to improve the negotiated savings. These incentives are to be paid after the first trial year and actual savings, over and above the negotiated savings, are being realized.

Investment Data

The investment data for each of the following Tech Mod programs concerns the government investment only. Contractor investment in each of the projects is not available due to

the proprietary nature of the specific investments. The government investment includes all seed monies and monies related to the compensation of personnel involved in the programs. These personnel have been classified as direct, those located in the System Program Office; and indirect, those assisting the program offices by virtue of their management charter.

Pay data for personnel, whether involved in the Tech Mod programs or not, was obtained from the military and civilian Accounting and Finance Offices. Table VI shows the pay data for military personnel on a monthly basis. Data are shown only for those ranks of personnel involved in the Tech Mod programs and their period of involvement. The pay data includes base pay, housing and subsistence allowances. Table VII shows the pay for civilian personnel. All data in this table is on a yearly basis. Tables VI and VII formed the basis for all subsequent personnel calculations used in this research project.

Indirect Personnel Costs.

Indirect personnel costs attributable to all Tech Mod programs includes those associated with the HQ AFSC/PMI office, the Materials Laboratory, and the Centralized Tech Mod Office, all located at Wright Patterson Air Force Base.

The function of HQ AFSC/PMI is to oversee all aerospace industry modernization efforts conducted by Air Force Systems Command. Their activities are not limited to the Aeronautical Systems Division (ASD). But, with approximately 70 percent of

the Tech Mod programs, in numbers as well as value, being conducted by ASD; the percentage of overhead cost attributable to ASD was set at 70 percent. The total personnel cost of HQ AFSC/PMI is shown in Table VIII.

The Centralized Tech Mod Office (ASD/PMDP) is located in the Contracting and Manufacturing home office in ASD and serves all the matrixed manufacturing and contracting directorates located in the System Program Offices (SPOs). The purpose of the ASD/PMDP is to assist all the SPOs in the conduct and implementation of Tech Mod Programs. This office controls all PE78011F funds for ASD; from budgeting through allocation. Personnel costs associated with ASD/PMDP are shown in Table IX.

Personnel from the Materials Laboratory assist the SPOs in the technical evaluation of all Tech Mod projects. The majority of the Lab's work deals with Manufacturing Technology (ManTech); the development of new technologies related to manufacturing for the subsequent use by industry. Personnel data related to Tech Mod are shown in Table X.

The data sets for HQ AFSC/PMI, ASD/PMDP, and the Materials Lab are applicable to all the Tech Mod projects conducted by the SPOs. These indirect personnel costs were equally divided among the six program offices between fiscal years 1982 through 1987. During the following fiscal years, 1988 through 1990, the SPOs have been allocated one fifth of the total indirect cost due to the anticipated completion of the B-1B program in 1987.

TABLE VI

Pay Data for Military Personnel on a Per Month Basis

Fiscal Year	Rank						
	0-6 ov/20	0-5 ov/16	0-4 ov/12	0-3 ov/8	0-2 ov/2	0-1 un/2	E-6 ov/12
77		2265.29		1673.35			
78		2359.68		1743.07			
79		2458.00		1815.70			
80		2630.41	2241.52	1943.11			
81		2945.78	2511.38	2177.78			
82	3971.17	3367.09	2870.29	2489.29	1771.69	1430.59	1718.40
83	4136.64	3501.67	2985.07	2588.77	1842.37	1487.77	1664.10
84	4309.00	3641.80	3104.50	2692.30	1915.90	1547.50	1730.40
85	4481.36	3787.47	3228.68	2799.99	1992.54	1609.40	1799.61
86	4660.61	3938.97	3357.82	2911.99	2072.24	1673.70	1871.60
87	4847.03	4096.53	3492.14	3028.47	2155.13	1740.73	1946.46
88	5040.92	4260.39	3631.82	3149.61	2241.33	1810.35	2024.32
89	5242.55	4430.80	3777.10	3275.59	2330.98	1882.77	2105.29
90	5452.25	4608.04	3928.18	3406.62	2424.22	1958.08	2189.50

TABLE VII

Pay Data for Civilian Personnel on a Per Year Basis

Fiscal Year	Grade/Step						
	GS-15 /5	GS-14 /5	GS-13 /5	GS-12 /5	GS-9 /5	GS-5 /5	GS-4 /5
79				28,323		15,124	11,521
80			35,082	29,503		14,542	12,001
81			36,545	30,732		13,983	12,501
82	52,909	44,981	38,068	32,013	22,073	14,566	13,022
83	55,025	46,781	39,586	33,290	22,956	15,153	13,541
84	56,952	48,418	40,972	34,454	23,761	15,681	14,015
85	59,230	50,355	42,611	35,832	24,711	16,308	14,575
86	61,599	52,369	44,315	37,265	25,700	16,961	15,159
87	64,063	54,464	46,088	38,756	26,728	17,639	15,765
88	66,626	56,642	47,931	40,306	27,797	18,345	16,396
89	69,291	58,908	49,849	41,919	28,909	19,078	17,051
90	72,062	61,264	51,842	43,595	30,065	19,841	17,733

TABLE VIII

HQ AFSC/PMI Personnel and TDY Costs

Fiscal Year	Grade/Rank Percentage of Time					
	0-3 70%	0-5 70%	0-3 70%	GS-13 70%	GS-13 70%	GS-13 70%
82	20,910			26,648	26,648	26,648
83	21,746			27,710	27,710	27,710
84	22,615		22,615		28,680	28,680
85		31,815	23,520		29,828	29,828
86		33,087	24,461		31,021	31,021
87		34,411	25,439		32,262	32,262
88		35,787	26,457		33,552	33,552
89		37,219	27,515		34,894	34,894
90		38,708	28,616		36,290	36,290
	0-6 30%	GS-15 30%	GS-13 30%	GS-13 30%	E-6 70%	GS-13 70%
82	14,296	15,873	11,420	11,420	14,435	26,648
83	14,892	16,508	11,876	11,876	13,978	27,710
84	15,512	17,086	12,292	12,292	14,535	28,680
85	16,133	17,769	12,783	12,783	15,117	29,828
86	16,778	18,480	13,295	13,295	15,721	31,021
87	17,449	19,219	13,826	13,826	16,350	32,262
88	18,147	19,988	14,379	14,379	17,004	33,552
89	18,873	20,787	14,955	14,955	17,684	34,894
90	19,628	21,619	15,553	15,553	18,392	36,290
	total		TDY		TOTAL	
82	194,945		45,000		239,945	
83	201,716		45,000		246,716	
84	202,988		50,000		252,988	
85	219,403		50,000		269,403	
86	228,178		50,000		278,178	
87	237,306		55,000		292,306	
88	246,797		55,000		301,797	
89	256,671		55,000		311,671	
90	266,938		60,000		326,938	

Source: (30)

TABLE IX

Personnel and TDY Costs for Centralized Tech Mod Office

Fiscal Year	Grade/Rank Percentage of Time		0-2 90%	0-1 75%	GS-13 50%	GS-13 95%
	0-3 75%	0-3 100%				
83	23,299	31,065	19,898		19,793	37,607
84	24,231	32,308	20,692	13,928	20,486	38,923
85	25,200	33,600	21,519	14,485	21,306	40,480
86	26,208	34,944	22,380	15,064	22,158	42,099
87	27,256	36,342	23,275	15,667	23,044	43,784
88	28,346	37,795	24,206	16,293	23,966	45,534
89	29,480	39,307	25,175	16,945	24,925	47,357
90	30,660	40,879	26,182	17,623	25,922	49,251
		GS-12 10%	total	TDY	TOTAL	
83		3,329	134,990	10,000	144,990	
84		3,445	154,012	10,000	164,012	
85		3,583	160,173	10,000	170,173	
86		3,727	166,579	10,000	176,579	
87		3,876	173,243	10,000	183,243	
88		4,031	180,172	10,000	190,172	
89		4,192	187,380	10,000	197,380	
90		4,360	194,875	10,000	204,875	

Source: (35)

TABLE X

Personnel Costs for Materials Lab
(All TDYs are Funded by the SPOs)

Fiscal Year	Grade/Rank Percentage of Time		0-3 100%	5 GS-13s 7.5%	5 GS-12s 5%	Total
	0-4 100%	0-5 100%				
82	34,443	40,405		14,276	8,003	97,127
83	35,821	42,020		14,845	8,323	101,008
84	37,254	43,702	32,308	15,365	8,614	137,241
85	38,744		33,600	15,979	8,958	97,281
86	40,294		34,944	16,618	9,316	101,172
87	41,906		36,342	17,283	9,689	105,219
88	43,582		37,795	17,974	10,077	109,428
89	45,325		39,307	18,693	10,480	113,805
90	47,138		40,879	19,441	10,899	118,357

Source: (22)

F-16 System Program Office

The F-16 Tech Mod Program was developed to establish a manufacturing environment that would minimize the manufacturing costs of the F-16 aircraft. The ultimate goal of the program was to reduce the original cost projection, of the 1388 U.S. aircraft, by \$370 million (33:1).

General Dynamics.

During the full-scale development program, the YF-16 was being built on the same production line as the F-111. With the conclusion of the F-111 program in 1976, the facility layout was considered non-conducive towards the production of the F-16. The problem was that many structural parts destined for the F-16 were required to follow a circuitous maze enroute to completion (34:312).

Because of the low production base, General Dynamics management had little incentive to modernize the facility. Encouraged by the F-16 SPO and Air Force facilities planners, General Dynamics developed a modernization plan for replacing the older government-owned equipment with modern new-technology equipment which would have a high impact on labor-intensive areas and, at the same time, provide higher quality finished parts (34:313).

From 1977 through 1983, the General Dynamics, Fort Worth Division's total capital investment amounted to \$187.2 million, of which, \$111.9 million was apportioned to modernization. Modernization has taken the form of increasing the number of robots in use at the Fort Worth plant. Under the

Air Force's Integrated Computer-Aided Manufacturing program, General Dynamics started using robots for production drilling and routing in 1979 (38:77-78).

The Phase I effort of the Tech Mod program was aimed at definition of the overall program objectives and establishment of a preliminary analysis of proposed concepts through feasibility evaluations by technical consultants (Booz, Allen, and Hamilton, Inc.) and by application of cost performance standards. The Phase I effort extended from November 1978 through April 1979.

During the Phase II effort (April 1979 - October 1979), the final selection and integration of concepts were developed into what are now the Work Center Design, Factory Integration, and Enabling Technologies developments. During this same period, specific methodologies were refined to meet performance assessment and cost tracking requirements of the program.

Industrial Technology Modernization Program.

The success of the F-16 Tech Mod program, coupled with a sound F-16 production business base and the potential support of the multi-year procurement concept, led the Air Force and General Dynamics to initiate another unique program entitled "Industrial Technology Modernization". The goal of this program is to increase sub-contractor productivity, enhance quality, and reduce material or component acquisition cost, to the prime contractor, on the F-16 program and other USAF and/or DOD contracts. The ITM program assists the subcon-

tractor in defining, developing, and implementing industry/factory modernization improvements. General Dynamics has been authorized by the Air Force to manage all aspects of the ITM Program with participating sub-contractors (21:1-9).

The subcontractors involved in the ITM and their associated phases of the Tech Mod program include:

Subcontractor	Phase of Tech Mod
Westinghouse (Lima, Ohio)	II
Simmonds Precision	II & III
Tracor	II & III
Sperry Flight Systems	II
Delco	II
Sierracin/Sylmar	II
Sundstrand	II
Goodyear (Arizona)	I
Aerospace Avionics	I
Airesearch	I
Arkwin	I
Menasco	I
Goodyear Wheels & Brakes	I
National Waterlift	I
Honeywell, Inc.	I
TRW (Cleveland)	I
Gull Airborne Ind.	I
* Applied Technology	
* Pacific Electro Dynamics	
* Dynamic Controls	

* Phase I proposals received, not yet on contract

Simmonds Precision Corporation.

Simmonds Precision Corp., one of the subcontractors who has entered Phase III of the Tech Mod program, is working in conjunction with General Dynamics in the development of new technologies which include automatic in-circuit testing of printed circuit boards, progressive line flow assembly techniques, laser metal cutting and an optical scanning indicator test.

With automatic in-circuit testing of printed circuit boards, the boards are automatically tested prior to their installation into assembled units. This will reduce test and troubleshooting labor at the unit functional level and will eliminate the need for 100% component inspection for parts location, value and polarity.

The progressive line flow assembly technique involves the reorganization of material flow to take advantage of the economy and time-saving aspects of the progressive line flow assembly concept. Currently, a single production operator performs the entire sequence of assembly operations in the manufacture of a certain assembly such as fuel tanks. With the proposed process, a unit assembly will flow to individual work stations dedicated to a specific assembly operation. Each dedicated work station will contain the instructions, tooling, and fixtures required to perform a specific job, allowing each assembly operator to become highly proficient in his/her own portion of the total assembly.

A laser metal cutting project was designed to reduce deburring operations through the use of a laser. Normally, thin-walled aluminum tubes have holes drilled in various patterns using conventional cutting tools and a specialized numeric control (NC) machine tool. Burrs are removed using hand deburring and automated processing prior to surface finishing. With laser metal cutting, holes are cut with a high speed metal-cutting laser that will be integrated with an NC machine. The laser will be controlled by a computer

numerically controlled machine and will produce relatively burr-free holes in the aluminum tubing. The laser's high speed cutting rates and the reduction of expendable cutting tools provide additional savings.

The objective of an optical scanning indicator test is to perform automated testing of fuel measurement indicators utilizing an optical sensory system. Currently, all final testing of fuel quantity indicators is accomplished using specialized test systems capable of producing electronic signals that simulate actual systems operating signals. This requires a test technician to constantly monitor the indicator during the test sequence. The technician verifies, visually, that the indicator pointer moves to the correct location on the dial. The proposed testing approach will implement an optical scanning system to monitor the fuel gauging indicator during the final test. The scanning system will focus on specified locations on the indicator dial and monitor dial pointer movements in response to signal inputs to the indicator. When the pointer response is acceptable, the test automatically cycles to the next test sequence.

F-16 SPO Return on Investment.

Personnel and TDY costs for those persons involved in all aspects of the F-16 Tech Mod program are shown in Table XI. Total number of manyears attributed to the General Dynamics Tech Mod program is 18.458; towards the ITM program, 18.362 for an overall total of 36.82 manyears.

The savings and investment associated with each of these

programs is shown in Table XI. The return on investment for the General Dynamics program, as shown in Table XII, is approximately 190 percent with personnel cost included. The return on investment without personnel cost is 194 percent; a reduction of four percent overall. The return for the Industrial Technology Modernization program, as shown in Table XIII, is less than 0.01% with or without personnel cost included. It should be noted that the savings used in these calculations are those attributable to the F-16 program only. Savings on other USAF and DOD programs for the ITM program are estimated at \$550 million. If these savings were included in the return on investment calculation, the return would approximate 330%. When all investments, seed monies as well as personnel cost, are combined for the General Dynamics and the ITM program, the overall return on investment for the F-16 program is 187% with personnel cost included; 191% without personnel costs.

TABLE XI

**Personnel and TDY Costs for
F-16 System Program Office**

Fiscal Year	Grade/Rank Percentage of Time						
	0-2 90%	0-4 70%	0-5 70%	GS-12 25%	GS-4 5%	0-3 5%	0-5 10%
77			19,028			1,004	
78			19,821			1,046	
79			20,647		576	1,089	2,950
80			22,095		600	1,166	3,156
81			24,745		625	1,307	3,535
82	19,134	24,110		8,003	651	1,494	4,041
83	19,898	25,075		8,323	677	1,553	4,202
84	20,692	26,078		8,614	701	1,615	4,370
85		27,121			729	1,680	4,545
86		28,206			758		4,727
87		29,334			788		
88		30,507			820		
89		31,728			853		
90		32,997			887		
	0-4 15%	0-2 25%	0-3 25%	total	TDY	TOTAL	
77			5,020	25,052	8,000	33,052	
78			5,229	26,096	8,000	34,096	
79			5,447	30,709	9,000	39,709	
80			5,829	32,847	9,000	41,847	
81			6,533	36,745	9,000	45,745	
82	5,167	5,315		67,915	10,000	77,915	
83	5,373	5,527		70,627	10,000	80,627	
84	5,588	5,748		73,405	10,000	83,405	
85	5,812	5,978		45,864	10,000	55,864	
86	6,044	6,217		45,951	10,000	55,951	
87	6,286			36,408	10,000	46,408	
88	6,537			37,864	10,000	47,864	
89				32,580	10,000	42,580	
90				33,883	10,000	43,883	

Source: (28)

TABLE XII

Government Savings and Investment
F-16 System Program Office
General Dynamics Program

Fiscal Year	Government Investment	%	Personnel Cost SPO	Indirect	Total Investment
77		100	33,052		33,052
78	4,800,000	100	34,096		4,834,096
79	5,400,000	100	39,709		5,439,709
80	6,700,000	100	41,847		6,741,847
81	7,100,000	90	41,171		7,141,171
82	7,100,000	80	62,332	44,943	7,207,275
83	7,100,000	70	56,439	57,484	7,213,922
84	7,100,000	60	50,043	55,424	7,205,467
85	7,100,000	50	27,932	44,738	7,172,670
86	2,500,000	40	22,380	37,062	2,559,442
87	2,500,000	30	13,922	29,038	2,542,961
88	2,500,000	20	9,573	24,056	2,533,629
89	2,500,000	10	4,250	12,457	2,516,707
90		10	4,388	13,004	17,392

Savings	Net Savings W/Personnel \$	Net Savings W/O Personnel \$
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77	0	(33,052)	0
78	0	(4,834,096)	(4,800,000)
79	10,200,000	4,760,291	4,800,000
80	22,900,000	16,158,153	16,200,000
81	30,500,000	23,358,830	23,400,000
82	24,200,000	16,992,725	17,100,000
83	26,900,000	19,686,078	19,800,000
84	30,100,000	22,894,533	23,000,000
85	41,100,000	33,927,330	34,000,000
86	43,700,000	41,140,558	41,200,000
87	49,300,000	46,757,039	46,800,000
88	59,700,000	57,166,371	57,200,000
89	65,600,000	63,083,293	63,100,000
90	64,600,000	64,582,608	64,600,000

Return on investment with personnel cost 190%

Return on investment without personnel cost 194%

Source: (28)

TABLE XIII

Government Savings and Investment
F-16 System Program Office
Industrial Technology Modernization Program

Fiscal Year	Government Investment	%	Personnel Cost SPO	Cost Indirect	Total Investment
81	0	10	4,575		4,575
82	4,900,000	20	15,583	11,236	4,926,819
83	8,100,000	30	24,188	24,637	8,148,824
84	15,000,000	40	33,362	36,950	15,070,312
85	19,300,000	50	27,932	44,738	19,372,670
86	19,400,000	60	33,571	55,593	19,489,164
87	20,900,000	70	32,486	67,758	21,000,243
88	21,100,000	80	38,291	96,223	21,234,514
89	22,200,000	90	38,250	112,087	22,350,364
90	0	90	39,495	117,031	156,525

	Savings	Net Savings W/Personnel \$	Net Savings W/O Personnel \$
81		(4,575)	0
82		(4,926,819)	(4,900,000)
83	4,200,000	(3,948,825)	(3,900,000)
84	6,300,000	(8,770,312)	(8,700,000)
85	11,400,000	(7,972,670)	(7,900,000)
86	15,700,000	(3,789,164)	(3,700,000)
87	15,700,000	(5,300,244)	(5,200,000)
88	16,800,000	(4,434,514)	(4,300,000)
89	16,800,000	(5,550,337)	(5,400,000)
90	17,800,000	17,643,474	17,800,000

Return on investment with personnel cost less than 0.01%
Return on investment without personnel cost less than 0.01%

Source: (28)

B-1B System Program Office

This Tech Mod program entails a total productivity improvement effort at various Rockwell facilities and subcontractors engaged in the production of the B-1B. In early FY 83, Rockwell completed a top down factory analysis. Areas being reviewed or analyzed include: diffusion bonding,

structural machining, and assembly at the prime contractor's facility (44:4-2-17).

Subcontractors engaged in other Tech Mod programs include AVCO (wings) and Vought (aft and aft intermediate fuselage). Other potential subcontractors on the B-1B who are being approached with a Tech Mod program include: Cleveland Pneumatic (main landing gear), Menasco (nose gear), Grumman (horizontal stabilizer), and Martin Marietta (vertical stabilizer) (44:4-2-17).

Rockwell International.

Much of Rockwell's B-1B Tech Mod deals with labor saving devices as well as improved methods for producing aircraft parts at lower cost. These include technologies to improve drilling, cutting, inspection, etc.

One new development is a device called CANDIS which inspects composite type materials used in making aircraft wings and fuselages. Parts are composed by the bonding of different types of material to form the aircraft skin. A sonar type inspection system, CANDIS, is used to "look" between the layers of materials to ensure there are no air gaps which would reduce the total strength of the part being manufactured. This eliminates destructive test sampling and reduces material costs as well as making a stronger material.

Rockwell is also investing in a Capacitance Hole Probe which drills and measures the thousands of high tolerance requirement holes in the aircraft skin and inspects the overall work at the same time. This procedure decreases

set-up time, eliminates the need for additional inspection and reduces the overall work-in-process time.

Rockwell's investment in a fluid systems project will reduce materials requirement and work-in-process time. The new process will check the pressure requirements for titanium tubes used to transport hydraulic fluid throughout the aircraft without having to destroy part of the tubing. Currently, the tubes are held in an extremely tight vice grip during inspection due to the high pressure requirements within the tubes. This procedure often causes damage to the tube ends which must be cut off after testing. The old inspection procedure required the tubes to be made longer than necessary. The new project will enable the manufacturer to make all tubes to the required length, thus reducing material cost and damage to the tubes resulting from metallic scraps which occur after the tube has been cut.

A final example of Rockwell's attempt to lower production costs through Tech Mod is its investment in water-jet cutting machines. These tools are used to cut composite material by the use of high powered streams of water. This reduces the dust created using older procedures, thus eliminating the need for elaborate exhaust systems for worker protection. It also decreases much of the noise created in cutting materials that contributes to noise pollution. Water-jet cutting makes a cleaner, more accurate cut than normal cutting tools reducing the time needed to deburr the cut edges.

AIL- Defensive Avionics.

The B-1B SPO is also involved in Tech Mod contracts with AIL, the prime contractor for defensive avionics. AIL has two Tech Mod contracts with the B-1B SPO. The first contract is for a Leadless Chip Carrier - for the manufacture and fabrication of computer chips. This is a work system that identifies the chips, where to place them, attach and test the chips. The test and inspection of the chips is the most critical part. Previously, this was done on a visual basis, it is now done on a scanning basis by the computer.

The second Tech Mod contract with AIL is similar to the General Dynamics ITM contract. The purpose of this contract is for AIL to go out and find potential Tech Mod candidates for their subcontractors. Three subcontractors of AIL have Tech Mod contracts: General Electric Electronic Systems Division for a coaxial cable bender and a flexible machining center; Northrup, to attempt to find a way for building and inspecting traveling wave tubes; and, Sedco, for a log video amplifier, phaser driver and a frequency shifter.

B-1B SPO Return on Investment.

Personnel and TDY cost for those involved in the B-1B Tech Mod program are shown in Table XIV. The total number of man-years associated with this Tech Mod is 34.67 with 11.59 attributable to the Phase I effort; 4.74 towards Phase II; and 18.34 towards Phase III.

The savings and investment attributed to the B-1B program are shown in Table XV. The return on investment,

including personnel costs, is 38% while the return without personnel cost is 41.4%.

TABLE XIV

Personnel and TDY Costs for
B-1B System Program Office

Fiscal Year	Grade/Rank Percentage of Time					total
	0-3 100%	0-5 50%	GS-12 60%	GS-4 5%	GS-12 65%	
79	21,788	14,748	16,994	576		54,106
80	23,317	15,782	17,702	600	19,177	76,579
81	26,133	17,675	18,439	625	19,976	82,848
82	29,871	20,203	19,208	651	20,808	90,741
83	31,065	21,010	19,974	677	21,639	94,365
84	32,308	21,851	20,672	701	22,395	97,927
85	33,600	22,725	21,499	729	23,291	101,843
86	34,944	23,634	22,359	758		81,695
87	36,342	24,579	23,254	788		84,963

TDY TOTAL

79	45,000	99,106
80	45,000	121,579
81	45,000	127,848
82	45,000	135,741
83	50,000	144,365
84	50,000	147,927
85	50,000	151,843
86	50,000	131,695
87	50,000	134,963

Source: (9)

TABLE XV

Government Savings and Investment
B-1B System Program Office

Fiscal Year	Government Investment	Personnel Cost SPO	Indirect	Total Investment
79		99,106		99,106
80		121,579		121,579
81		127,848		127,848
82	2,300,000	135,741	56,179	2,491,920
83	15,500,000	144,365	82,119	15,726,484
84	16,200,000	147,927	89,476	16,440,301
85	6,000,000	151,843	89,476	6,241,319
86		131,695	92,655	224,350
87		134,963	96,796	231,759

	Savings	Net Savings W/Personnel \$	Net Savings W/O Personnel \$
79		(99,106)	0
80		(121,579)	0
81		(127,848)	0
82		(2,491,920)	(2,300,000)
83		(15,726,484)	(15,500,000)
84		(16,440,301)	(16,200,000)
85	32,000,000	25,758,681	26,000,000
86	31,400,000	31,175,650	31,400,000
87	24,400,000	24,168,241	24,400,000

Return on investment with personnel cost	38%
Return on investment with personnel cost	41.4%

Source: (9)

Airlift and Trainer Systems Program Office

The Airlift and Trainer SPO has responsibility for the production and ultimate deployment of cargo and training aircraft. The SPO is currently conducting Tech Mod programs with Fairchild; Lockheed, Georgia and their subcontractor AVCO; and Boeing Military Airplane Company.

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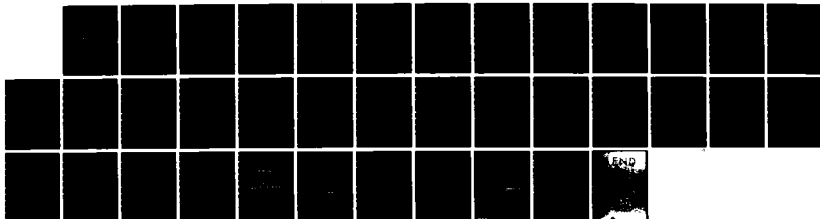
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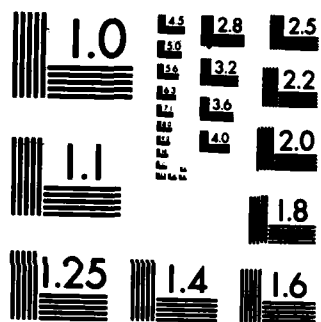
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Fairchild.

Fairchild Industries, Inc., is the prime contractor for the T-46A advanced trainer which is to replace the T-37B currently used in Undergraduate Pilot Training. At this time, Fairchild has four Air Force approved Tech Mod candidate projects under development. They include an automated machining center, partsmaker cell, machine shop tool preparation with numerically controlled (NC) grinder and a robotic drill/rout cell.

The automated machining center is a system intended to provide milling, drilling, tapping, reaming and boring capabilities to high variety, small quantity parts. The system will have self-monitoring sensors, automated material tool handling and inspection machinery. A control system will be used to ensure constant work flow using real-time scheduling logic through simulation. The present system uses manual and conventional NC equipment and manual material handling techniques.

The partsmaker cell is a 4-axis, 4-spindle NC machining system which performs cutting, routing and drilling operations. Spindles move along three linear axes with the work holding chuck providing a fourth rotary axis. A self-feed capability provides multiple small detail parts from a single setup. In the present system, material cut is manually loaded, unloaded and transported from station to station for accomplishment of routing and drilling. At times, multiple setups are required for a single operation.

Through the use of a machine shop preparation with NC grinder, tools for use in NC machines would be prepared accurately through use of an NC grinder. A reground tool with highly qualified geometry, exact tooth to tooth consistency, constant rake angle and high surface finish would be produced. The system includes storage of all geometric and grinding data for tools in use, inspection of ground tools and organized tool storage. Currently the manual preparation of tools produces inconsistent results with lower tool life and quality of cutting operations.

In the robotic drill/rout cell; trimming, drilling, routing and deburring, of complex contour sheet metal parts are to be accomplished in one setup. Parts will be loaded onto movable shuttle tables which present the part to the robot. A ten-tool change station allows selection of the proper cutting tools. Three tables allow for setup while other parts are in work. Presently, contour parts take five operations - marking, trimming, drilling, routing and deburring - which requires five setups, one fixture, four transportation moves and two classifications of workers.

Lockheed, Georgia Division and AVCO.

Lockheed-Georgia and their subcontractor; AVCO, Aerostructures Division; are attempting to improve the productivity and operations of those facilities which impact the cost of the C-5A wing modification program through Tech Mod. The C-5A wing modification Tech Mod was initiated in 1980. This program is currently in Phase III. Areas where

manufacturing improvements are being made include an advanced DNC system to operate 16 machines; computer-aided shop setup program; voice data entry system in which the operator talks to a computer through a microphone; a brush deburring system; and an electromagnetic clamp to secure skin panels together during drilling (31:51).

Efforts are currently underway to restructure this Tech Mod program, giving more independence to AVCO. This is being done to recognize AVCO's importance to the entire large aircraft base. AVCO is a prime manufacturer of aircraft wings. The new program will expand the current limited AVCO Tech Mod to a total factory effort that will assist the company's entire business base (44:4-2-19).

Brush deburring involves a deburring machine which will provide both edge-breaking and deburring capability for flat sheet metal parts. Existing equipment will deburr but requires manual edge-breaking to meet quality requirements. Hand deburring is very extensive and labor intensive. The new system is currently being used in production.

Direct Numeric Control will establish centralized programming and control of Lockheed's NC machines. Currently, 57 total NC machines are designated to be included in the system. Each machine is equipped with sensors to report maintenance information to the centralized control center. The benefits of this project will be in reduced set-up times, better machine utilization, reduced scrap and rework and reduced run times.

The computer aided set-up program will provide set-up instructions to machine operators. These computer generated instructions will replace hand generated instructions. Additionally, this program will retain within the computer the tricks-of-the-trade developed by highly experienced operators which, in turn, will be available to new machine operators. The benefits of this project will be reduced run times, reduced set-up times, and a reduction of scrap and rework.

The voice data entry system (VDES), developed under this Tech Mod program, will not be put to use in the plant. Problems with tonal inflection, worker reluctance to use the system, cost and background noise were encountered. Although the system will not be used, the technologies developed from the system will be transferred to other companies for further development and use. Boeing Military Airplane Company (BMAC) has proposed the VDES as a possible candidate project for their Tech Mod program. The Air Force will not pay for further development and implementation of this system during the BMAC Tech Mod but does encourage BMAC to work on it using their own funds.

Boeing Military Airplane Company.

Boeing Military Airplane Company, Wichita, Kansas, made a commitment for involvement in the Air Force's Tech Mod program and is developing a plan for short- and long-term plant modernization. From 1978 to 1982, the company spent \$380.1 million which included \$44 million for USAF Plant No.

13, \$28.5 million in new construction and more than \$245 million in plant equipment. The new equipment will consist of computer aided design, computer aided manufacturing, and a robotics and automated fabrication and test facility (7:48-49). While the KC-135 re-engine program will be the principal beneficiary, the B-52 and B-1B will benefit (44:4-2-19).

EMAC's main Tech Mod project is called REACH (robotically enabled assembly of cables and harnesses). It is a totally integrated computer-aided design/manufacturing program that addresses aircraft cables 16-160 feet long. The program should fit all of the requirements of the on-going aircraft programs, except for a few cables and harnesses for the B-1B. The company believes it would not be economically feasible to design the system to handle these. The extra cost would not be valid for the low quantity needed.

The system would consist of a computer-aided manufacturing engineering function, a computer-aided design function, and a robotics and automated fabrication and completed harness test facility. The computer-aided design engineering and wiring integration cell would include use of interactive three-dimensional computer graphics to develop detailed wiring requirements, including cable lengths and bundle configurations.

Chemical process and finishing of parts is another Tech Mod innovation under development at EMAC. Key technology in this process involves anodizing or alodizing parts against

corrosion and applying a paint primer coating. This will include design of an automated system that will take the parts, placed on racks for the complete process, and move them through the corrosion protection and primer coating processes without any interim manual handling. A computer based control and information system will control the movement of the racks and each treatment the parts are to receive. Parts will be bar-coded so they can be tracked at all times. Automatic positioning devices will have sensors that would direct spray guns to turn on whenever the part is in position.

Airlift and Trainer SPO Return on Investment.

Personnel and TDY costs for those persons involved in all three of the Airlift and Trainer SPOs Tech Mod programs is as shown in Table XVI. The total number of manyears attributed to these programs is 61.37.

The savings and investment associated with these programs is shown in Table XVII. The return on investment, including personnel costs, is approximately 61.1% while the return without personnel cost is 63.4%.

TABLE XVI

Personnel and TDY Costs for Airlift and Trainer SPO

Fiscal Year	Grade/Rank Percentage of Time						
	0-4 60%	0-4 50%	GS-13 70%	GS-9 10%	GS-13 25%	0-5 10%	
80	16,139	13,449	24,557			2,718	
81	18,082	15,068	25,582			2,832	
82	20,666	17,222	26,646	2,207	9,517	2,950	
83	21,493	17,910	27,710	2,296	9,897	3,156	
84	22,352	18,627	28,680	2,376	10,243	3,535	
85	23,246	19,372	29,828	2,471		4,041	
86	24,176	20,147	31,021	2,570			
87	25,143	20,953	32,262	2,673			
88		21,791		2,780			
89		22,663		2,891			
90		23,569		3,007			
	GS-12 50%	0-3 100%	0-5 100%	0-4 5%	0-3 100%	GS-14 5%	GS-13 5%
80							
81							
82	16,007		40,405				
83	16,645		42,020			2,339	
84	17,227	32,308		1,863		2,421	2,049
85		33,600		1,937	33,600	2,518	2,131
86		34,944		2,015	34,944	2,618	2,216
87		36,342		2,095	36,342	2,723	2,304
88		37,795		2,179	37,795		
89		39,307		2,266	39,307		
90		40,879		2,357	40,879		
	GS-13 50%	0-4 25%	0-3 20%	total	TDY	TOTAL	
80	17,541		4,663	79,068	9,000	88,068	
81	18,273		5,227	85,063	9,000	94,063	
82	19,033	8,611	5,974	169,237	10,000	179,237	
83	19,793	8,955	6,213	178,427	10,000	188,427	
84		9,314	6,462	157,456	10,000	167,456	
85		9,686	6,720	169,149	11,000	180,149	
86		10,073	6,989	171,713	11,000	182,713	
87		10,476	7,268	178,582	11,000	189,582	
88		10,895	7,559	120,795	12,000	132,795	
89		11,331	7,861	125,627	12,000	137,627	
90				110,691	12,000	122,691	

Source: (6)

TABLE XVII

Government Savings and Investment
Airlift and Trainer Systems Program Office

Fiscal Year	Government Investment	Personnel Cost		Total Investment
		SPO	Indirect	
80		88,068		88,068
81	2,250,000	94,063		2,344,063
82	3,000,000	179,237	56,179	3,235,416
83	5,684,000	188,427	82,119	5,954,546
84	14,200,000	167,456	92,374	14,459,830
85	15,000,000	180,149	89,476	15,269,625
86	33,305,000	182,713	92,655	33,580,368
87	7,000,000	189,582	96,796	7,286,378
88	8,815,000	132,795	120,279	9,068,074
89		137,627	124,571	262,198
90		122,691	130,034	252,725

	Savings	Net Savings w/Personnel \$	Net Savings w/o Personnel \$
80		(88,068)	0
81		(2,344,063)	(2,250,000)
82		(3,235,416)	(3,000,000)
83	2,000	(5,952,546)	(5,682,000)
84	4,677,000	(9,782,830)	(9,523,000)
85	15,239,000	(30,625)	239,000
86	45,214,000	11,633,632	11,909,000
87	65,883,000	58,596,622	58,883,000
88	78,231,000	69,162,926	69,416,000
89	61,802,000	61,539,802	61,802,000
90	66,702,000	66,449,275	66,702,000

Return on investment with personnel cost 61.1%

Return on investment without personnel costs 63.4%

Source: (6)

Propulsion Systems Program Office

A general, industry-wide propulsion Tech Mod is being developed to upgrade productivity, alleviate critical bottlenecks and reduce critical/strategic materials consumption at

both the prime and subcontractor levels. The initial efforts in the propulsion arena focuses on the prime contractors (Pratt & Whitney, Garret, Williams and General Electric) with special emphasis on key subcontractors (44:4-2-20).

The manufacturing processes currently employed on turbine engines requires extensive machining of complex alloys and manual inspection using old equipment and processes that have not kept up with current design and manufacturing state-of-the-art. A primary objective of the General Electric Tech Mod program is to utilize a tri-service approach to develop a large Tech Mod Program that encompasses smaller programs and involves the integration of advanced technologies. Some programs being considered are automated integrated fabricated parts manufacturing, automated integrated composites manufacturing, factory management system, and an automated integrated manufacturing grinding cell (44:4-2-20).

The initial Tech Mod objectives for Pratt & Whitney provide for conceptual studies and preliminary design efforts for disk manufacturing centers. Follow-on efforts will establish work center design, validate enabling technologies, and assure factory integration of selected manufacturing processes to support the disk facility. In addition, conceptual studies and preliminary design of the mid-term airfoil manufacturing center would be initiated. This effort would extend beyond the Air Force and provide benefits for all current and future DOD engine/engine spares acquisitions (44:4-2-20).

Vendors and suppliers to engine prime manufacturers receive approximately 50 percent of funds spent on new engines. The objective of the subcontractor Tech Mod program is to address methods of improving productivity, cost reduction, materials utilization, substitution of critical/strategic materials, and to establish manufacturing methods to reduce costs and to optimize properties in the processing of powder composites and ingots, castings, and forgings prior to component fabrication. Specific company Tech Mod funding profiles assume that only one Tech Mod effort will be accomplished for a vendor/subcontractor that serves any of the prime contractors (44:4-2-20).

General Electric Aircraft Engine Group.

General Electric Aircraft Engine Group plans to install an integrated blade inspection system to automate inspection of gas turbine engine blades and vanes. The system's primary benefit should be improved reliability since automation removes human decision-making from the process of determining whether a part meets specifications. General Electric also plans to modify their computer-aided design equipment for compatibility with the inspection system and prepare a design study of automated material handling for the transfer of parts between system modules.

The inspection system will have a computer data management network controlling four inspection modules, each with robotic manipulation of parts within the module. The data management system will consist of a Digital Equipment

VAX 11/780 connected to minicomputer controllers on each module and with one data transfer channel for interface with the factory's overall control computer.

Other General Electric plans include:

- Replacement of forklifts with computer-controlled vehicles.
- Automated reporting of production status in which information from NC tools on job progress is made available to foremen for supervision purposes.
- Automatic inspection of part dimensions where a tool controller, versus a human, monitors the tool path and can feed data on variations to the factory control system for automatic adjustment of the programming.

Propulsion SPO Return on Investment.

Table XVIII shows the personnel and TDY costs for those involved in the Tech Mod programs. The total number of manyears associated with these programs is 43.82 with 14.54 manyears attributable to Phase I; 5.16 to Phase II; and 24.12 towards Phase III.

Table XIX displays the return on investment for this program; 85% with personnel cost included and 86.2% without personnel cost.

TABLE XVIII

**Personnel and TDY Costs for
Propulsion Systems Program Office**

Fiscal Year	Grade/Rank Percentage of Time					
	GS-14 100%	GS-14 75%	O-4 100%	GS-12 50%	GS-12 25%	O-4 10%
82	44,981		34,443	16,007	8,003	3,444
83	46,781		35,821	16,645	8,323	3,582
84	48,418		37,254	17,227	8,614	3,725
85	50,355		38,744	17,916	8,958	3,874
86	52,369		40,294	18,633	9,316	4,029
87		40,848	41,906		9,689	4,191
88		42,482	43,582		10,077	4,358
89		44,181	45,325		10,480	4,533
90		45,948	47,138		10,899	4,714

	O-5 10%	GS-5 5%	total	TDY	TOTAL
82	4,041	728	111,647	27,600	139,247
83	4,202	758	116,111	28,800	144,911
84	4,370	784	120,392	30,000	150,392
85	4,545	815	125,208	31,200	156,408
86	4,727	848	130,216	32,500	162,716
87	4,916	882	102,431	33,700	136,131
88	5,112	917	106,528	35,000	141,528
89	5,317	954	110,789	36,500	147,289
90	5,530	992	115,220	37,900	153,120

Source: (16)

TABLE XIX

Government Savings and Investment
Propulsion SPO

Fiscal Year	Government Investment	Personnel Cost		Total Investment
		SPO	Indirect	
82		139,247	56,179	195,426
83		144,911	82,119	227,030
84	51,100,000	150,392	92,374	51,342,766
85	31,500,000	156,408	89,476	31,745,884
86	39,500,000	162,716	92,655	39,755,371
87	47,600,000	136,131	96,796	47,832,927
88	54,000,000	141,528	120,279	54,261,807
89	54,800,000	147,289	124,571	55,071,860
90	60,500,000	153,120	130,034	60,783,154

	Savings	Net Savings w/Personnel \$	Net Savings w/o Personnel \$
82		(195,426)	0
83		(227,030)	0
84		(51,342,766)	(51,100,000)
85	20,600,000	(11,145,884)	(10,900,000)
86	86,400,000	46,644,629	46,900,000
87	152,100,000	104,267,073	104,500,000
88	201,400,000	147,138,193	147,400,000
89	257,900,000	202,828,140	203,100,000
90	307,500,000	246,716,846	247,000,000

Return on investment with personnel cost 85%

Return on investment without personnel cost 86.2%

Source: (16)

Tactical Fighter Systems Program Office

The Tactical Fighter SPO is involved in two separate Tech Mod programs, the Maverick Missile and the F-15 Radar. Although Armament Division, Eglin AFB, has control of the overall Maverick program, the SPO maintains control of the guidance system installed in the missile. Hughes Aircraft Company is involved in both of the Tech Mod programs

conducted by the SPO. Hughes Missile Systems Group has a Tech Mod program for the Maverick Missile. The proposal for Phase II of this Tech Mod program has not been received, but, the business deal has been arranged. Therefore, personnel, savings and investment data for the Maverick program have not been included in this study.

Hughes Radar Systems Group is entering Phase III of their Tech Mod program for the F-15 radar. The SPO is working with the Navy on this Tech Mod program. The projects undertaken in this program include an Infrared Solder Joint Integrity System; Automatic Chemical Analysis Process; and a Precision Measurement System. Other projects, part of the continuing Phase II effort, are still under consideration for the Hughes Radar System Group.

The investments and savings shown in the following tables reflect those undertaken by the Air Force only for the F-15 Radar Tech Mod program. Other investments by the Navy total \$2.1 million. The overall savings for DOD resulting from this Tech Mod program amount to \$17 million. The break-out of investment by the Navy and the Air Force was not systematically determined. This may be a reason for the low return on investment experienced by the Tactical Fighter SPO when personnel costs are considered.

Tactical Fighter SPO Return on Investment.

The personnel and TDY cost for those Air Force personnel associated with the F-15 Tech Mod program is depicted in Table XX. The total number of manyears associated with the

program is 30.42; 6.28 attributed to Phase I efforts; 10.18 towards Phase II; and, 13.96 towards Phase III.

The return on investment with personnel cost included is less than 0.01%. The return without personnel costs is 23.2%. These cost are displayed in Table XXI.

TABLE XX
**Personnel and TDY Costs for the Tactical Fighter
Systems Program Office**

Fiscal Year	Grade/Rank Percentage of Time			total	TDY	TOTAL
	GS-14 50%	GS-13 20%	O-3 25%			
82	22,491	7,614	7,468	32,508	11,000	48,572
83	23,391	7,917	7,766	34,607	11,500	50,574
84	25,178	8,194	8,077	37,603	12,000	53,449
85	25,178		8,400	30,377	12,500	46,077
86	26,185		8,736	43,656	13,000	47,920
87	27,232		9,085	45,402	13,500	49,817
88	28,321		9,449	47,219	14,000	51,770
89	29,454			49,108	14,500	43,954
90	30,632			51,072	15,000	45,632

Source: (17)

TABLE XXI

Government Savings and Investment
Tactical Fighter SPO

Fiscal Year	Government Investment	Personnel Cost SPO	Indirect	Total Investment
82		48,572	56,179	104,749
83	565,000	50,574	82,119	697,693
84	120,000	53,449	92,374	265,822
85	172,000	46,077	89,476	307,554
86	121,000	47,920	92,655	261,575
87		49,817	96,796	146,612
88		51,770	120,279	172,049
89		43,954	124,571	168,525
90		45,632	130,034	175,666

	Savings	Net Savings W/Personnel \$	Net Savings W/O Personnel \$
82		(104,749)	0
83		(697,693)	(565,000)
84		(265,822)	(120,000)
85	269,000	(38,554)	97,000
86	354,000	92,425	233,000
87	344,000	197,388	344,000
88	322,000	149,951	322,000
89	397,000	228,475	397,000
90	423,000	247,334	423,000

Return on investment with personnel cost less than 0.01%

Return on investment without personnel cost 23.2%

Source: (17)

Reconnaissance Warfare Systems Program Office

The Reconnaissance Warfare SPO is involved in Tech Mod Programs for Seek RAM, an early warning system for jamming; INEWS, the next-generation jamming system of Seek RAM; and LANTIRN. The Seek RAM and INEWS Tech Mod programs are in the development stages. The development and implementation of projects under the guise of Tech Mod are elements being considered during the Source Selection process. Contractor's

submitting proposals with Tech Mod considerations are Raytheon, Goleta, California and Westinghouse, Baltimore, Maryland. The LANTIRN Tech Mod, in Phase II, is being conducted by Martin Marietta.

Martin Marietta Orlando Aerospace.

Martin Marietta's Tech Mod goal is to design and implement an integrated work center to reduce the production cost for 300 LANTIRN (Low Altitude Navigation and Targeting Infrared System for Night) pods. Their general goals in the design of the work center are:

1. minimize human intervention;
2. paperless operation;
3. require no special tooling;
4. automatic set-up of machinery and tooling;
5. overlap set-up time with run time;
6. minimize work-in-process inventory;
7. maximize equipment utilization;
8. minimize product flow time and handling;
9. measure performance at the lowest possible level;
10. minimize the impact of configuration changes;
11. accept high mix, small lot production; and
12. flexibility to accept future product designs.

The specific LANTIRN Tech Mod contract calls for the development of an integrated work center to produce and test 300,000 hermetic chip carriers (HCC) per year and to produce and test 30,000 circuit card assemblies (CCA) per year.

The automated work center consists of four cells. Fac-

tory analysis, supported by Air Force industrial engineers, found that direct touch labor in all four cells was the major cost driver to be addressed by the Tech Mod program. The measure of cost reduction through the Tech Mod is the difference between "as-is" and "to-be" touch labor. Actual labor hours were determined from industrial engineering standards verified by production of 32,000 devices prior to July 1982.

In Cell 1, HCCs are transported in "boats" which are loaded into and unloaded from each process. Through the use of robots, human intervention will occur after each group of ten HCCs, as opposed to each HCC in the current system.

Cell 2 is where HCC "burn-in" is accomplished. Automation of loading and unloading of HCCs for burn-in was shown to be the only area in cell 2 that would be cost effective.

The use of direct numeric control computers in cell 3 to accomplish the process of placing components on each CCA is expected to reduce touch labor by 90 minutes per CCA. Bar code scanning throughout cell 3 will track the movement and completion of each CCA. This information will be transmitted to the VAX 11/750 computer for real time work-in-process information.

Cell 4, the inspection station, will use a video inspection system which compares a good CCA to the assembly being evaluated. The operator determines if the comparison is satisfactory and communicates the results to the VAX 11/750 by touching a menu selection on a video terminal. The process

in cell 4 will allow all 135 types of CCAs to be tested on a common system.

Reconnaissance Warfare SPO Return on Investment.

Personnel and TDY costs associated with these Tech Mod programs are shown in Table XXII. Total number of manyears is 26.82. The savings and investment associated with these programs is depicted in Table XXIII. The return on investment without personnel cost is 15.3% while the return with personnel cost included is 12.2%.

TABLE XXII

Personnel Costs for Reconnaissance Warfare
Systems Program Office

Fiscal Year	Grade/Rank Percentage of Time				
	0-4	0-3	GS-9	GS-4	0-3
	50%	20%	20%	5%	10%
82	17,222	5,974	4,415	651	2,987
83	17,910	6,213	4,591	677	3,107
84	18,627	6,462	4,752	701	3,231
85	19,372	6,720	4,942	729	
86	20,147			758	
87	20,953			788	
88	21,791			820	
89	22,663			853	
90	23,569			887	
	Total		TDY	TOTAL	
82	31,249		13,900	45,149	
83	32,498		14,400	46,898	
84	33,772		15,000	48,772	
85	31,763		15,000	46,763	
86	20,905		15,000	35,905	
87	21,741		15,000	36,741	
88	22,611		14,000	36,611	
89	23,515		14,000	37,515	
90	24,456		14,000	38,456	

Source: (20)

TABLE XXIII

**Government Savings and Investment
Reconnaissance Warfare SP0**

Fiscal Year	Government Investment	Personnel Cost SP0	Indirect Cost	Total Investment
82	900,000	45,149	56,179	1,001,328
83	2,100,000	46,898	82,119	2,229,017
84	2,100,000	48,772	92,374	2,241,146
85	2,600,000	46,763	89,476	2,736,239
86		35,905	92,655	128,560
87		36,741	96,796	133,537
88		36,611	120,279	156,890
89		37,515	124,571	162,086
90		38,456	130,034	168,490

	Savings	Net Savings W/Personnel \$	Net Savings W/O Personnel \$
82		(1,001,328)	(900,000)
83		(2,229,017)	(2,100,000)
84		(2,241,146)	(2,100,000)
85		(2,736,239)	(2,600,000)
86	160,000	31,440	160,000
87	3,120,000	2,986,463	3,120,000
88	4,870,000	4,713,110	4,870,000
89	4,870,000	4,707,914	4,870,000
90	1,580,000	1,411,510	1,580,000

Return on investment with personnel cost 12.2%

Return on investment without personnel cost 15.3%

Source: (20)

VI. Findings and Recommendations

Productivity

Productivity growth within the United States has been on the decline for the past 10 years. Reasons attributed to this decline include: using older equipment for production; desire for an immediate return on investment while utilizing a lower rate of capital investment - throughout the nation, more investments have been made in labor versus capital equipment; and social programs such as OSHA and EPA. As reported by Mr. Dennison, productivity increased in the U.S. from 1948-73 due to increased emphasis on advancements in knowledge; increases in education; improvements in resource allocations; and economies of scale. But, since that time, the emphasis in these areas has declined causing a decline in productivity growth.

One theory as to the cause for the decline in productivity growth is that industries are continuing to rely on old technologies. According to the theory developed by the System Dynamics Group (see chapter 1; Technological Change), investments in old technologies will not appreciably improve the productivity growth rate. Rather, investments in the newer, developing technologies - solar energy, biogenetics, computers, etc., - will prove to be the best method to increase the growth of productivity.

While the DOD is aiding defense contractors in devel-

oping these new technologies, the transfer of information regarding these new developments is a major concern. For the DOD, this is an important concern due to an ever increasing desire for weapon systems to out-perform any system deployed by the Soviets or their allies. New technologies for production are required to meet the advances in the structural and electronic components of these new systems.

Technology Modernization and Productivity

The Technology Modernization Program was designed by the DOD to share increased productivity with defense contractors while reducing the overall price of a weapon system. The impetus of this program is to get defense contractors to invest in new, modern, technologically advanced equipment for the production of weapon systems and their components. Reduced system acquisition cost and modernization are not the only goals of the Tech Mod program. Others include industrial base/military worth considerations; such as shorter lead times, decreased use of critical materials, improved surge capability and the potential for technology transfer. The economic benefit of a Tech Mod is the return to be realized over the production life of a system.

The results of this study have shown that, through the Tech Mod program, contractors are investing in new equipment. According to this study, these investments appear to be saving the DOD money while allowing the contractor to realize an improved return on their investment. These

estimated savings, again, are subject to scrutiny due to the inability to adequately verify them.

The Air Force, Aeronautical Systems Division in particular, is conducting Tech Mod programs with thirty-four different contractors at differing levels of the contracting tier; prime contractor, sub-contractor, and vendor. The government plans to invest \$670,232,000 for productivity improvements with these contractors for an expected savings of \$2,025,230,000. The government's return on this investment, without personnel cost included is 178%; with personnel cost included, 171%. This return does not include the additional savings accruing to other USAF or DOD programs. They are attributable to specific programs as shown in Table XXIV. Table XXV shows the aggregated investment, personnel cost, and savings for each year of ASD's involvement in Tech Mod.

Table XXIV

Savings and Investment Data for All ASD Tech Mod Programs
(in 000s)

Program Office	Govt. Inv.	Pers. Cost	Savings	Svgs Less Investment
F-16 SPO	193,300	1,613	573,500	378,587
B-1B SPO	40,000	1,705	97,800	56,095
Airlift and Trainer SPO	89,254	2,501	337,750	245,995
Propulsion SPO	339,000	2,216	1,025,900	684,684
Tactical Fighter SPO	978	1,001	2,109	130,000
Reconnaissance Warfare SPO	7,700	1,257	14,600	5,643

TABLE XXV

**Aggregate Return on Investment for All Tech Mod Programs
(in 000s)**

Fiscal Year	Gvmt. Inv.	Pers. cost	Savings	Net Sugs. w/Pers \$	Net Sugs. w/o pers \$
77		33		(33)	0
78	4,800	34		(4,834)	(4,800)
79	5,400	139	10,200	4,661	4,800
80	6,700	251	22,900	15,949	16,200
81	9,350	268	30,500	20,882	21,500
82	18,200	963	24,200	5,037	6,000
83	39,049	1,149	31,102	(9,096)	(7,947)
84	105,820	1,206	41,077	(65,949)	(64,743)
85	81,672	1,174	120,608	37,762	38,936
86	94,826	1,173	222,928	126,929	128,102
87	78,000	1,174	310,847	231,673	232,847
88	86,415	1,013	344,894	257,466	258,479
89	79,500	1,032	407,369	326,837	327,869
90	60,500	1,054	458,605	397,051	398,105
	670,232	10,662	2,025,230	1,344,336	1,354,998

Similarities Between Tech Mod Programs

The premise of this study was to determine if the savings generated by each Tech Mod program, would be as great if the government's management costs were included. The basis of this premise was that "33 manyears of effort are expended on a typical Tech Mod program". This study shows that the average is 38.99 manyears per SPO with a standard deviation of 12.4 manyears. Another result of this study is that there is no "typical" Tech Mod program. Savings, as well as, investments, both contractor and government, are based on the capabilities of each program.

There are very few similarities among these Tech Mod programs. The main theme that all have in common is that

they are functionally managed by the personnel within the Manufacturing Directorates of the SPOs. This was one complaint proposed by the Tech Mod managers. They believe the programs should be managed in the Special Projects Directorates of the SPO in order to have complete visibility into all aspects of the program. This management concept is being used in the Airlift and Trainer SPO. But, the manufacturing personnel appear to have an in-depth knowledge of all aspects of the program.

Another similarity between each of the programs is that there are not enough personnel assigned to the programs to fully understand each program. One person stated that the Tech Mod program in his SPO was being managed on an ad hoc basis; the program was assigned to no one in particular. When an urgent requirement for the program arose, the first available person was assigned to work the problem.

Project Managers' Perceptions of Tech Mod.

Along with reducing costs and raising productivity for specific contractors, the goal of Tech Mod is to encourage all contractors to modernize or update their production facilities. Many of the project managers contacted in this study, have stated that Tech Mod has achieved this goal. Contractors have contacted the SPOs to determine if they are eligible for the program. If they are requesting aid to upgrade their factory, with off-the-shelf technologies, they are not eligible. But, if they want to invest in new technologies, beneficial to the DOD, they are eligible for

the program. Many contractors, unable to receive the seed monies, are requesting incentive provisions in their contracts for doing the investment on their own. The project managers believe the cause for this turn-around on the investment scene is due to the perceived competitive edge the current Tech Mod contractors have over the defense industry.

For those contractors not currently involved in Tech Mod, or are seeking new contracts with the government; capital investment in modern equipment or proposed Tech Mod programs is becoming a major factor in the source selection process. As stated previously, the contracts for the Seek RAM and INEW systems have Tech Mod programs as one of the considerations for source selection.

A concern espoused by the project managers is the lack of adequate means for the transfer of information on current manufacturing improvements. This lack is especially pronounced in the contractors' arena. Current methods for getting information to all the contractors include: Defense Technical Information Center (DTIC); an annual "Industries Day" where all contractors display their best production capabilities; and, the National Technical Information Services which publishes one-page briefs describing completed manufacturing technology projects.

Concern was also expressed for the exchange of information between the services; Air Force, Army, Navy, and other governmental agencies. The means of transferring information are much the same as those used for the contractors. Yet,

the resources available are not well enough known or adequate for the type of information necessary to make an investment/improvement decision.

Recommendations for Further Study

With Tech Mod Project Managers being concerned about the lack of transfer of information, a better system to aid in the dissemination of this information may need to be developed. This study did not specifically address this problem if in fact it does exist. A better understanding of the data requirements on each Tech Mod contract is needed before the issue can be addressed. Currently, each contractor submits an end-of-phase report to the government addressing the methods used to determine the technologies developed as well as a technical report on the status of each phase of the program.

Tech Mods' goals include decreasing the need for critical materials, reduction of the lead times for weapon system production, and improving the surge capability of defense contractors. Here, again, this aspect of the Tech Mod program was not addressed in this study. The accomplishments of these goals might be determined by looking at Rockwell's Tech Mod program. The Aluminum Precision Forging project, in particular, may be helpful in reducing critical materials as well as reducing lead times.

A continual look at the current Tech Mod programs is needed. Areas of concentration would be on the savings

reported by the contractors. Many of the programs, General Dynamics, Lockheed and others, purport to save the DOD monies on different programs other than the ones for which they were structured (F-16, C-5A). Although the savings accruing to these programs may not be determined on the surface, an analysis of the rate of cost growth from an older weapon system to a new one may indicate if savings have occurred. Other potential comparison areas lie in the General Dynamics program, should they be awarded a contract for the Advanced Tactical Fighter, or the Rockwell program, should the current acquisition extend beyond 100 aircraft. These two programs are subject to the acceptance and approval of Congress.

Other areas of investigation might include an analysis of the contractor's annual reports. Has their return on investment ratio changed? Has there indeed been an increase in capital equipment expenditures? Are there plans to continue investment in current technologies, or will these contractors stagnate in the investment arena once the Tech Mod program has been completed?

Related to the contractor's investment decisions, a study comparing those contractors currently involved in Tech Mod with those who are not, should be undertaken. This study could lend greater or less support to the total concept of the Tech Mod program. This, in turn, may lend greater credence to the use of multiyear contracting and other methods the DOD has arranged for reducing weapon system costs while increasing productivity.

Bibliography

1. "A Technology Lag That May Stifle Growth," Business Week, 2740: 126-130 (October 1982).
2. Aeronautical Systems Division, Air Force Systems Command. A Guide To Technology Modernization and Contracting For Productivity. Wright-Patterson AFB OH: AFSC, 1982.
3. Air Force Institute of Technology. Readings for Systems Production Management. Wright-Patterson Air Force Base OH, 1983.
4. Air Force Systems Command. Profit Study '82 Summary Report. DCS/Contracting and Manufacturing, Andrews AFB MD, 1983.
5. Air Force Systems Command. Technology Modernization (Tech Mod)/Industrial Modernization Incentives Program (IMIP) Policy. Andrews AFB MD: AFSC, 1983.
6. Brower, Major Denny, Chief, Manufacturing, Quality Assurance Tanker/Cargo and Trainer Division. Personal interview. ASD/AFDY, Wright-Patterson AFB OH, 6 July 1984.
7. Bulban, Erwin J. "Boeing's Wichita Facility Plans Plant Modernization," Aviation Week and Space Technology, 117: 48-50 (August 1982).
8. Castore, Carolyn P., et al. "Perspectives on Productivity in the US Defense Establishment," National Productivity Review, 2: 482-489 (Autumn 1983).
9. Ciscel, Captain David, B1-B Technology Modernization Program Manager. Personal interview. ASD/B-1B, Wright-Patterson AFB OH, 29 June 1984.
10. Congressional Budget Office. The Industrial Policy Debate. Washington: Government Printing Office, 1983.
11. Denison, Edward F. "Explanations of Declining Productivity Growth," Survey of Current Business Part II, 59 (8): (August 1979).
12. Department of Commerce Bureau of the Census. Statistical Abstract of the United States 1982-83. 103d Edition. Washington: U.S. Government Printing Office, 1982.

13. Department of the Air Force. Contracting and Acquisition: Should Cost. AFP 70-5. Washington: HQ USAF, 19 September 1979.
14. Department of the Air Force. Cost Accounting Standards Administrative Guide. AFCMD 70-33. Kirtland AFB NM: HQ AFCMD, 26 November 1980.
15. Edmond, Michael R. Macroeconomics Theory and Policy. Englewood Cliffs NJ: Prentice-Hall, Inc., 1983.
16. Ehler, Major William, Technology Modernization Program Manager for Deputy for Propulsion. Personal interview. ASD/YZD, Wright-Patterson AFB OH, 14 June 1984.
17. Ferrel, David D., Deputy Director Manufacturing and Quality Assurance. Personal interview. ASD/TAD, Wright-Patterson AFB OH, 12 June 1984.
18. Forrest, Major Al, Chief Electronics Division Manufacturing and Quality Assurance. Personal interview. ASD/RWDE, Wright-Patterson AFB OH, 14 June 1984.
19. Gansler, Jacques S. The Defense Industry. Cambridge MA: MIT Press, 1982.
20. General Accounting Office. Impediments to Reducing the Costs of Weapon Systems. Washington: Government Printing Office, November 1979.
21. General Dynamics, Industrial Technology Modernization: Program Introduction Plan, General Dynamics Corporation, 1 May 1983.
22. Gillespie, Major David, Technology Modernization Program Manager. Personal interview. Air Force Materials Laboratory, Wright-Patterson AFB OH, 26 June 1984.
23. Gray, Captain David L. and Lieutenant Larry W. Sanders, Multiyear Subcontractor Selection Criteria Analysis. MS Thesis, LSSR 106-83. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1983 (AD-A135 638).
24. Groover, Mikell P. Automation, Production Systems, and Computer-Aided Manufacturing. Englewood Cliffs NJ: Prentice-Hall, 1980.
25. Guralnik, David B., Editor in Chief. Webster's New World Dictionary. New York: World Publishing Company, 1972.

26. Heaton, George R. and Herbert J. Holloman. "Diffusing Technical Knowledge: A National Imperative," Technology Review, 86: 12-14 (October 1983).
27. Holmes, Peter A. "How to Match Money with Ideas," Nation's Business, 71: 29 (September 1983).
28. Johnson, Lieutenant Scott, Deputy Technology Modernization Program Manager for F-16. Personal interview. ASD/YPMA, Wright-Patterson AFB OH, 14 June 1984.
29. Kendrick, John W. et al. New Developments in Productivity Measurement and Analysis. Chicago: The University of Chicago Press, 1980.
30. Koechel, Captain Brian and Captain David Odor, Assistant Director HQ AFSC/PMI. Personal Interview. HQ AFSC/PMI, Wright-Patterson AFB OH, 6 December 1983.
31. Kolcum, Edward. "C-5A Wing Modification Using Advanced Methods," Aviation Week and Space Technology, 117: 51-53 (August 1982).
32. Lehn, Lloyd L. PhD. "DOD Manufacturing Technology Program," National Defense, 63: 42-44 (May/June 1979).
33. Lindstrom, F. S., et al, F-16 Technology Modernization Phase III - Detailed Work Center Design and Enabling Technologies. General Dynamics Final report to F33657-80-G-0007, December 1983.
34. McMahan, Andrew H., "F-16 Program Spurs Modernization," National Defense, 72: 312-313 (January/February 1978).
35. Moeller, 1Lt Roger, Project Officer Centralized Technology Modernization Office. Personal interview. ASD/PMDPP, Wright-Patterson AFB OH, 18 May 1984.
36. Porter, Roger B. "Perspectives on Productivity: America's Productivity Challenge in the 1980s," Public Productivity Review, 7: 68-81 (March 1983).
37. Reeves, Douglas A., "The Industrial Modernization Incentives Program: An Experimental Effort to Improve Defense Contractor Productivity," Seminar, 135-142 (November 1983).
38. "Robots Enhance Drilling Productivity," Aviation Week and Space Technology, 117: 77-79 (August 1982).

39. Seidman, L. William. "The White House Conference on Productivity," National Productivity Review, 2: 420-422 (Autumn 1983).
40. Skousen, Fred K., et al. Principles of Accounting. New York: Worth Publishers, Inc., 1983.
41. "The Costly High Cost of Capital," Technology Review, 86: 86 (October 1983).
42. "The Saving Rate: How Serious the Decline?," The Morgan Guaranty Survey, 11-15 (February 1980).
43. Tregoe, Benjamin B., "Productivity in America: Where it Went and How to Get it Back," Management Review, 72: 23-28 (February 1983).
44. United States Air Force. Production Base Analysis (U) for FY 83. Wright-Patterson AFB OH., January 1983.
45. United States Congress. House of Representatives. Defense Industrial Base Panel. The Ailing Defense Industrial Base: Unready for Crisis. Washington: Government Printing Office, 1980.
46. United States Government. Federal Acquisition Regulation: DOD Supplement. Washington: 1 April 1984.
47. Waite, Jim, ASD/PM. Memorandum to ASD/TA, ASD/B1, ASD/YP, ASD/YY. Subject: ASD Aircraft Sector Analysis. 25 January 1983.
48. Wall, Maj Richard J. "Depreciation Policy Reform and the Defense Industrial Base," Defense Management Journal, 18: 29-49 (Third Quarter 1982).

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This investigation outlines the factors affecting the slowed productivity growth in the United States with emphasis on Department of Defense contractors. One of the primary causes of this phenomena is a reduction in investment for capital equipment.

The Technology Modernization Program was designed to assist defense contractors in capital investment decisions. The contractors and the government are reporting large savings as a result of the Tech Mod program.

This study is a look at the government's investments in ASD's Tech Mod programs, the type of capital equipment being purchased by the contractors, and the government's management costs for the programs. The analysis of the government's investments, money and personnel, was made to determine the overall return on investment rate for a particular program.

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