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THE DEPARTMENT OF DEFENSE CONTRACTOR INVESTMENT POLICY MODEL

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The primary aim of this system dynamics study was to understand aerospace defense contractor investment behavior, and evaluate government policies designed to motivate investment in capital within the current fighter/attack aircraft manufacturing market structure. The approach taken analyzes investment projects and capital equipment expenditure flows that arise as a result of the overall decision framework of the firm. The continuous corporate computer simulation model addresses several of the determinants which enter into the capital investment decision. The experimental design includes analysis of various tax and profit policies. Simulation results suggest that increased capital investment is closely linked to the amount of aircraft orders. Consequently, the short-term motivator of increased capital investment is a higher market demand. Tax and profit policy changes, as those suggested by Carlucci Initiative #5, have minor and only long-term effects on the rate of capital investment.

1. Introduction

In April 1981, former Assistant Deputy Secretary of Defense Frank C. Carlucci revealed the DOD Acquisition Improvement Package which consists of 32 fundamental changes in the management of weapon system acquisition. A major focus of most of the proposed changes is the revitalization of the defense industrial base. One particular proposal, Initiative #5, is targeted toward the implementation of policy initiatives to "Encourage Capital Investment to Enhance Productivity" (Carlucci 1981). It reads:

> Productivity in the defense sector of the U.S. economy has been lagging, in large part because of the low levels of capital investment compared to U.S. manufacturing in general. Cash flow problems, tax policy, high interest rates, and low return on investment (ROI) tend to limit available investment capital. This industry views low profits and program instability as precluding investment in capital equipment. This situation has two major implications: a tendency to shift from defense to commercial business, and a decrease in funds available for facilitization (Carlucci 1981).

Actions recommended by Initiative #5 were:

> ... permit more rapid capital equipment depreciation ... modify the Defense Acquisition Regulation (DAR) profit formula ... provide for negotiation of profit levels commensurate with risk and contractor reinvestment (Carlucci 1981).

The ideas presented in Carlucci's Acquisition Improvement Package are not totally new. A major study on the weapon acquisition process and contractor incentive policy was performed in the early 1960's by Peck and Scherer. They published two books which addressed a multitude of weapon procurement problems, and offered various incentive policies to help solve identified problems (Peck and Scherer 1962, Scherer 1964). Fox conducted a more recent study of weapon acquisition problems and their solutions (Fox 1974). In 1976, DOD conducted an introspective study on profit policy (U.S. Department of Defense 1976). Called "Profit 76", it called for an increase in the weight of allowable profit from 5 to 10 per cent, based on defense contractor's investment in plant and equipment. Presently, this weight ranges from 16 to 20 percent. More studies and articles that address the task of motivating defense contractor investment have been published since 1976 (Bertrand 1976, Babione 1977, Grossman 1978, U.S. Air Force 1980, Janicke 1980, Lewin 1981, Simonson 1981). The reexamination of incentive and profit policy suggests that there is little understanding of defense contractors' motivators of capital investment activity.

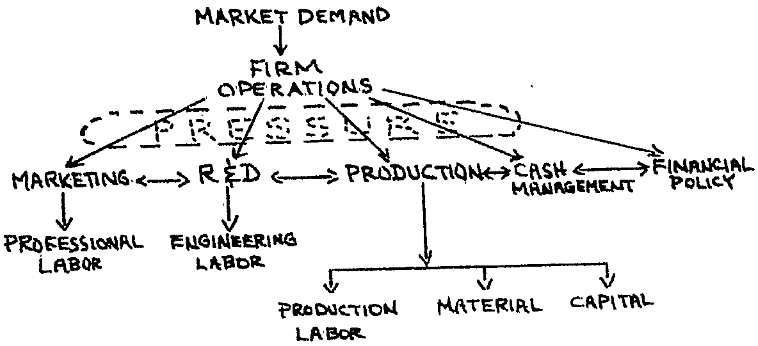

Figure 1. Overall System Relationships

Additionally, it seems that only a retrospective look is the approach taken to evaluate the effectiveness of candidate capital investment incentive policies. Hence, the purpose of this research was to analyze the structure of the capital investment process of a typical contractor in the fighter/attack segment of the defense aerospace industry, and to build a dynamic policy model which represents that structure. The model could then be an interactive tool for the policy maker to evaluate input incentive policies and output investment behavior effects. The conceptualization and validation of such a structural model was the overall objective of this study.

Traditional analysis of the capital investment process stresses equilibrium analysis. However, as Bonini (1963) stressed in his corporate simulation study, many of the forces at work in a firm are indirect or second-order effects. For this reason, the system dynamics methodology, with its ability to incorporate the complex feedback structures of this system, is appropriate.

The model consists of over 400 difference equations written in DYNAMO, a FORTRAN-based continuous simuation language whose development parallels the evolution of the system dynamics methodology (Pugh 1970). The 400 equations represent the flow of money, men, material, information, and capital equipment within the firm. Although the particular activity of interest for DOD policy makers is the capital investment process, they would want to insure that unforeseen and unintended side influences on such things as personnel or material stability did not occur. The model organizes these equations into ten sectors. These sectors, shown in Figure 1, include the managerial decision structures that determine capital investment (CAPITAL SECTOR), the hiring and firing of employees (PROFESSIONAL, R&D ENGINEERING, and PRODUCTION WORKFORCE SECTORS), the acquisition of raw materials and subcontracted parts and components (MATERIAL SECTOR), and the acquisition and expenditure of firm funds (CASH MANAGEMENT and FINANCIAL POLICY SECTORS). These decision activities are a function of orders received (MARKET SECTOR) to either produce aircraft (PRODUCTION SECTOR) or advance product design technology (R&D or TECHNOLOGY SECTOR). Capital investment behavior and the policies affecting the flow of funds so vital to realizing investment plans are principally contained in three of the ten sectors: the CAPITAL, CASH MANAGEMENT and FINANCE POLICY SECTORS. The next section discusses these three sectors.

2. Sector Structure Discussion

2.1 Capital Sector

The relationships mathematically expressed in this sector incorporated some of the theoretical concepts found in the statistical economic and the system dynamics literature (Chenery 1952, Koyck 1954, Jorgenson 1968 & 1970, Mass 1975). The overall orientation of the investment function is of the stock-variable variety that has been argued by system dynamicists to be more appropriate for economic modeling (Mass 1975). The capital investment function formulated in this model is oriented towards capturing three stated reasons for capital investment related both in the literature (Eisner 1958 & 1972, Feldstein and Foot 1971) and by aerospace defense contractors during personal interviews. These reasons, stated as investment categories, and in order of precedence, were the following: (1) necessary or replacement investment; (2) expansion investment to qualify for contract consideration; and (3) modernization investment.

Similar to the capacity accelerator model of investment behavior developed by Chenery (1952) and Koyck (1954), this model's investment function has capital adjusting toward its desired level based on the discrepancy between desired and actual capital for each time period. This is depicted in the first of two negative feedback loops of the capital sector casual structure (see Figure 2). Casual diagrams use arrows to indicate relationships between variables. The sign (+ or -) associated with each arrow indicates whether an incease in one variable (CAPITAL INVESTMENT) causes an increase in a second (CAPITAL STOCK) thereby receiving a "+" designation or whether the first variable (CAPITAL STOCK) causes a decline in a second (DESIRED CAPITAL) thereby receiving a "-" designation. Any continuous loop with an odd number of negative arrows is called a negative feedback or goal-seeking loop since the relationships tend to be self-stabilizing. On the other hand, an even number of negative arrows in a loop creates what is known as a positive feedback or selfreinforcing loop (Richardson and Pugh 1981). The first negative loop controlled the amount of capital invested so that overshoot and collapse behavior would not be exhibited by the firm.

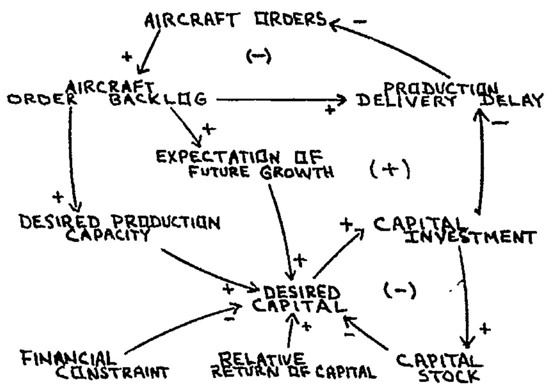

Figure 2. Capital Sector Casual Diagram

The determination of desired capital is a very important relationship in the contractor investment policy model. As shown in the casual loop structure, there are five major factors to desired capital.

Two of the five factors in the formulation of desired capital are desired production capacity, and expectation of future firm growth. These two variables are used in descriptions of the generalized accerlerator model of investment, but rather than just sales influencing desired production capacity, backlog of aircraft orders is also used. Desired production is equal to the average amount of production units coming into the system as aircraft orders plus a correction factor for aircraft order backlog. When backlog is equal to its desired value, the firm's productive capability is adequate to cover demand. But if backlog becomes excessive, there will be pressure to expand output, and consequently desired capital will increase if all other relationships are constant. Aircraft order backlog also infludences the factor labeled as "expectation of future growth." The incorporation of future growth expectations is similar to accelerator theory of investment (Low 1976) for desired capital is adjusted by the average fractional annual growth rate in production output.

The importance of aircraft order backlog is apparent. Aircraft order backlog is part of the second negative feedback loop of the capital sector that includes production delivery delay and aircraft orders. An increasing amount of aircraft orders will increase aircraft order backlog, which in turn increases the production delivery delay time of the orders entering the system. An increasing delay time will then have a negative effect on the number of aircraft orders. The buyer has some maximum threshold value for product delivery time, and will look elsewhere if his timetable is not satisfied. Such action was demonstrated when the Navy threatened alternatives to the F-18 weapon system when that program encountered scheduling difficulties. Aircraft order backlog is also within a major positive feedback loop structure of the sector. An increase in backlog will increase desired production capacity, which then causes an increase in desired capital. A higher desire for capital will increase the amount of capital investment which makes the firm's productive process more efficient. A more efficient production process will decrease production delivery delay which consequently attracts more aircraft orders, and the feedback loop depicted in the figure is completed.

The third factor to desired capital is determined similarly to the neoclassical theory of investment (Jorgenson 1963, 1968 & 1970 Jorgenson and Stephenson 1963). A Cobb-Douglas production function generates a capital-labor ratio which minimizes production costs. Thus, the goal of profit maximization is attained by adjusting capital intensity due to the relative return of each factor of production. But unlike the neoclassical model, this system generates orders for capital equipment that enter into a planning and scrutinization process rather than actual capital investment expenditures. In this way, the ideal capital desires can be tempered by real world operating constraints such as organizational politics and the firm's current financial ability.

The fourth factor influencing the investment decision was the embodiment of technology in capital stock. This was included in the system model to reflect that pressure which would be exerted to modernize the firm's capital base as a result of the technological capability of the competition. Previous studies have highlighted the contractors' perception of DOD's overriding concern with state-of-the-art technology in its selected weapon systems (Peck and Scherer 1962). Technology embodied in plant and equipment is a very important component of technical change:

> Technical progress is linked very directly with the process of capital accumulation; each successive investment decision may involve the purchase of equipment of a type qualitatively different (presumably more productive) than those already in use, and hence any gross investment (even if purely to replace existing equipment) tends to raise productivity (Clark 1980).

The literature on previous capital investment models did not reveal a direct orientation of technology embodiment in capital. Technology in capital stock is addressed in the investment function because "in the short run, the existing stock of physical plant and equipment obviously is an important factor in determining the extent to which technology can be applied" (Nelson, Peck and Kalachek 1967).

The last factor in determining desired capital is "financial contraint." Financial contraint impacts the system's investment behavior via the capital rationing process:

.... Capital rationing may be defined as a situation in which an organization does not have and is unable to make all of the investments that meet its usual financial criteria of profitability or its nonfinancial criteria for justification (Fregmen 1972).

In a survey of the actual practices used by financial managers in 177 business firms connected with major capital investment decisions, 72% of the respondents with a capital budget over $100 million reported experience with capital rationing (Fregmen 1972). Hence, capital equipment orders, which are the end result of the previous four investment factors (present quality of capital stock, amount of desired capital determined by desired production, desired capital intensity, and future growth expectations), are scrutinized over a six month planning period. The model implicitly assumes some portion of the total capital equipment orders do not meet specified ROI criteria. This reflects equipment orders which fail to clear the initial financial scrutiny. However, explicit consideration is given to what the firm's financial status would become if the remaining capital orders are committed, and orders are executed if financial ability of the firm warrants the expenditure commitment.

2.2. Cash Management Sector

The cash management sector provides quantitative measures of firm performance. It maintains the flow of dollars through several types of accounts. There are three distinct parts to the cash management sector: Balance sheet relationships, income statement relationships, and financial information relationships (i.e., ratios such as current ratio, dept-equity ratio). The information created by this sector is used by other sectors in major feedback structures, and also used for comparison purposes with actual defense aerospace firm data to ascertain the model's mode reproduction ability, and descriptive realism.

Money flows into the firm via increased reimbursements from the U.S. Government. These reimbursements are either for research and development work or production work (see Figure 3).

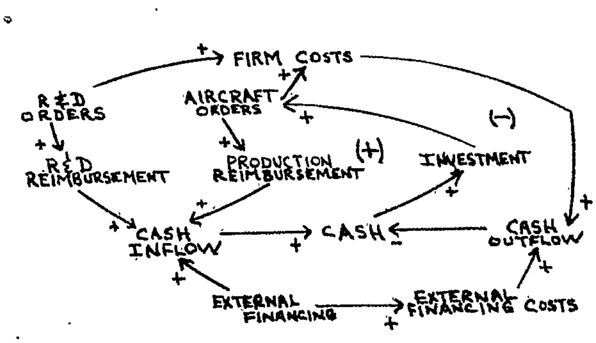

Figure 3. Cash Management Causal Diagram

Timing and the amount of government reimbursement to the contracting firm are critical because of cash flow considerations. An increase in government orders for R&D and production work increases the cost of firm operations, and consequently cash outflow is also increased. Notice also that the increase in work contracts received also increases total reimbursements and cash inflow. Government regulations and policies on what are allowable reimburseable costs of contract performance, and determination of profit greatly affect the amount of cash inflow. Thus, the reconciliation of these two flows, cash inflow and cash outflow, affects the overall level of cash over time. All other variables remaining constant, an increase in cash or internal funds available will increase the ability of the firm to begin capital investment projects. Increased investment will attract more orders for aircraft, reimbursements will increase, and thus a major positive feedback loop is established. However, this positive feedback structure is counterbalanced by the possible need of the firm to obtain external financing with its associated costs to fund capital investment projects. So a negative feedback loop structure that consists of cash outflow, cash, investment, aircraft orders, and firm costs illustrates the constraining effect that cash flow has on the amount of firm capital investment expenditures.

2.3 Finance Policy Sector

A realistic approach to simulating investment behavior must consider the situation of limited financial resources. The financial sector of the model specifies the manner in which the firm borrows (DEBT FINANCING), issues stock (EQUITY FINANCING), and pays dividends. The reason for production sector and market sector variables in the casual loop structure (see Figure 4) is to illustrate that in the absence of any financial constraints on ordering production capacity, customer order rate provides the driving force behind production capacity orders. Financial resources are limited, therefore, investment in production capacity is restricted.

There are two major feedback structures which influence the investment process. The first structure is a negative feedback loop, whose goal is to keep investment expenditures equal to some percentage of the supply of the financial resources available to the firm. The second structure is positive feedback, and it generates increased cash flow from investment. Therefore, the second feedback structure creates an increased supply of financial resources for future investment.

In the negative feedback loop, an increase in production capacity orders leads to an increase in production capacity arrivals, and therefore an increase in investment expenditures. The greater investment expenditure causes the firm to increase debt financing. Increased debt financing increases the level of debt outstanding, and raises the debt-equity ratio and lowers the current ratio. These ratios are hypothesized to be the major criteria used by banks for constraining the supply of financial resources availalbe for future capital orders in increasing production capacity of the firm.

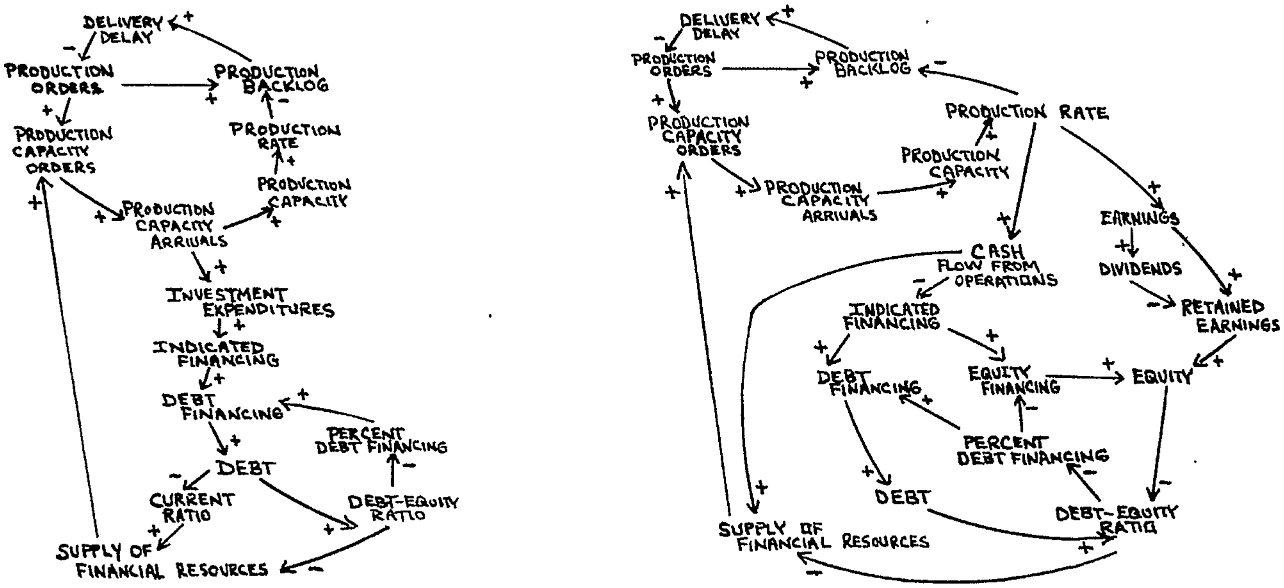

Figure 4. Finance Policy Sector Causal Diagram

The positive feedback loop begins with an increase in production capacity orders that eventually increases the production rate. An increase in production rate increases both cash flow from operations and earnings. An increase in cash flow reduces indicated financing and therefore debt financing. As less debt accumulates, the company has more flexibility to allocate and obtain funds for future investment. The increase in the firm's earnings also results in an increase in equity and a reduction in the debt-equity ratio which consequently loosens financial constraints. Thus, an increase in investment, working through the positive feedback structure, has the effect of generating a greater supply of financial resources for future investment.

In conclusion, this structural discussion of the model has characterized the model's investment function as a derivative of capacity accerlerator theory of investment. Capacity accelerator motivation was deemed to be more important than profits or interval funds in explaining the cyclical path of investment. Nevertheless, profits and interval funds available have an important role in the model as they are important determinants to the rate at which the firm's capital stock increases toward a desired level of capital. Moreover, the desired level of capital is also based on profit maximization via a Cobb-Douglas production function which calculates the relative returns of the factors labor and capital. Hence, the theory of capital rationing, and neoclassical theory of investment are also woven into this model's investment function.

3. Verification and Validation

The model developed during this study was subjected to testing in order to establish confidence in its soundness and usefulness as a tool to evaluate proposed DOD policies to motivate increased capital investment. System dynamics models do not rely on probabalistic events to predict behavior. Rather, they rely on the presumption that system behavior is a necessary consequence of the overall system structure and the interrelationships among the system variables and parameters. For this reason, the verification and validation of a system dynamics model must follow a different approach. Forrester and Senge detail a number of tests to build confidence in a model (Forrester and Senge 1980). Several of these tests, shown in Table 1, were performed on the model.

The behavior characteristic test revealed interesting results. Model generated financial ratio data was compared to actual composite data from the five firms representing over 97% of the fighter/attack market in the United States. For practically all categories of ratios, the model output was generally in the same range of behavior. In fact, return-on-sales (ROS), return-in-investment (ROI), total asset turnover (TAT), and the debt-to-equity ratio (DER), were very close to actual data obtained from several sources (see Table 2). Consequently, since the model has shown similar patterns of financial ratio behavior as the actual system, the confidence in the relative sizing of the firm's functional areas was heightened. The use of

Tests of Model Structure

1. Structural Verification
2. Parameter Verfication
3. Extreme Conditions
4. Boundary Adequacy
5. Dimensional Consistency

Tests of Model Behavior

1. Behavior Reproduction
2. Behavior Prediction
3. Behavior Anomaly
4. Family Member
5. Surprise Behavior
6. Extreme Policy
7. Boundary Adequacy
8. Behavior Sensitivity

Tests of Policy Implications

1. System Improvement
2. Changed Behavior Prediction
3. Boundary Adequacy
4. Policy Sensitivity

Table 1. Confidence Building Tests

SOURCE: Stanford Research Institute (SRI)
DATA TYPES: ROI, ROS, ROE, TAT
Aggregation: Aerospace Weighted Average
Time: 1947-1961

		MODEL	
	SRI AVG	RANGE	AVG
ROI	6.3	5.0-10.0	7.0
ROS	2.6	3.0- 4.0	3.5
ROE	11.7	5.0-12.0	9.0
TAT	2.4	1.8- 2.1	2.0

SOURCE: Hughes Corporate Financial Planning (21 Sep 82)
DATA TYPES: ROI, ROS, ROE, TAT, CR, DER
Aggregation: Firm (3 in fighter/attack market)
Time: 1976-1981

	HUGHES		MODEL	
	RANGE	AVG	RANGE	AVG
ROI	3.7-9.5	7.1	5.0 -10.0	7.0
ROS	2.4-5.7	4.0	3.0 - 4.0	3.5
ROE	9.4-24	13.0	5.0 -12.0	9.0
TAT	1.3-2.3	2.1	1.8 - 2.1	2.0
CR	1.4-2.4	2.2	1.4 - 3.0	2.0
DER	.1- .25	.15	.18- 0.50	.2

SOURCE: Standard & Poors Industry Surveys (7 Oct 82)
DATA TYPES: ROI, ROS, ROE, CR, DER
Aggregation: Firm (five firm fighter/attack)
Time: 1977-1981

	S & P		MODEL	
	RANGE	AVG	RANGE	AVG
ROI	2.0-12.5	6.6	5.0 -10.0	7.0
ROS	1.1- 6.0	3.3	3.0 - 4.0	3.5
ROE	5.4-33.6	16.3	5.0 -12.0	9.0
CR	1.1- 4.2	1.7	1.4 - 3.0	2.0
DER	.2- .45	0.15	.18- 0.5	.2

Table 2. Financial Ratio Data

financial ratios, regarded as critical by financial analysts in the study of corporate behavior, offers promise in the verification and validation of many types of corporate simulation models.

Results obtained during the model structural and behavioral testing supported the interval consistency and output plausibility of the model.

Experimentation on the impact of various governmental policies could now be performed. A key concern was the development of a sound experimental design to test alternatives.

4. Experimental Design

The objective in research design is to highlight the effects that would follow from the introduction of new DOD profit policy or government tax policies. Governmental policy makers need to know which incentive policies for investment are central to motivating aerospace defense contractors. By virtue of taxing, spending, lending, and regulating powers, government policy makers are in a position to modify incentives and disincentives to investment brought to bear on defense firms.

The choice of experimental variables was dictated by those variables which policy makers can and are willing to control, or might reasonably learn to control. Carlucci Initiative #5 alluded to variables that impact firm financial status. Thus, the variables used in this research design as experimental variables were the following: accelerated depreciation, facility investment weight range within the weighted guidelines of profit negotiation, investment tax credit, and the corporate tax rate. The major output variable used was the investment-to-sales (IVS) ratio exhibited by the firm because it reflects investment activity undertaken by the firm (that activity desired to be stimulated by governmental policy). Other variables were observed to fully characterize the system. Experimentation was limited to investigating the separate effect of each experimental variable on the capital investment profile of the firm. Two or more experimental variables in combination are possible if it was deemed that the combination might be more attractive for motivating defense contractor capital investment. This would involve a full or partial factorial design on a scale undertaken by

Bonini (1963). However, for simplicity only separate effects were analyzed.

A diagram of the model experimental design is shown in Figure 5. This design was first applied to the model of a typical defense firm which has access to the financial markets if its financial condition permits banks or institutions to offer funds availability. The design was also performed on the model with an environment that had no external financing available. In both cases, with or without external financing, the design expanded to three different types of demand streams: stable, unstable, and more unstable. This procedure allowed examination of the robustness of the policies under varied conditions. For example, one policy run might be designated "A-1-a". This would reflect testing of an accelerated depreciation policy on a firm with financing readily available and experiencing stable market demand.

FINANCIAL ENVIRONMENT	1			2		
DEMAND PROFILE / POLICY	a	b	c	a	b	c
A						
B						
C						
D						

Figure 5. Experimental Design

1 -- Firm with Financing Readily Available

2 -- Firm with Constrained Financing

A -- Accelerated Depreciation Policy

B -- Facilities Investment Profit Policy

C -- Investment Tax Credit Policy

D -- Corporate Tax Rate Policy

a -- Stable Market Demand

b -- Unstable Market Demand

c -- More Unstable Market Demand

5. Results

Analysis of the simulation model output from the experimental design revealed that the most effective way that rejuvination of the industrial base can be stimulated is through increased government demand. Figures 6, 7, and 8 depict the strong lagged relationship between aircraft order backlog and subsequent capital investment levels. This relationship is not surprising and supports the satistical work of Collins (1981) on the matter. This approach has historically been taken by the U.S. Government (Barker and Konwin 1982). Preliminary indications on the impact of President Reagan's defense buildup show a strong, positive correlation between increased procurement rates and investment-to-sales figures; recent Standard & Poor's Aerospace Basic Analysis data indicates that the aerospace sector IVS was near 10% for the 1981-1982 time period. While this approach may not be considered economically and politically palatable for a long period of time, measured use of elevated procurement levels and continued use of contracting tools and procurement strategies such as multi-year procurement and contract termination protection clauses can do much to remove financial risk from the contractor community.

On the other hand, all candidate policies included in Carlucci Initiative #5 had only minor and long-term impact on investment-to-sales behavior. Investment-to-sales rates vary by less than 1% and require 15-20 years for noticeable changes from the baseline rates. Therefore, the type of involvement the government elects to pursue in its efforts to revitalize the defense industrial base depends on the government's purpose and timetable. For a more thorough discussion of experimentation results, see Barker and Konwin (1982).

6. Conclusions

The policy model developed and tested to characterize the capital investment behavior in a typical fighter/attack manufacturing firm showed a strong casual relationship between the backlog of unfilled orders (BUO) and investment-to-sales (IVS). BUO generally leads IVS by one year and therefore the most direct and effective motivator of capital investment remains an elevated production order rate. Given that backlog is the major determinant and that other policy effects are minor, the issue of whether there should be additional governmental involvement in profit policy, tax policy, or government secured loans is a critical management question. The recommendation of this research indicates that the money and effort that might be used in these policy areas might be better spent on increased hardware orders.

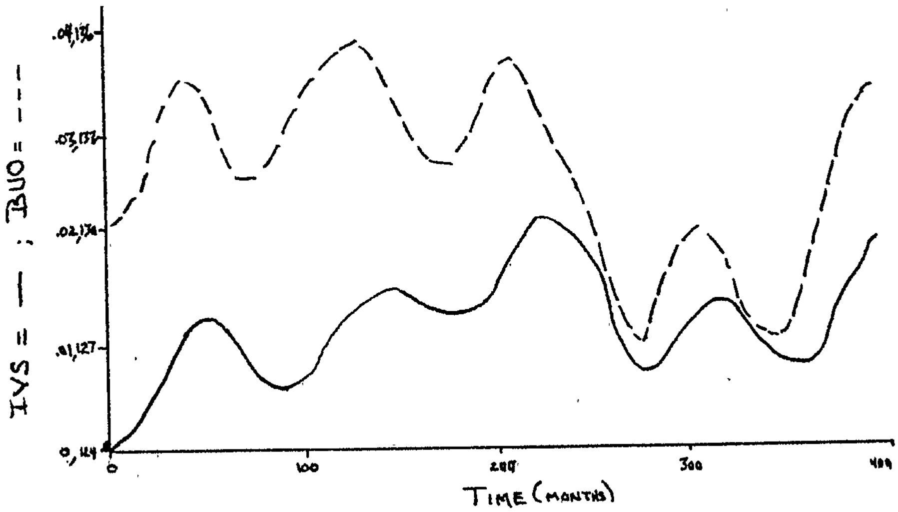

Figure 6. IVS vs. BUO under "1a" Profile

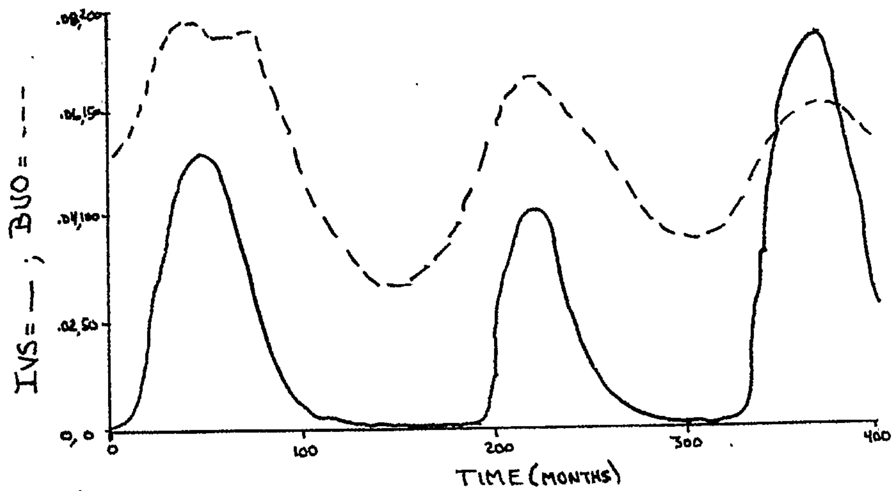

Figure 7. IVS vs. BUO under "1b" Profile

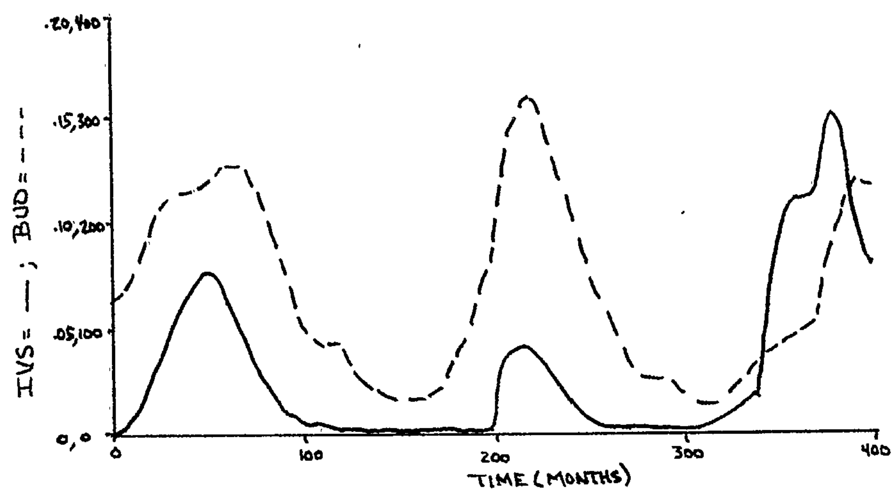

Figure 8. IVS vs. BUO under "1c" Profile

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