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AN ANALYSIS OF THE PREDICTED BENEFITS
OF MULTI-YEAR PROCUREMENT

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LSSR 1-82

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Multi-year procurement (MYP) is a method for acquiring weapon systems over a period of several years with a single contract. The Department of Defense has identified MYP as a key initiative for improving the weapon system acquisition process. The objective of this thesis was to evaluate eight predicted MYP benefits. A survey of 34 defense contractor locations and a system dynamics model of a large aerospace contractor were used to evaluate the predicted MYP benefits. The research analysis supported the following seven benefits: modernization of plant facilities, stabilized work force, lower production costs, advanced material buys, improved surge capability, increased standardization, and improved productivity. In addition, advanced material buys were found to be dependent on advanced material progress payments. The researchers found negligible support for the prediction that MYP would increase competition on defense contracts. The DYNAMO model that was formulated and tested during this research effort provides a method for evaluating MYP and other acquisition policies.

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AN ANALYSIS OF THE PREDICTED BENEFITS OF MULTI-YEAR PROCUREMENT

A Thesis

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In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Systems Management

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CHAPTER 1

MULTI-YEAR PROCUREMENT

Multi-year procurement (MYP) is a "generic term which describes procedures for acquiring needed items over several years through one contract [7:126]." MYP allows the Department of Defense (DOD) to award procurement contracts with durations of up to five years. Although not a new concept, MYP has not been used for several years due to statutory restrictions. In 1981, with the urging of the Reagan Administration, Congress authorized DOD to use MYP for major system acquisition (39).

The Defense Department has already moved to implement MYP. On 26 January 1982, the U.S. Air Force (USAF) awarded General Dynamics a four year contract for 480 F-16 fighter aircraft; USAF stated the MYP contract would cost $350 million less than four annual contracts (16:64). The FY 1983 Defense budget proposed 13 new multi-year programs, which included the A-6E attack aircraft, the Navstar navigation satellite, and the CH-53 helicopter. DOD anticipates total cost savings of $2.3 billion over the next five years (12:17).

BACKGROUND

Restrictions of MYP

Prior to passage of the 1982 DOD Authorization Act, MYP was not used due to restrictions on contract cancellation ceiling, reimbursable costs, and advanced buys of materials.

After 1970, the maximum contract cancellation ceiling (maximum Government liability in the event of cancellation) was $5 million unless Congress approved "such cancellation ceiling by statute [40:34-35]." This Congressional restriction virtually eliminated multi-year contracts because of the impracticability of seeking specific statutory exceptions (40:35).

DOD was also prohibited from including certain costs in the cancellation ceiling. Recurring costs are "any costs of labor and materials, or other expenses, which might be incurred for performance of subsequent program year requirements [40:36]." Non-recurring costs are one-time expenditures, such as design and training costs, mock-ups, and major tooling. The Defense Acquisition Regulation (DAR) does not authorize reimbursement of recurring costs in the event of program cancellation; only non-recurring costs are reimbursed. This reimbursement policy places a burden on the contractor, since any investment in recurring cost items (such as labor saving equipment and material) for use in other than the current program year will not be reimbursed if the program is cancelled, although savings would be passed on to the Government (39:36).

Buying material in advance to cut costs is specifically prohibited by the standard DAR multi-year contract: "items only qualify for advance procurement if they have significantly long production lead times [7:31]." A contractor attempting to beat inflation (and lower program cost) by advanced material buys stands to lose the investment if the program is cancelled (39:36-37; 7:31).

Advantages of MYP

Multi-year procurement has been identified as a policy needed to reform the weapons acquisition process (10). The following potential MYP benefits have been identified in the DAR and in testimony before Congress (14:p.1-39; 40:33):

1. Reduced costs;
2. Increased standardization;
3. Reduced administrative and labor costs through longer term contracts;
4. Increased productivity;
5. Stabilized work force;
6. Plant modernization;
7. Increased competition; and
8. Improved industrial surge capability.

Costs are reduced through economies of scale, higher learning rates, economic quantity buys, and more efficient production rates (40:32-33). Guaranteed program stability increases productivity and steadies labor force levels. The opportunity to amortize investment costs over a long term contract encourages plant modernization, and makes defense contracts more attractive, thereby encouraging competition (40:22,33). Since MYP encourages advanced material buys and modernized plants, the U.S. defense industry can better respond to a national emergency (7:84).

MYP Drawbacks

Enthusiasm for multi-year procurement is not universal. Decision makers with reservations about MYP most often cite the following considerations (7:88-97):

1. Decreased budget flexibility;
2. Cancellation liability;
3. Front-loaded costs;
4. Less competition; and
5. Production rate.

The House Appropriations Committee is concerned that widespread use of MYP will place a large portion of the defense acquisition budget beyond its, as well as DOD's and OMB's, control. Although it does not object to MYP in principle, the Committee feels that multi-year contracts should constitute a limited portion of the total procurement program (7:90-91). Some DOD managers fear that the prospect of a large cancellation settlement will prevent the termination of programs that are no longer in the nation's best interest, due to contractor performance or a change in the threat (20). Other managers are wary of the large appropriations required at the beginning of a program to finance advanced material buys and plant modernization (4). There is additional concern that awarding long term contracts will limit bidding opportunities and therefore decrease competition in the defense industry (37:93-94). Also, some managers are concerned that a contractor's optimum production rate may exceed the Government's ability to deploy the produced units, resulting in additional storage costs (37:94).[1]

Program Selection Criteria

Anticipating that Congress would remove restrictions to MYP, Deputy Secretary of Defense Frank C. Carlucci issued a 1 May 1981 "Policy Memorandum on Multi-year Procurement" to senior DOD managers. The memo included broad guidelines for selecting candidate programs for multi-year contracts.

> 1. Benefit to the Government. A multi-year procurement should yield substantial cost avoidance or other benefits when compared to annual contracting methods. MYP structures with greater risk to the Government should demonstrate increased cost avoidance or other benefits over those with lower risk. . .
>
> 2. Stability of Requirement. The minimum need for the production item or service is expected to remain unchanged or vary only slightly during the contemplated contract period in terms of production rate, fiscal year phasing, and total quantities.

[1]Breary (7) offers a detailed discussion of MYP advantages and disadvantages.

3. Stability of Funding. There should be a reasonable expectation that the program is likely to be funded at the required level throughout the contract period.

4. Stable Configuration. The item should be technically mature, have completed RDT&E [test and evaluation] with relatively few changes in item design anticipated and underlying technology should be stable. . .

5. Degree of Cost Confidence. There should be a reasonable assurance that cost estimates for both contract costs and anticipated cost avoidance are realistic. Estimates should be based on prior cost history for the same or similar items or proven cost estimating techniques.

6. Degree of Confidence in Contractor Capability. There should be confidence that the potential contractor can perform adequately, both in terms of Government furnished items and the firm's capabilities. . . [11:Enclosure 2].

Funding Issues

Currently, the most vocal debate concentrates on how to fund multi-year contracts. Colonel Richard Johnson of the Air Force Comptroller's Office said it was the position of the DOD and USAF comptroller's staffs to support full funding (23), in which "funds are available at the time of contract award to cover the total estimated cost to deliver a given quantity of complete militarily useful end items [7:126]," to include a fully funded cancellation ceiling (7:126).

The Office of the Secretary of Defense (OSD) and HQ USAF acquisition staff officers interviewed (4; 20) advocate incremental funding, where "funds are not available at time of contract award to cover the total estimated cost to complete delivery in a finished and militarily useable form [7:126]." In this case the cancellation ceiling is not funded.

Both of the above funding methods have compelling arguments in their favor. Incremental funding advocates contend that full funding would severely limit the use of MYP due to the large first year appropriation needed to cover first year end items and the cancellation ceiling. They also fear that the large initial appropriations would squeeze out other programs (4:20). Full funding proponents feel that fiscal responsibility demands that the Government buy end items, not pieces. Although the total contract price is known in both funding methods, full funding advocates say that the use of incremental funding would make the appropriation levels for individual contract years dependent on contractor expenditures, rather than weapons manufactured; this results in uncertain future funding commitments (23).

One potential compromise seeks to satisfy the full-funding advocates' desire for buying end items, while also decreasing first year appropriations. In this proposal (See Figure 1.1a), the Congress would annually fund the purchase of end items and contractor billings for future advanced material buys. The cancellation ceiling, made up of nonrecurring costs and unbilled recurring costs, would be unfunded. The appreciable decrease in first year funding

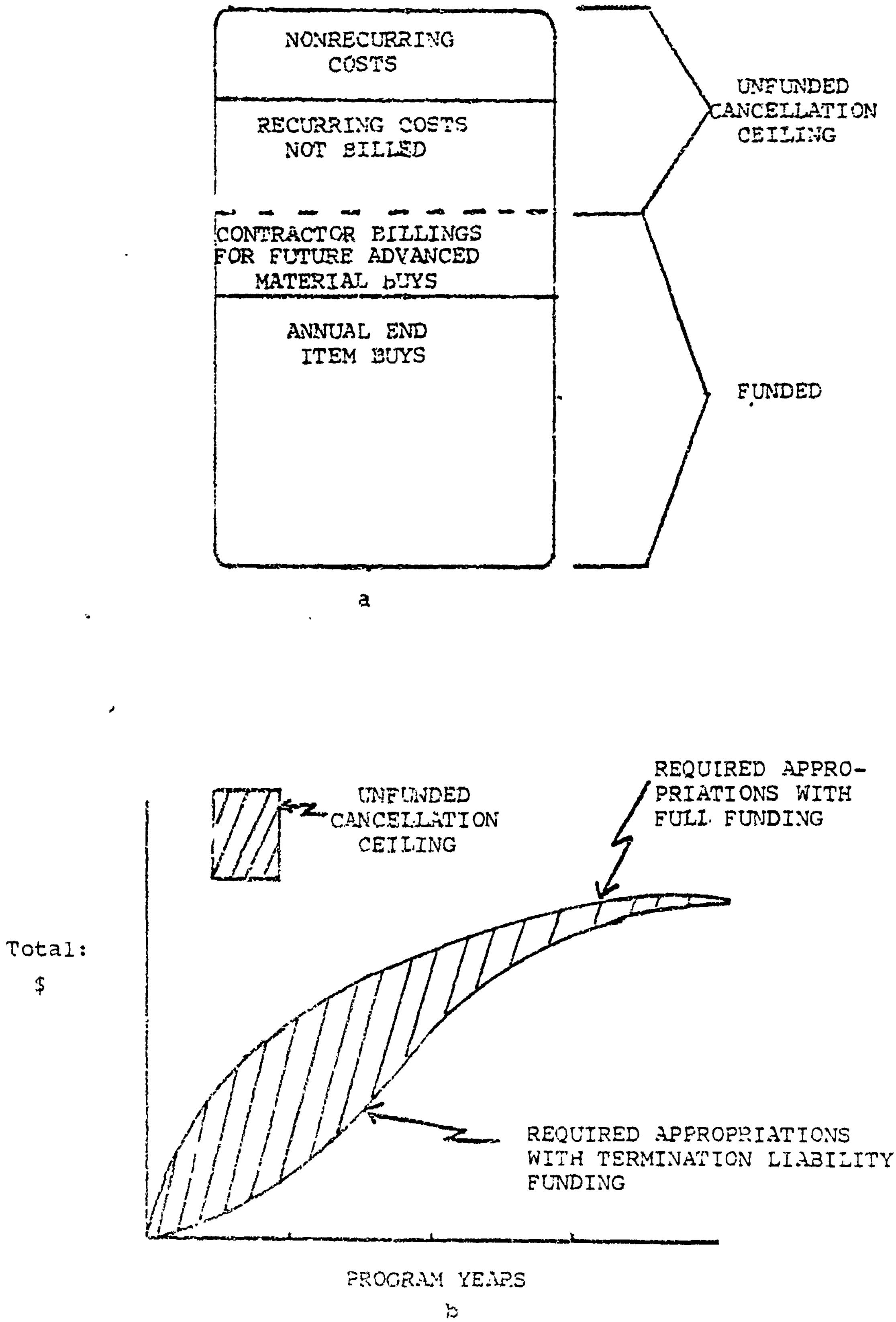


Figure 1.1

MYP Funding Concepts

requirements, as shown in Figure 1.1b, would appeal to incremental funding advocates by making funds available to other programs, as well as diminishing the fiscal impact of a multi-year contract (4). DOD calls this alternative "funding to termination liability [11]."

Current DOD policy dictates full funding. Full funding is required by OMB Circular A-11 and DOD Instruction 7200.4 (40:37). However, a 5 October 1981 memo from the Under Secretary of Defense for Research and Engineering (USDR&E), R. D. DeLauer, directs the services to budget based on full funding with termination liability funding for out year material buys (13). The funding issue is not currently resolved.

CURRENT STATUS OF MULTI-YEAR PROCUREMENT

DOD Initiatives

The Department of Defense supports multi-year procurement. A DOD policy memorandum (11) states that property and services should be obtained by the most economic means. The acquisition methods should result in reduced "costs to the government and provide incentives to contractors to improve productivity through sound investment. . .[11:1]." The memorandum continues to state that the benefits should be weighed against the potential risks involved.

The memorandum specifically addresses funding alternatives. It states that full funding is the preferred method, but it acknowledges that advanced multi-year concepts "permit more economic and efficient acquisitions of weapons systems. . .[11:2]." The advanced multi-year concepts are:

1. Full funding with expanded advanced buy. The Government purchases a single year's end items, but provides for advanced material buys for anticipated future production.

2. Multi-year with expanded advanced buy. The Government commits to end item purchases over several years, with provision for advanced material buy.

3. Funding to termination liability. Discussed on page 6 (11:2-3).

It is important not to confuse the concept of full funding discussed earlier with the first contract type explained above. It should also be mentioned that both "full funding with expanded advanced buy" and "multi-year with expanded advanced buy" are fully funded (11:2).

A policy letter from Richard DeLauer, Under Secretary of Defense for Research and Engineering, encourages the use of termination liability funding in choosing multi-year programs (13).

Congressional Actions

Congress has approved both the DOD Appropriations Bill and the Authorizations Act of 1982. The latter authorizes DOD to use multi-year contract whenever (38:164-165):

1. Such contract would promote national security and reduce total costs;

2. There would be a continuing requirement for the item to be purchased in quantities during the contract period;

3. There would be a low risk of contract cancellation; and/or

4. Technical risks are not excessive.

The Authorization Act allows the use of all three advanced multi-year concepts. The cancellation ceiling has been raised to $100 million and now includes both recurring and non-recurring costs. In the event a higher ceiling is required, the Committee on Armed Services and Appropriations must be notified, in writing, thirty days prior to contract award (38:165).

The FY 82 Appropriations Act also requires that all MYP contracts for major weapon systems be approved by Congress (35:53). Advocates of MYP see the Appropriations Act requirement as an unnecessary restriction that may hinder the use of multi-year procurement (5).

Furthermore, the Authorization Act states that MYP is not a panacea for the defense industry, but with proper implementation it can save both the Government and contractor money, while bolstering the defense industrial base (36: 166).

The Appropriations Act recognizes the benefits of MYP, but with an added caution. It urges careful implementation of multi-year contracting for several reasons. The savings are not automatic; further, since MYP has front loaded costs, substantial savings may not be realized until the latter years of the contract. If a contract is cancelled early, the Government may actually lose money on a major program. In addition, the loss of program flexibility, the inflation rate, and the decrease in the discretionary defense dollar may offset the actual benefits of MYP (37:185-190).

F-16 Contract

The F-16 contract is the first major Air Force acquisition under the new MYP guidelines. The contract is a multi-year with expanded advanced buy type. The F-16 program was selected for MYP for several reasons: (1) the USAF had a firm requirement for 1388 aircraft, (2) the F-16 is a mature program with stable technical requirements, and (3) a total of 559 deliveries have been made as of October, 1981 with reliable cost performance history. The F-16 System Program Office projects a $350 million savings from the initial multi-year contract with another $650 million in savings from two follow-on contracts (34:22).

The F-16 fully funded cancellation ceiling includes the following (2:17):

1. Non-recurring costs;

2. Out year recurring cost. The term out year refers to "the four fiscal years following the target year [1:504];"

3. Reversionary cost impact on non-cancelled aircraft. In the event of program cancellation, the settlement will allow for renegotiation of unit price due to the shortened production run;

4. USAF manufacturing line closing costs. Due to large foreign military sales orders, the USAF is liable for only its portion of closing costs; and

5. Profit on claim amount. In the event of program cancellation, contractor profit will be based on final program cost

STATEMENT OF THE PROBLEM

Although the Department of Defense used multi-year procurement in the 1960's, it has not been used for a major weapon system since the early 1970's (7:44). Historical data on multi-year procurement for a major system is at least ten years, and perhaps more important, four administrations and six defense secretaries old. MYP research is handicapped by this absence of empirical data on contractor performance under multi-year contracts. As the first major multi-year contract (the F-16) was awarded at the end of 1981, it will likely be some years before such data is available.

Due to the lack of recent quantitative data, Congressional and DOD policy making has been understandably conservative and ambiguous. For example, Congress, in approving multi-year procurement in the FY 82 DOD Authorization

Act, declared a multi-year contract appropriate when an agency head finds

> . . . that there is a reasonable expectation that throughout the contemplated contract period the Department of Defense will request funding for the contract at the level required to award contract cancellation;
>
> . . . that there is a stable design for the property to be acquired and that the technical risks associated with such property are not excessive; and
>
> . . . that the estimates of both the cost of the contract and the anticipated cost avoidance through the use of a multi-year contract are realistic [36:22].

The FY 82 DOD Appropriations Act further restricted multi-year by requiring specific Congressional approval for multi-year contracts (35:53).

Similarly, DOD's approach to MYP has been cautious. Deputy Secretary of Defense Frank Carlucci outlined six criteria for MYP in a memorandum to senior DOD management (11). His criteria are: (1) benefit to the Government; (2) stability of requirement; (3) stability of funding; (4) stable configuration; (5) degree of cost confidence; and (6) degree of confidence in contractor capability (11). Notice the relatively high abstraction level of criteria 5;

> There should be a reasonable assurance that cost estimates for both contract costs and anticipated avoidance are realistic. Estimates should be based on prior cost history for the same or similar items or proven cost estimating techniques [11:Enclosure 2].

DOD currently plans to insure configuration stability and a high degree of cost confidence by using MYP only on mature programs. As a consequence, DOD may sacrifice industrial improvements that would save money throughout the production cycle (20). To maximize the benefits of modernization, the contractor should modernize his industrial plant prior to the start of production. If the multi-year contract is not awarded until production year three or four, the contractor may delay or diminish his capitalization efforts, unit cost would rise, and industry modernization would suffer (4).

The financial and political stakes involved in multi-year procurement policy have made stability the most important consideration in choosing multi-year candidates (20). DOD acquisition executives (4:13) fear that a $100 million cancellation settlement would jeopardize MYP. As more empirical and analytic data of MYP become available, DOD may be more willing to accept the risk of early multi-year contract award.

This research will address the following problem: the anticipated benefits of MYP have not been subjected to rigorous empirical/analytic evaluations. In order to make objective and quantitatively based MYP policy, DOD managers need evidence that projected MYP benefits are substantiated.

RESEARCH OBJECTIVES

This research concentrates on the following two objectives:

1. <u>Develop a system dynamics model of an aerospace contractor and use it to evaluate certain anticipated MYP benefits</u>.

System dynamics is a systems modeling technique developed by the Systems Dynamics Group at the Massachusetts Institute of Technology. Initially articulated by Jay W. Forrester (17), system dynamics techniques are applicable to systems that change over time and are capable of internal reaction to performance, referred to as feedback (31:9). Initially developed as "industrial dynamics [9:478]," this technique has been applied to world population growth, community drug addiction programs, and urban decay (9:478).

The model developed in this research was designed to demonstrate the impact of MYP on a contractor's industrial modernization, advanced material buys, production costs, work force stability, and surge capability.

2. <u>Survey contractor attitudes and opinions about anticipated benefits of MYP</u>.

The survey attempts to gather empirical data the following MYP benefits: advanced material buys, reduced production costs, stabilized work force, increased productivity, plant modernization, increased competition, increased standardization, and improved surge capability. The survey was administered through students in the Air Force Education With Industry (EWI) program.

SCOPE AND LIMITATIONS

Survey

Due to time limitations, the survey was administered through the Air Force Education With Industry (EWI) program. There was insufficient time available for a direct survey of contractor personnel to be approved and conducted. The Education With Industry program offered a medium through which a survey could be administered, although the survey sample was limited by the number of EWI students.

The responses to the survey questionnaire were based on the attitudes and impressions of the key contractor personnel with which the EWI students interact. Since MYP is yet to be fully implemented, most responses were based on what contractors anticipated MYP will do, rather than actual experience. Response accuracy was dependent on the time that contractor managers spent with the EWI student on the survey.

Model

The model developed in this research effort represents a Government products division of a major aerospace contractor. This model is a refinement and extension of a model of the same firm constructed by Brechtel (8). Changes to Brechtel's work were based upon the experience and attitudes of USAF and contractor management personnel. Although the model represents the strategic policy making structure of only one firm, it still should possess general applicability since the firm is one of the ten largest in the industry and is engaged in a major production program.

The ability of the model to demonstrate the effect of MYP cannot be validated against actual data, since MYP is only now being implemented. If simulation results show no evidence of an anticipated MYP benefit, that does not mean the benefit does not exist. It may well be that the model lacks the accuracy and sophistication necessary to reflect that aspect of MYP.

CHAPTER 2

METHODOLOGY

Overview

This research used two separate approaches to evaluate the predicted MYP benefits. One approach used a survey of Government contractor managerial personnel. The other approach involved a simulation model of a Government aerospace contractor. The research design used the complementary nature of both methods to conduct the overall MYP study.

The survey offered access to a broad range of opinions about the eight predicted MYP benefits listed in Figure 2.1. The respondents included middle managers and executive managers from 34 contractor locations throughout the United States; the products manufactured at these contractor locations range from large transport aircraft to small submunitions. The survey identified the areas of industry-wide consensus about MYP benefits. It also identified areas of disagreement that deserved further study with the other research method, simulation.

Simulation study allowed the researchers to concentrate on specific issues. Although the simulation model was based on the policy making structure of a single Government aerospace contractor, the simulation experiments allowed the

PREDICTED MYP BENEFIT	EVALUATED WITH SURVEY	EVALUATED WITH MODEL
Modernization of Plant Facilities	Yes	Yes
Stabilized Work Force	Yes	Yes
Lower Production Costs	Yes	Yes
Advanced Material Buys	Yes	No
Improved Surge Capability	Yes	Yes
Increased Competition	Yes	No
Increased Standardization	Yes	No
Improved Productivity	Yes	No

Figure 2.1

Summary of Methodology

researchers to evaluate the impact of different company policies on MYP benefits. The simulation study also allowed the researchers to independently evaluate the four MYP benefits identified by a "Yes" in the rightmost column of Figure 2.1.

SURVEY

The Education With Industry (EWI) program sponsors 132 students assigned to 70 industrial firms located throughout the country (2:1). Not all of the firms were applicable to this research. As a selection criteria, the researchers chose those firms to which are assigned a Government program office or a Defense Contract Audit Agency (DCAA) representative (15). Appendix A lists the firms surveyed. Each EWI student was mailed one questionnaire to be completed by the highest ranking executive, one dealing with defense contracts, to which the EWI student had access.

The survey questionnaire consisted of four sections, the first of which was demographics. This section was intended to define the management level, experience, and MYP background of the sampled managers. The researchers used this information to judge the validity of the survey results, and to perform data analyses comparing the opinions of various demographic categories.

The ten questions which comprise Section II relate to MYP issues. The responses were based on a seven-point Likert scale that ranged from strongly disagree (1) to strongly agree (7). A seven-point scale was chosen because it offers more reliability than smaller scales and less complexity than larger scales (26:595-596; 33).

Section III consists of four questions which were applied to two situations: annual contracting and MYP contracting. The responses were based on a seven-point percentage scale that reflected the percentage change for each type of cost between the two situations.

In Section IV, the effects of MYP and annual contracting are compared. Twelve of the fifteen questions in this section are presented with two answer scales. The first answer scale was for the response under situation I, annual contracting. The second scale was for the response under situation II, MYP contracting. The last three questions addressed a modified version of the MYP situation. Instead of the Government reimbursing the firm for materials purchased for use up to two years in the future, the modified situation only provided for advanced buy reimbursement in the event of contract cancellation.

Since the goal of this research was to evaluate the stated advantages of MYP, the researchers designed the null hypothesis to state there is no difference between MYP and annual contracting. The alternative hypothesis was that MYP is better than annual contracting; that is, MYP promotes the predicted advantages. The researchers grouped the survey questions (as shown in Figure 2.2) to evaluate each predicted benefit. The survey questionnaire is provided in Appendix B.

Predicted MYP Benefit	Survey Questions
Modernization of Plant Facilities	14, 33
Stabilized Work Force	13
Lower Production Costs	8, 10, 11, 18-21
Advanced Material Buys	30, 31, 34, 35
Improved Surge Capability	17, 24, 27-29, 32, 36
Increased Competition	15, 16, 22, 23, 25, 26
Increased Standardization	9
Improved Productivity	12

Figure 2.2

Survey Breakdown

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) was used to analyze the data (22). Two analytical tools were used, frequencies and t-tests.

Frequency distributions were obtained for each section to verify the transfer of data from the questionnaires to the data file. These frequencies also provided the researchers with the demographics of the sample. The subprogram FREQUENCIES of SPSS uses one way frequency distributions with descriptive statistics including the mean and standard deviation (22:194). This information allowed the responses to be reviewed for anomalies. A visual inspection was performed to ensure the response distribution could be approximated by a normal distribution. Analysis of responses to questions in Sections III and IV of the survey instrument required specific statistical tests.

A one-tailed t-test was used to analyze the data from Section III of the questionnaire. For each question in Section III, the test hypotheses were:

$H_o: \mu \geq 0$

$H_a: \mu < 0$

The null hypothesis, H_o, states that the mean response, μ, reflects either no change or an increase in cost due to MYP. The alternate hypothesis, H_a, is that the mean response indicates a decrease in cost due to MYP.

The t statistic used in the Section III data analysis was calculated as follows (24:390):

$$t = \frac{\bar{Y}}{S/\sqrt{n}},$$ with n-1 degrees of freedom,

where Y = sample mean,

S = sample standard deviation, and

n = sample size.

The null and alternate hypotheses were tested by comparing the calculated t value to the critical value of t that defined the rejection region (significance level of $\alpha = .05$). If the t value was greater than or equal to the critical value to t, the null hypothesis (H_o) was accepted, implying that MYP had no effect on cost. If the t value was less than the critical value of t, the null hypothesis was rejected, indicating a cost reduction due to MYP.

The researchers used paired sample t-tests to analyze the data from Section IV of the questionnaire. Paired sample t-tests in SPSS are based upon a paired difference variable, D;

$$D = X_1 - X_2$$

where X_1 = response to situation I and

X_2 = response to situation II

D is normally distributed with mean δ.

For Questions 22, 23, 30, 31, and 32, a negative value of D would support the predicted MYP benefits. For these questions, the test hypotheses were formulated as follows:

$$H_o: \delta \geq 0$$

$$H_a: \delta < 0$$

These hypotheses were tested with a one-tailed t-test at $\alpha = .05$.

Questions 24, 25, 26, 27, 28, 29 and 33 were phrased so that positive values of D supported the proposed MYP benefits. For these questions, the test hypotheses were:

$$H_o: \delta \leq 0$$

$$H_a: \delta > 0$$

These hypotheses were also tested with a one-tailed t-test at $\alpha = .05$.

The researchers used Questions 34, 35, and 36 to obtain contractor opinions regarding the importance of advanced material buy reimbursement (progress payments) to certain MYP benefits. Since the objective of the questions was to determine if advanced material buy reimbursement was an important issue, a two-tailed t-test ($\alpha = .05$) was used to test the following hypotheses:

H_o: $\delta = 0$

H_a: $\delta \neq 0$

In this case, rejection of the null hypothesis indicated that advanced material buys reimbursement was an important issue to the surveyed contractor managers.

For all statistical tests of data from Section IV of the questionnaire, the t statistic was calculated with the following equation (22:270):

$$t = \frac{\bar{d} - \delta}{S_{\bar{d}}}$$, with n-1 degrees of freedom,

where n = number of pairs,

$\bar{d}$ = sample mean paired difference,

δ = mean paired difference of the null hypothesis ($\delta = 0$), and

$S_{\bar{d}}$ = sample standard deviation

The SPSS program computed the two-tailed probability of the occurrence of a t value greater than that calculated above

(22:172). This two-tailed probability value was then used in the hypothesis testing of data from Section IV of the survey questionnaire.

For Questions 22, 23, 30, 31, and 32, a one-tailed t-test was performed by dividing the two-tailed probability by two, yielding the appropriate one-tailed probability. This one-tailed probability was then compared to the desired significance level (α = .05). If the one-tailed probability was less than .05 and the t value was negative, the null hypothesis was rejected (22:271).

The hypotheses for Questions 24, 25, 26, 27, 28, 29, and 33 were also tested using the one-tailed probability. In this case, the null hypothesis was rejected if the one-tailed probability was less than .05 and the t value was positive (22:271).

The researchers used a two-tailed t-test for Questions 34, 35, and 36. If the two-tailed probability calculated by SPSS was less than .05, the null hypothesis was rejected (22:271).

MODEL

The goal of the modeling phase of this research effort was to develop a system dynamics model of an aerospace contractor and use it to evaluate MYP benefits. The overall research plan was to build a model capable of demonstrating contractor performance in both annual contracting and MYP environments. This model was then used to compare the effects of annual contracting and MYP on an aerospace contractor.

Richardson and Pugh identified seven stages to system dynamics model formulation:

1. Problem identification and definition;
2. System conceptualization;
3. Model formulation;
4. Analysis of model behavior;
5. Model evaluation;
6. Policy analysis; and
7. Model use or implementation [31:16].

The research methodology was developed within this framework.

Model Development

In 1964, Packer (27) published a monograph that dealt with a system dynamics model of corporate growth. Packer used system dynamics concepts to describe both interactions between the firm and the market and the relationships within the firm that affect organizational expansion and contraction; of particular concern was the process of resource acquisition.

Building upon the work of Packer and others, Brechtel developed a system dynamics model of a specific aerospace contractor in 1981 (8). Brechtel's model describes the strategic policy making structure of a firm attempting to grow in a Government dominated, technology-oriented market. Like

Packer, Brechtel's model emphasized the importance of resource-acquisition policies to a firm's growth and stability (8:19).

Brechtel constructed a seven sector model, as shown in Figure 2.3. The market sector responds to production and engineering performance, as well as the firm's professional capability (engineers and managers). The financial sector responds to other sector needs by providing necessary funds. The design sector serves both the market sector and the production sector with product designs, as well as research and development effort. The firm's professional sector represents "the firm's professional effort, the acquisition and departures of professional employees, and the amount of effort actually expended in activities creating potential demand for the firm's products. . .[8:80]." The production sector, responding to the market sector, manufactures production units subject to the constraints of money, material, engineering design completion, and production capacity. The material sector provides production with the necessary raw materials and components. The pressure-for-expansion sector considers the firm's performance within the environment, and initiates expansion, steady-state, or contraction policies as appropriate (8:248-370).

Brechtel's work provided an excellent basis for the advancement of MYP research for two major reasons. First, it was a comprehensive model that recreated the actual

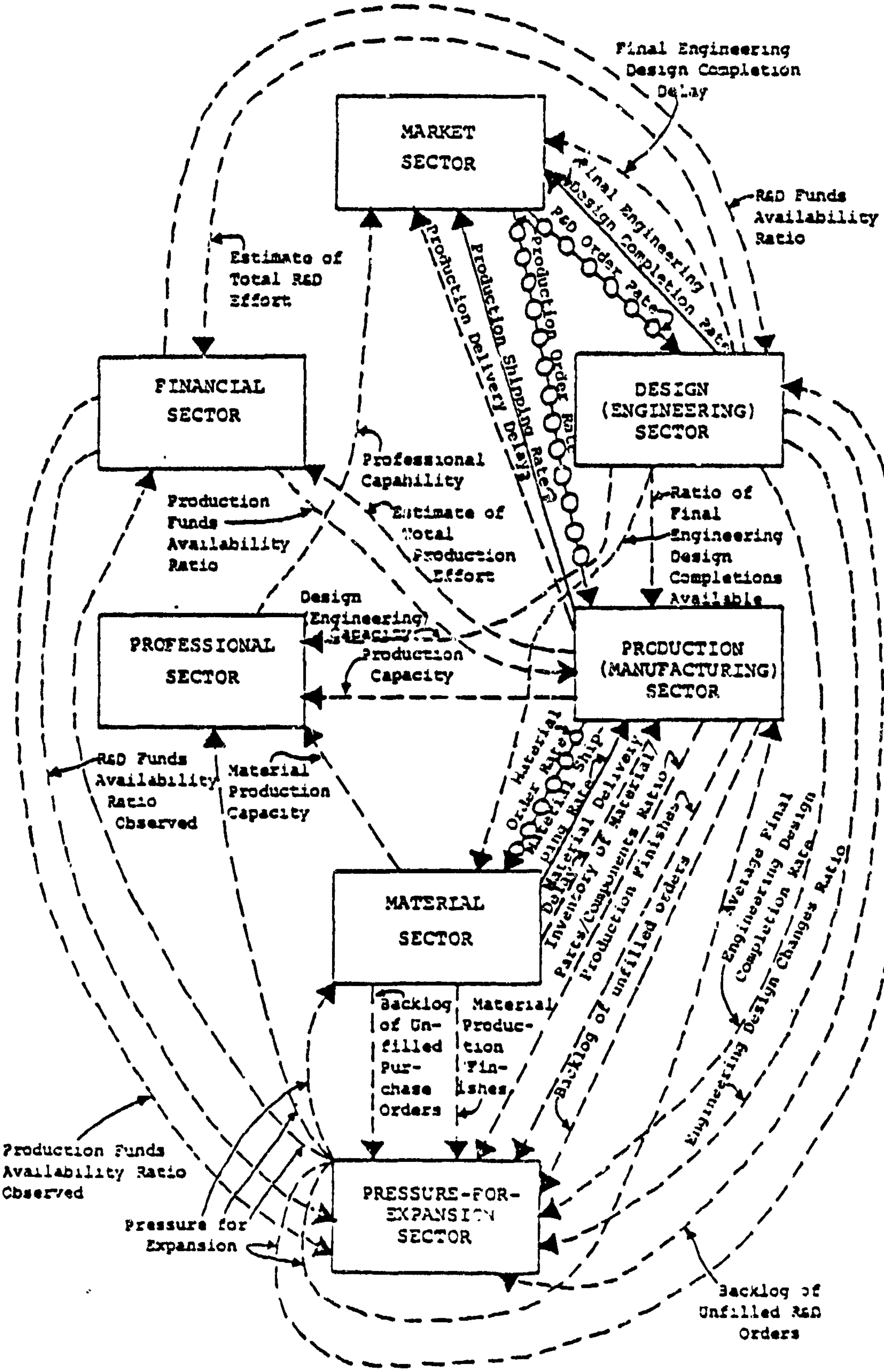


Figure 2.3

Macro Structure of Brechtel's Model (8:248) behavior of the modeled firm (8:389). Second, the modeled firm is engaged in a military production program that has been chosen for MYP. The firm was in the early stages of MYP policy making, and actual data about contractor performance under MY will be available in the near future to compare with model predictions.

Necessary Modeling Effort

As explained in Chapter 1, the modeling phase of this research was aimed at evaluating five predicted MYP benefits; plant modernization, advanced material buys, decreased production costs, improved work force stability, and improved production surge capability. The researchers recognized that Brechtel's model needed several enhancements before MYP evaluation could be performed.

The researchers identified and prioritized the necessary model modifications. They are listed here, in priority, with a brief discussion of their purpose.

1. Modify the financial sector to reflect investment in plant modernization. Brechtel's model did not include a financial sector capable of investment decisions. This modification allowed the model to arrive at investment decisions based upon project value, capital costs, and contract incentives.

2. Modify the production sector to account for the separate contributions of labor, plant, and modernization to production capacity. Brechtel's model treats production

capacity as an indivisible element. An evaluation of MYP benefits required separate consideration of labor, plant, and productivity programs.

3. Modify the marketing sector to allow for multi-year contracts. Model refinement was necessary for consideration of the effect of long term, stable order rates.

4. Modify the material sector to account for advanced material buys. Such a model modification would take into account both potential cost savings and possible reductions in lead time.

5. Modify the financial sector to reflect investment in advanced materials. This enhancement was very similar to item 1 above. Advanced material buys would be treated much like a plant investment.

6. Modify the model to afford closer study of costs. This last step would allow the researchers to study cost flows within the firm, as well as the effect of unit cost on the market sector.

The researchers concluded that incorporation of the first four modifications would provide an adequate basis for evaluation of the predicted MYP benefits. Due to time constraints, only these first four model modifications were undertaken. As will be discussed in Chapter 3, the advanced material buy modification was not completed. Therefore, advanced material buys were not studied with the researchers' MYP model, as shown on Figure 2.1.

Initial Model Work

The first modification to the financial, production, and market sectors was based upon commonly used capital investment models, early MYP contract provisions, and information gathered at an Aeronautical Systems Division (ASD) System Program Office (SPO) that works with the modeled contractor. These data sources were used to determine system characteristics that represent the strategic policy structure associated with MYP decisions.

Once the system conceptualization was accomplished, the model formulation was expressed in the DYNAMO simulation language. DYNAMO was written by Alexander Pugh to support system dynamics (31:x). The researchers' DYNAMO program was merged with Brechtel's DYNAMO model of a Government contractor. Following initial model debugging, model testing was begun.

Richardson and Pugh identify four iterative phases in model development: understanding model behavior, sensitivity analysis, refinement and reformulation, and model validation (31:267). Early modeling efforts were largely concerned with these issues. The researchers were especially concerned with model sensitivity to parameters used in the financial sector. Model validation is addressed in Chapter 4.

Interviews

The researchers conducted interviews with management personnel of the modeled firm. The primary objective of this methodology step was to evaluate model structure and model behavior. A secondary objective was to gather data necessary for modeling advanced material buys and cost flows.

The interviews were conducted using the interview guide shown in Appendix G. Section I of the interview guide contains questions regarding the manager's background, position in the company, and MYP involvement. In Section II, the interview subjects evaluated the accuracy of the researchers' model structure and parameters. The interviewees' opinions of each model modification were recorded on a five-point scale, with responses ranging from strongly disagree to strongly agree. The researchers chose a five-point scale due to the abstract nature of portions of the model; it was felt a five-point scale would make it easier for the interviewees to respond to questions. The researchers also recorded specific contractor criticisms of the model, as well as suggestions for improvement. Section III of the interview guide is devoted to the interviewee's evaluation of the model's ability to demonstrate contractor performance in an MYP environment. As in Section II, interview subjects were encouraged to make specific criticisms. Section IV of the interview guide was designed to acquire information about advanced material buys and contractor cost considerations.

The researchers then calculated the mean response for every interview guide question. A mean response score of 4.0 or greater was interpreted as full support for the model structure or behavior (8:166). Mean scores of less than 4.0 indicated a lack of agreement and meant model redesign might be necessary, using the specific interviewee comments relevant to that issue.

Model Refinement and Validation

The intent of this modeling step was to incorporate interview results into the model structure, analyze the behavior of the revised model, and evaluate model validity. At the end of this phase, the researchers planned to have a developed model that could be used for MYP policy analysis.

A major modeling effort involved demonstrating model validity. Richardson and Pugh define validation as "the formal processes that lead people to place confidence in a model [31:310]." Specific model validation issues addressed in this research project are discussed in Chapter 4.

Policy Analysis

The last step in the simulation study was actual policy analysis. The policy analysis phase of this research effort concentrated on three policy areas:

1. Comparison of contractor performance under annual versus MYP contracting;

2. The effect of varying cancellation ceiling levels; and

3. The effect of cost sharing ratio on contractor investment.

The researchers addressed the first policy area by conducting simulations with MYP and annual contracting profiles. These profiles included representative order rates and contract cancellation ceilings. The second policy area was evaluated by assuming MYP profiles for all simulation experiments and changing only the cancellation ceiling. Likewise, the third policy area was studied by varying cost sharing ratios in an MYP profile.

The MYP model was also used to investigate specific issues raised from the results of the research survey. Discussion of this policy analysis is included in Chapter 5.

CHAPTER 3

MODEL FORMULATION

Introduction

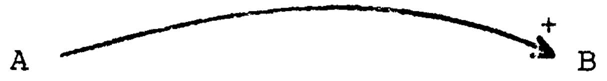
This chapter explains the conceptualization, assumptions, and coding of the MYP model. The chapter begins with a discussion of overall system conceptualization, as well as the causal structure of each modification to Brechtel's contractor model. There is then a brief summary of DYNAMO symbology, followed by the actual DYNAMO equations -- with supporting text -- for the three modified sectors: financial, market, and production. Discussion of the other model sectors can be found in Brechtel (8). Portions of the three modified sectors that are substantially unchanged are discussed in brief, followed by a specific reference to Brechtel's dissertation.

SYSTEM CONCEPTUALIZATION

As explained by Richardson and Pugh (31:19-66), system conceptualization is a necessary step in model formulation. To aid in describing the system conceptualization of this research, it is useful to discuss the use of causal-loop diagrams in system description.

Causal-Loop Diagrams

Causal-loop diagrams used in this chapter were built, in part, using causal links. A positive causal link is shown as



and means that an increase in A results in an increase in B. It also means that a decrease in A causes a decrease in B. On the other hand, a negative causal link is depicted as

and implies that an increase in A would result in a decrease in B A negative causal link also implies that a <u>decrease</u> in A would cause an <u>increase</u> in B. A causal-loop diagram results when the relationships among several variables are displayed using causal links (31:26-27).

MYP Causal-Loop Structure

The first step in the conceptualization process was to identify the unique attributes of an MYP contract and to isolate the effect of these attributes on contractor decision making. The result of that conceptualization is shown in Figure 3.1.

In this diagram, the firm analyzes the USAF MYP program and the non-USAF market to estimate future program revenue. This estimated future revenue is then an input to the

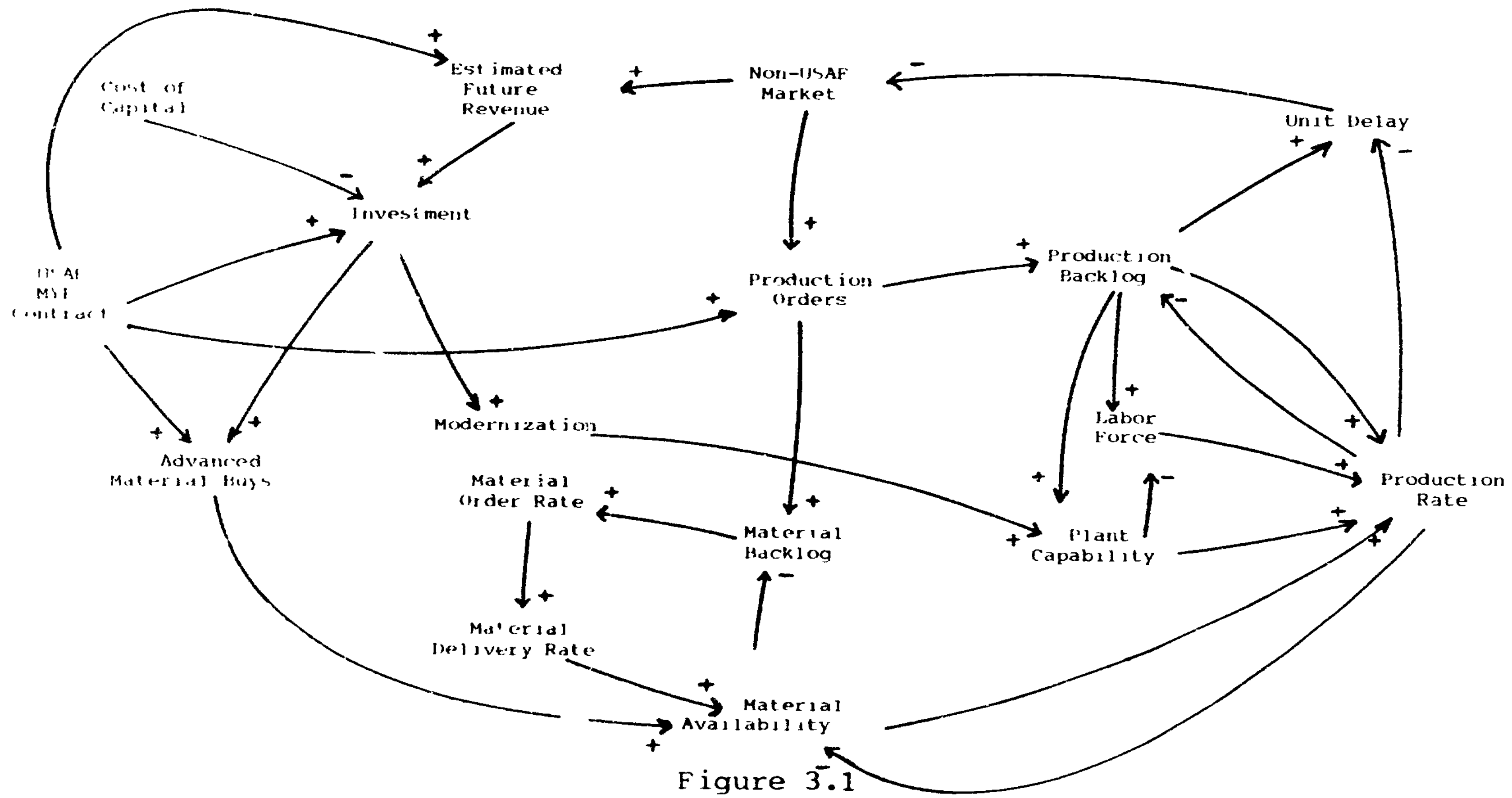


Figure 3.1

System Conceptualization - Causal-Loop Diagram investment decision, along with the cost of capital and pertinent contract provisions (such as cancellation ceilings). The investment decision directly affects the level of plant modernization and advanced material buys. Advanced material buys are also influenced by specific material provisions of the MYP contract.

Production orders are determined by the non-USAF market and the MYP contracted order rate. A production order rate rise tends to increase material backlog. As material backlog increases, so will material order rate. An increase in material order rate causes the material delivery rate to increase. Material deliveries increase material availability, which then decreases the material backlog. Advanced material buys also increase material availability.

An increased production backlog increases production rate and has a positive effect on labor force and plant capability. Plant capability is also influenced by the modernization program; a more modern plant should require a smaller labor force. Production rate is constrained by material availability, labor force, and plant capability. Increased production rate will decrease the production backlog and material availability. Unit delay (the time the customer waits for delivery) is positively influenced by production backlog and negatively influenced by production rate. A decrease in unit delays should tend to increase the non-USAF orders, so unit delay and the market are connected by a negative causal link.

The next conceptualization step was to divide the causal-loop structure into sectors for more detailed analysis. The result is depicted in Figure 3.2: a four-sector diagram composed of financial, material, production, and market sectors.

Financial Sector

In the system conceptualization, the financial sector decides on modernization and advanced material investment in light of the cost of capital, estimated future revenue, and anticipated investment return. The financial sector also considers contract provisions and incentive payments when making investment decisions. A detailed causal flow diagram of the financial sector is presented in Figure 3.3.

The investment decision begins with an estimate of future revenue by the market sector. Once the estimate is made, the financial sector can select those projects for which the return on investment exceeds the total cost of capital, resulting in an optimum modernization investment level. This optimum level is compared with the firm's existing modernization investment and the MYP contract cancellation ceiling to arrive at a decision regarding new modernization investment. An important consideration in this last step is the company's aversion to risk of corporate funds for modernization programs.

The firm will also, under cost plus incentive fee contracts and high interest rate conditions, probably have

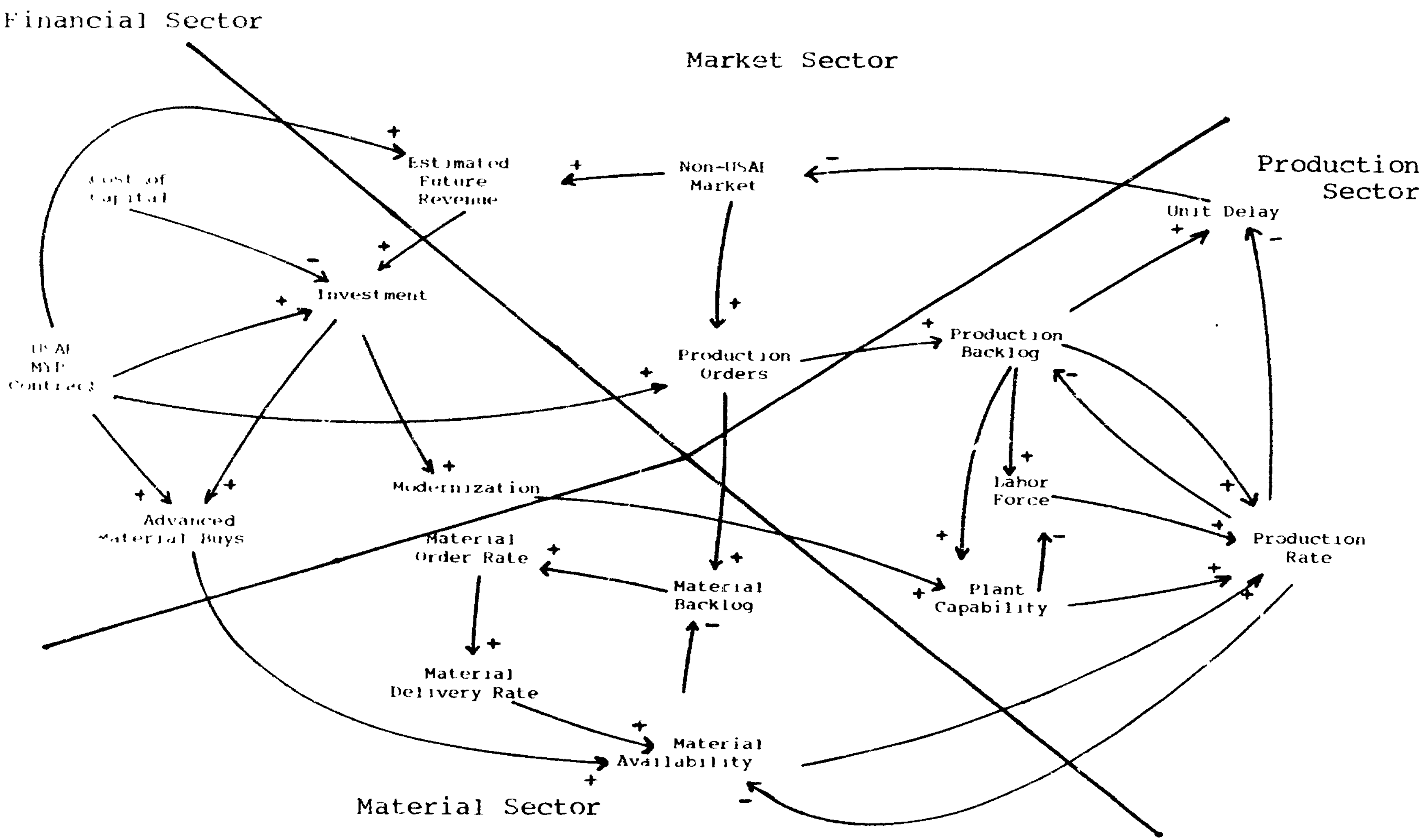


Figure 3.2

System Sectors

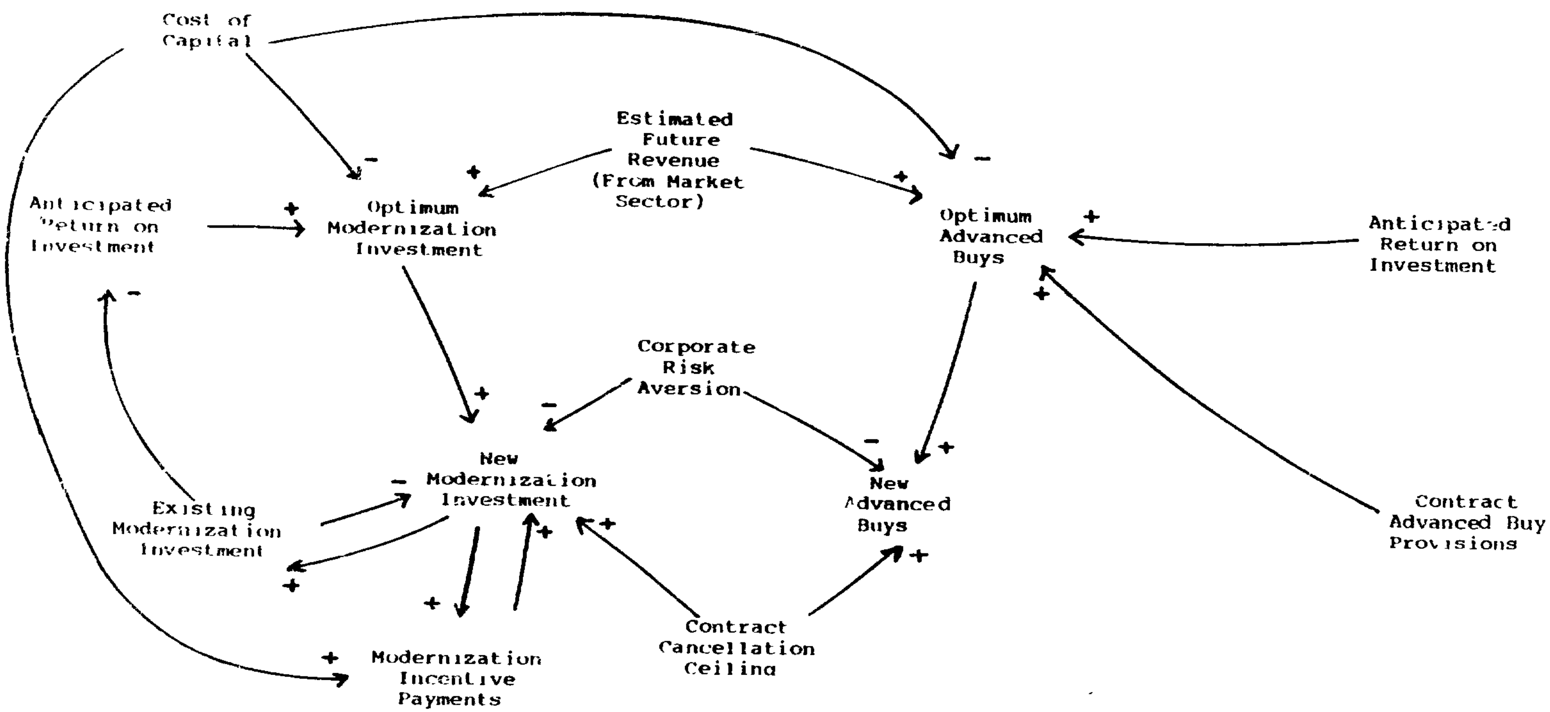


Figure 3.3

Financial Sector Conceptualization - Causal-Loop Diagram to negotiate modernization incentive payments from the customer awarding the MYP contract. Such incentive payments are necessary because of the effect of cost-sharing ratios upon the contractor's investment cash flow. Cost-sharing ratio includes the contractor's share of those program costs exceeding a target cost called for in the contract; in a 70-30 cost-share arrangement, the Government pays 70 percent of costs beyond the target while the contractor absorbs 30 percent. At the same time, a 70-30 cost-sharing ratio also means that the contractor receives only 30 percent of cost <u>reductions</u> below the target cost.

As an example, a contractor may be considering a $1 million dollar modernization investment with an annual rate of return of 20 percent, which, assuming a cost of capital of 15 percent, would generate net savings (return minus capital costs) of $50,000 per year ($200,000 - $150,000). If the contractor operates under a 70-30 cost-charing ratio, then the firm's annual return is cut to $60,000 (.3 x $200,000). Allowing for a 50 percent tax reduction for interest expense, the contractor's cash flow becomes a negative $15,000 ($60,000 -.50 X $150,000). A contractor is therefore motivated to seek incentive payments from the customer that will at least prevent modernization investment from causing negative cash flow.

The model makes advanced material buys in much the same manner, except for an additional contract consideration. The F-16 MYP contract provides for funds for advanced material buys, in addition to the contract cancellation ceiling (3). The availability of this money should have an impact on advanced buys by the contractor.

Production Sector

The production sector of an MYP model should have the ability to show the effect of steady order rate and long term contracts on plant capability and the labor force. The causal flow diagram of Figure 3.4 attempts to characterize production capacity as a function of work force size, plant capacity, modernization investment, and maximum labor hours per worker.

Figure 3.4 shows that production backlog is increased by production orders and decreased by production rate. As production backlog increases, work force size and plant capacity will tend to increase; work force size has a direct effect on production capacity, while increased plant capacity increases effective plant capacity. Effective plant capacity is also increased by productivity enhancements resulting from investment in plant modernization. Production rate is a function of production backlog, production capacity, and material availability. Labor hours per worker, the average number of labor hours per worker per week, is increased by larger production rates, but decreased by a growing work force and enhanced plant capacity.

An important facet of this sector formulation is the effect of a decrease in production backlog. As backlog

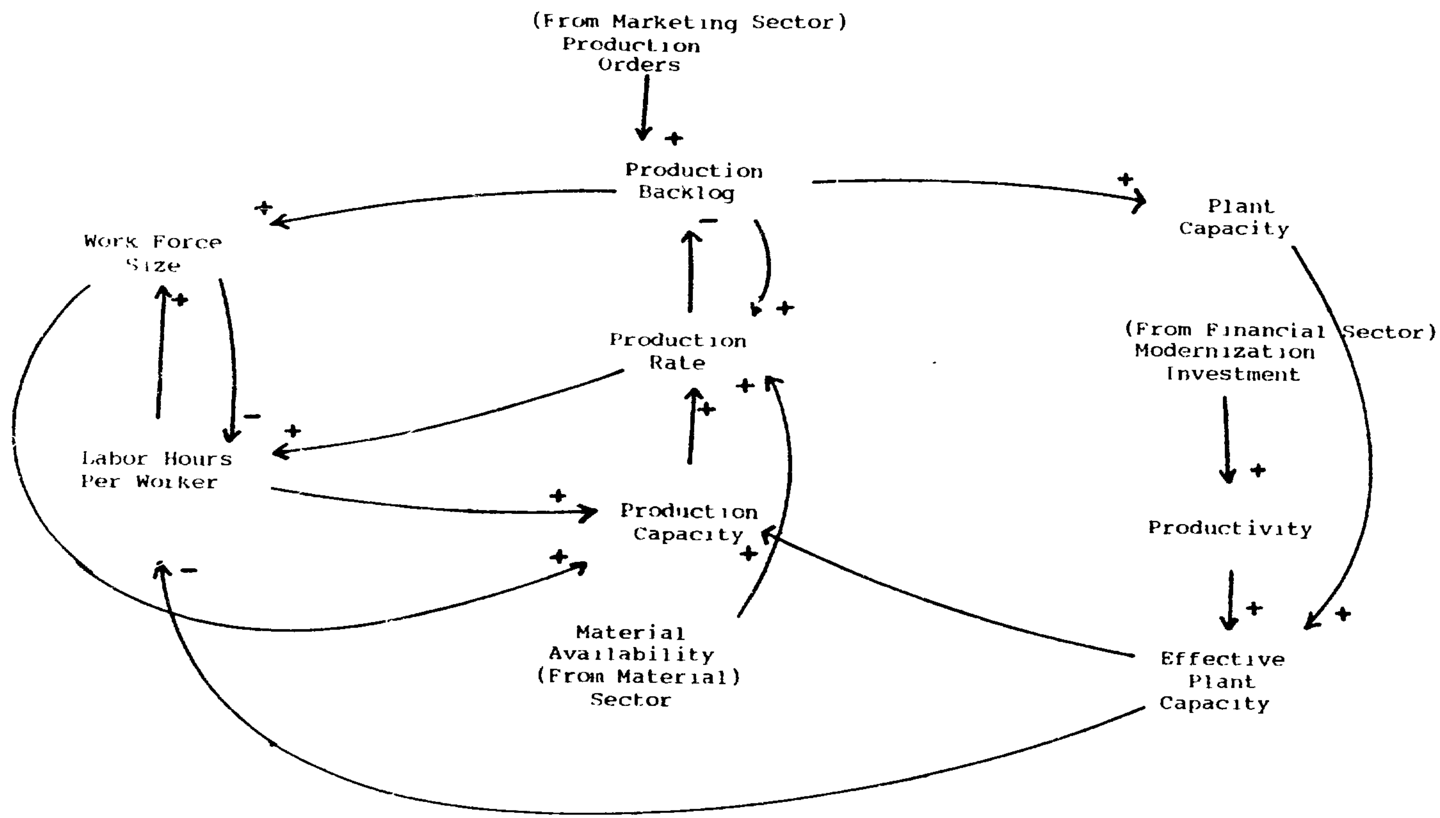


Figure 3.4

Production Sector Conceptualization - Causal-Loop Diagram decreases, work force size and plant capacity will tend to contract. A decreasing production backlog will also decrease production rate, decreasing labor hours per worker, further encouraging a work force decrease.

Market Sector

Figure 3.5 illustrates how the contractor's market sector estimates future revenue. The market factors fall into three basic categories: MYP, non-MYP, and potential follow-on MYP.

The MYP contract orders represents orders from the Government agency or service that is the primary customer for the contractor's product. The model assumes that this market is not affected by the contractor's performance. In other words, the primary customer is committed to meeting its requirements with the contractor's product. In calculating estimated future MYP revenue, the contractor applies a confidence factor; this confidence factor is the contractor's estimate of the probability that the MYP contract will be fulfilled.

The market sector may believe that a follow-on MYP contract may be awarded by the primary customer. The potential follow-on MYP market category allows the model to account for this possibility. As in the MYP market, the contractor applies a confidence factor to the future follow-on MYP revenue estimates.

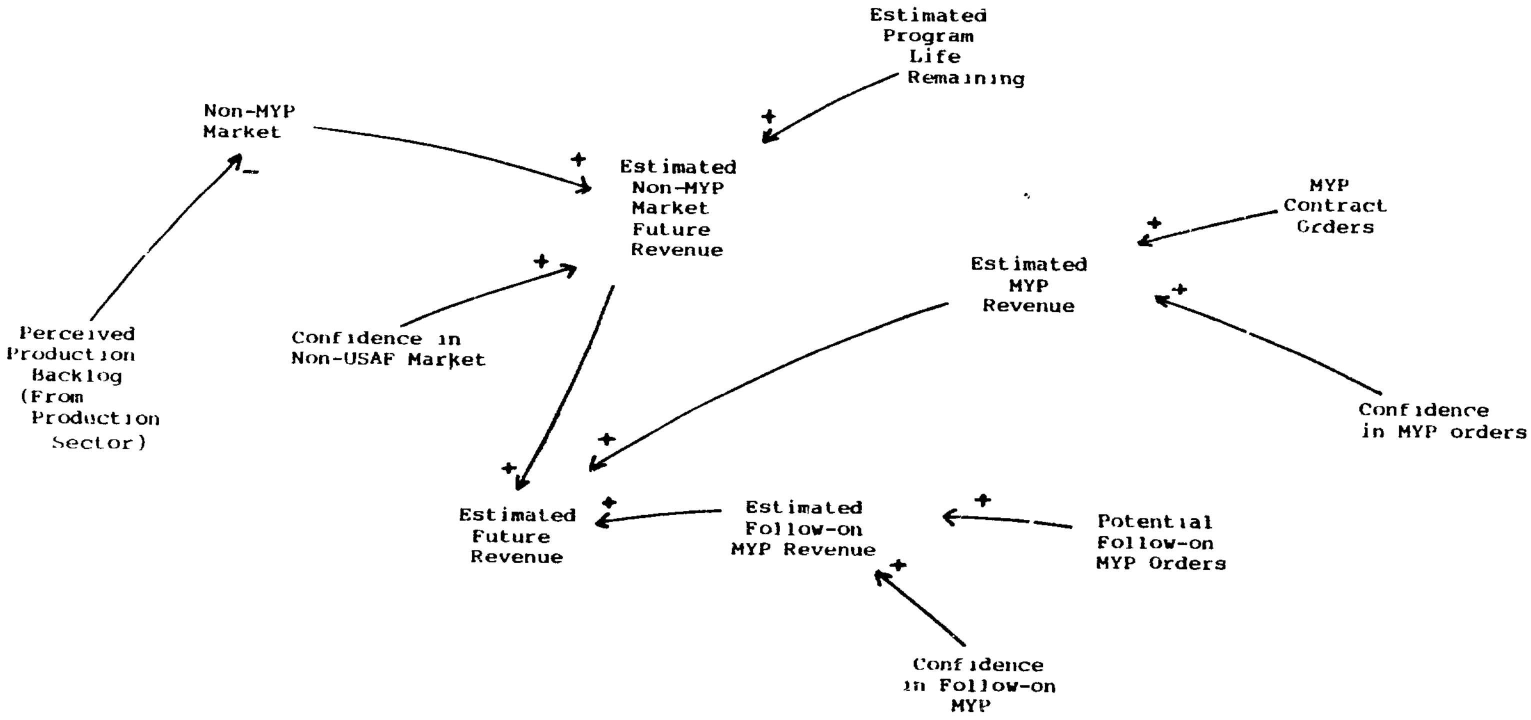


Figure 3.5

Market Sector Conceptualization - Causal-Loop Diagram

The non-MYP market accounts for orders that arise simultaneously with the MYP contract. These orders can come from many sources: foreign military sales, additional orders from the primary customer, and orders from other Government agencies or military services. This non-MYP market is influenced by the perceived time the customer must wait for its order to be filled, which is a function of production rate and production backlog. As the delay decreases, the non-MYP orders should increase; long production delivery delays should slow the non-MYP order rate. In calculating estimated future non-MYP revenue, the model uses an average non-MYP order rate, the estimated production program life remaining, and a confidence factor that is a function of program life remaining.

Material Sector

Initial detailed modeling of the material sector was not possible due to the lack of information available on advanced material buy decisions, as well as potential return on investment. Gathering relevant information was an objective of the interviews with contractor executives and will be discussed later in the thesis.

DYNAMO MODEL

System conceptualization was followed by model formulation in the DYNAMO simulation language. As discussed in Chapter 2, the highest modeling priorities were redesign of

Brechtel's financial, market, and production sectors. Detailed discussion of the model will be preceded by a summary of DYNAMO symbology.

DYNAMO

The DYNAMO simulation language is based upon the flow of information, funds, material, and orders. These flows collect at levels; a level is "a variable that accumulates over time an inflow and/or an outflow [31:76]." A level may represent the number of workers in a firm, the inventory on hand, or the number of units in production backlog. The "valves" which control the flows between levels are known as rates (31:76-80).

As an example, the hiring and dismissal of production personnel are symbolically represented in Figure 3.6. In this case, the box represents a level (the number of employees). The top "valve" is the flow into the level -- hiring rate; the bottom "valve" is the flow out of the level -- employee attrition.

In DYNAMO, flow quantity is determined by rate equations. Rate equations are based on a variety of factors and can be quite long and complex. To help make the model more understandable, DYNAMO features auxiliary variables, which act as blocks of information upon which rate equations are built. An auxiliary variable generally represents a meaningful piece of information used in controlling a system (31:80-81). One often used type of auxiliary variable

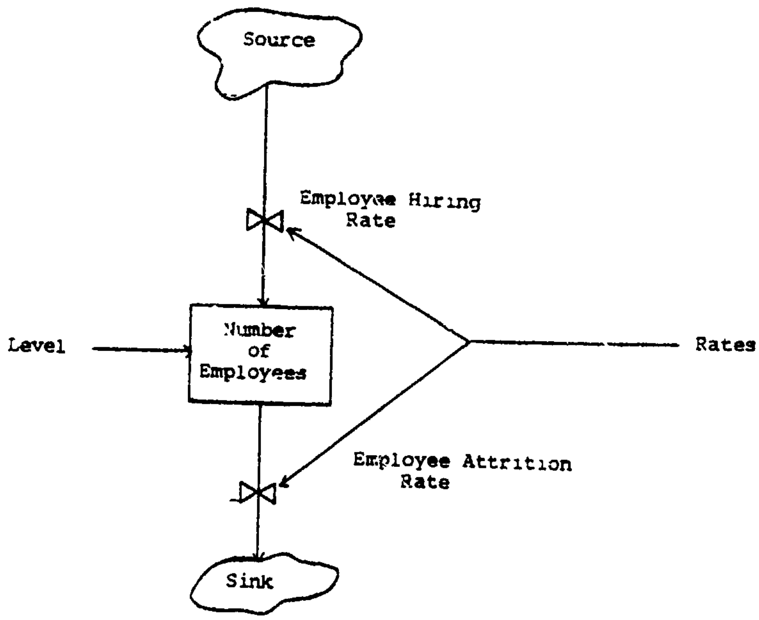


Figure 3.6

DYNAMO Symbology I

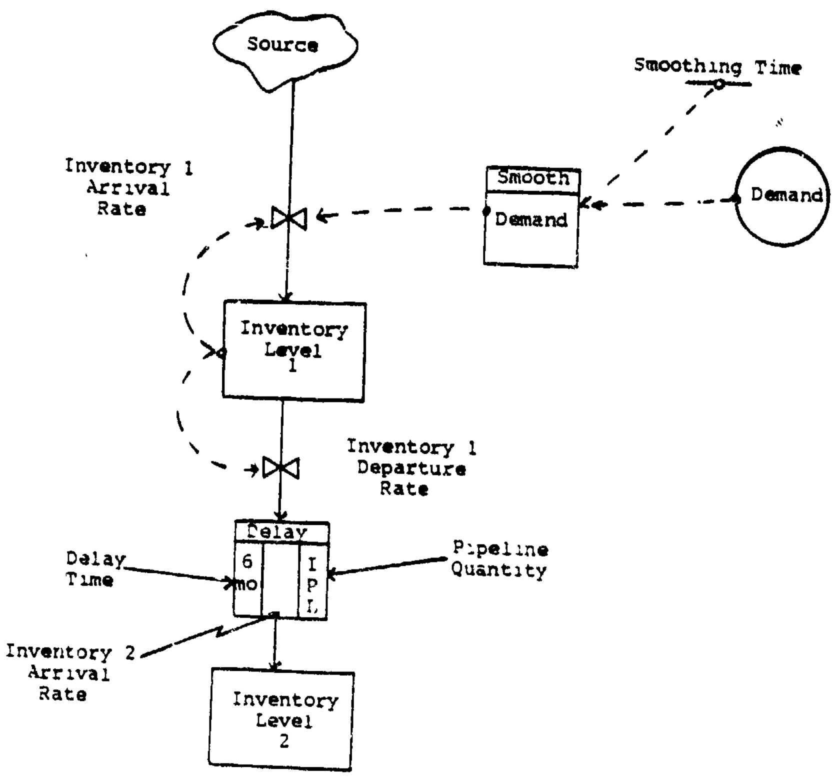


Figure 3.7

DYNAMO Symbology II

is a smoothed, or averaged, variable. Smoothed variables are appropriate when the system acts on trends, rather than on instantaneous variable values (31:109-111). DYNAMO also accounts for delays, such as manufacturing time or shipping time (31:103).

Figure 3.7 illustrates the DYNAMO concepts discussed above. Here, inventory is acquired at a rate determined by a smoothed value of demand. The inventory departure rate is based solely on the quantity in the inventory level. Material arrival at Inventory Level 2 is delayed for six months, and the material quantity in the pipeline between Level 1 and Level 2 is assigned the variable name IPL.

The above summary should allow the reader to understand the sector diagrams that accompany the model discussion. For information on the format of DYNAMO equations, the reader is referred to Introduction to System Dynamics Modeling with DYNAMO (31) or the DYNAMO User's Manual (29).

Macro Structure

The macro structure of the MYP model is presented in Figure 3.8. Comparison with Brechtel's model (Figure 2.3) reveals that three links have been added. First, the market sector provides the financial sector with an estimate of future production revenue. Second, the production sector sends the financial sector an estimate of annual direct labor cost. Last, production receives fractional increases in productivity from the financial sector's investments in

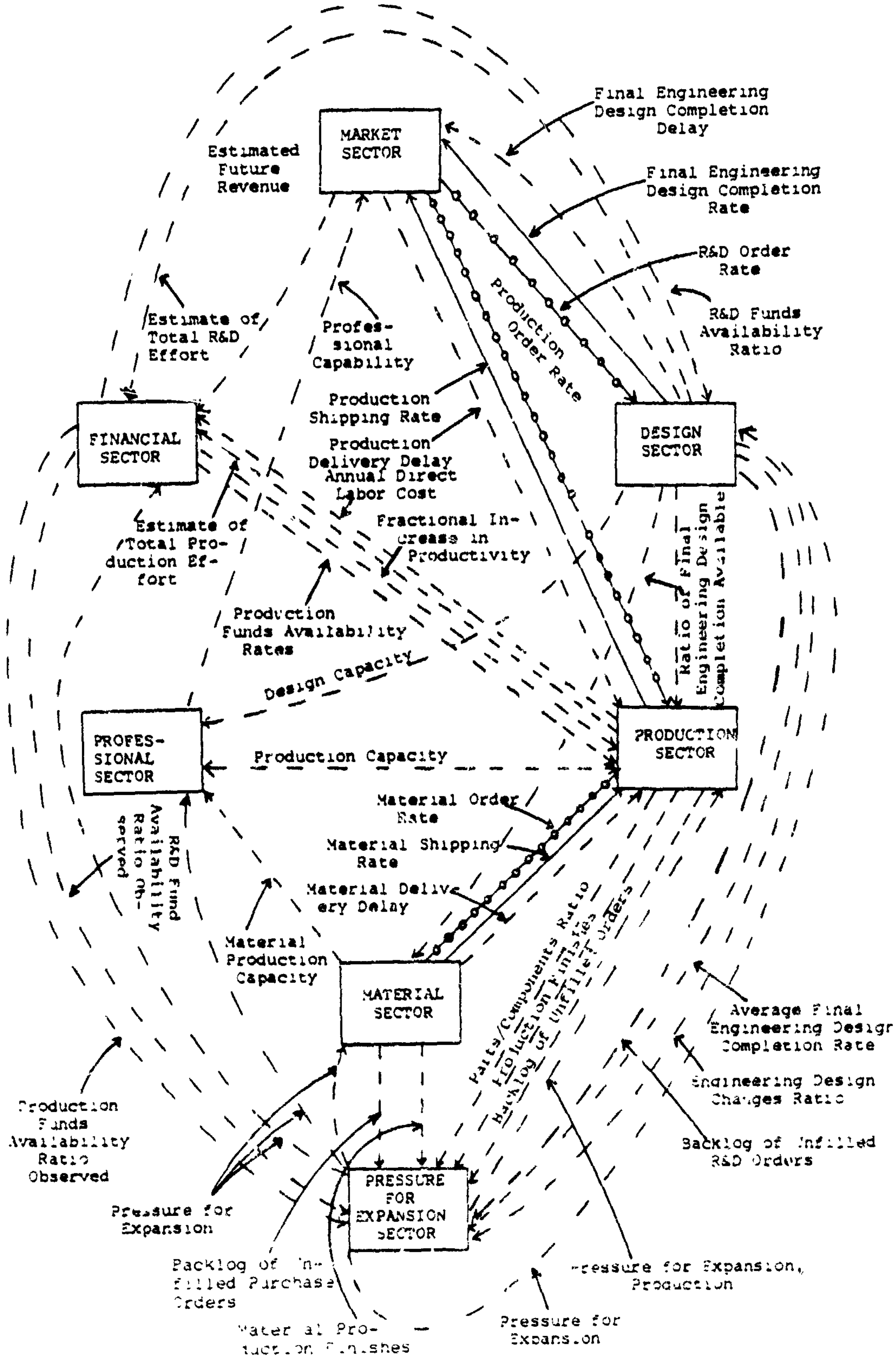


Figure 3.8

Macro-level Diagram of MYP Model

modernization. The only other change to Brechtel's model formulation is that the pressure-for-expansion sector input to production has been changed to a more specialized variable.

Formulation of this MYP model involved changes to only three sectors of Brechtel's model. For this reason, this chapter describes only those three sectors in detail. A complete model listing is available in Appendix E, and a detailed discussion of the unaffected model sectors can be found in Brechtel (8).

Market Sector

The market sector of the MYP model has three basic functions: generation of research and development (R&D) orders, generation of production orders, and estimation of revenue potential in the market. The first two functions are virtually identical to those identified by Brechtel (8:274-284); the last function is a modification designed for this research.

The structure of the market sector is shown in Figures 3.9a and 3.9b. R&D orders are essentially dependent upon the firm's professional effort and engineering design delay. Likewise, a portion of the production order rate is determined by professional effort and production delay. This portion of the total production orders is referred to as the contingent orders, those orders contingent on the firm's professional effort and production delay. The remaining production orders are assumed to be dictated by the primary

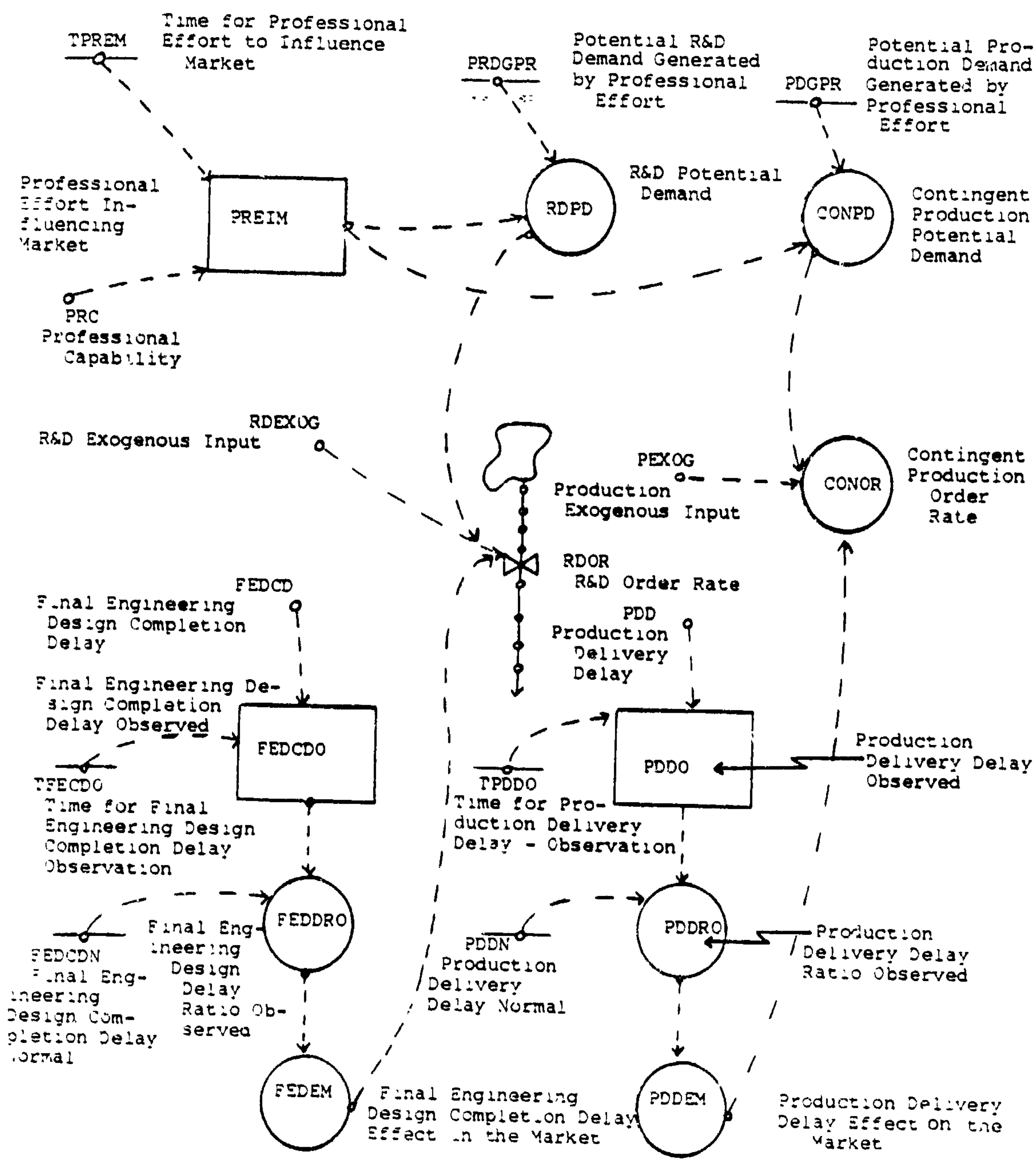


Figure 3.9a

Market Sector Model Structure, I

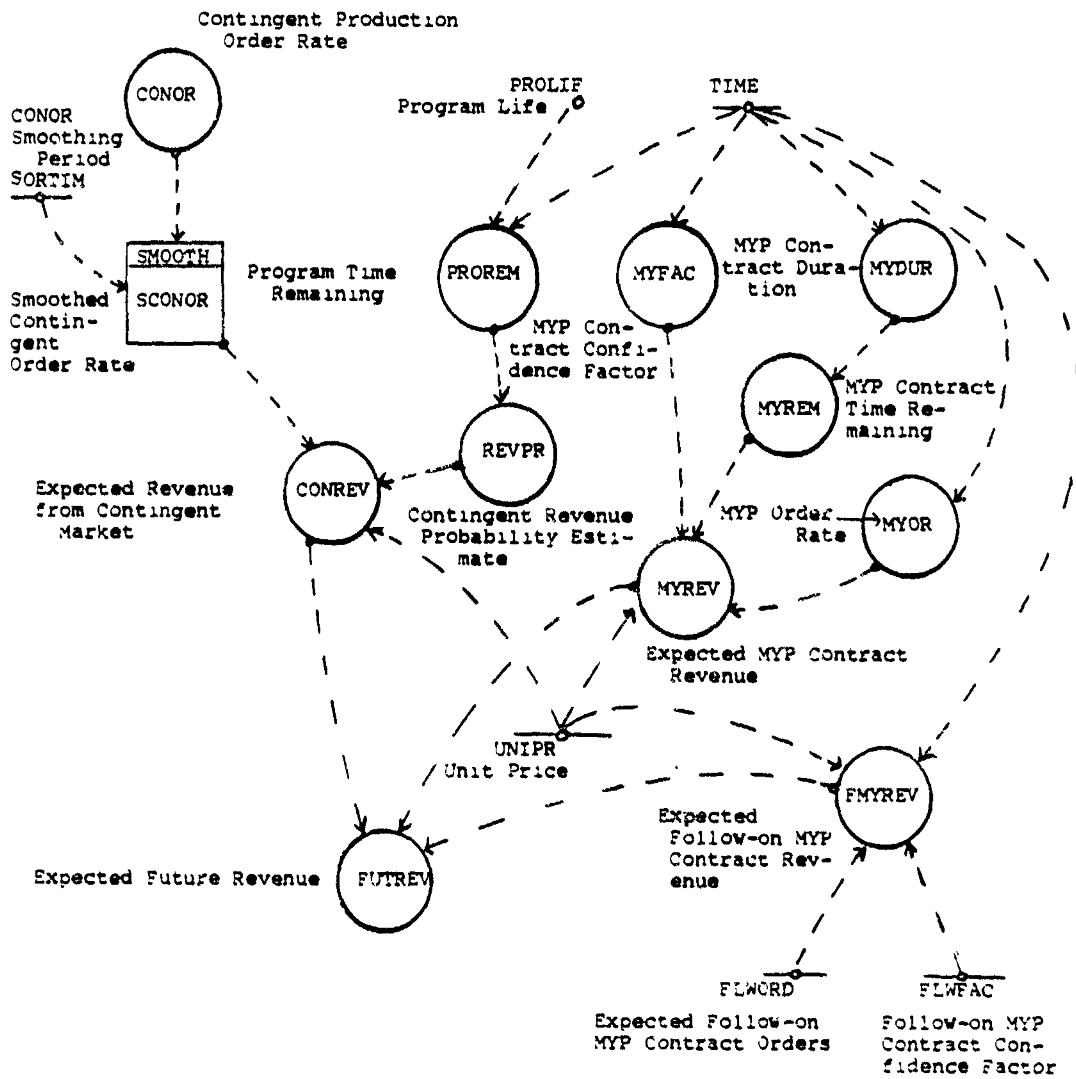


Figure 3.9b

Market Sector Model Structure, II

Government customer. The primary Government customer can award either annual or MYP contracts, both having order rates that are independent of the firm's professional effort and production delay.

The R&D and contingent markets are influenced by professional effort:

A	RDPD.K=(PREIM.K)(PRDGPR)	MK-1
C	PRDGPR=2	MK-2
A	CONPD.K=MAX(PREIM.K*PDGPR,CONPDM)	MK-3
C	PDGPR=.005	MK-4
C	CONPDM=15	MK-5

RDPD--R&D Potential Demand (engineering designs/month)

PREIM--PRofessional Effort Influencing the Market (workers)

PRDGPR--Potential R&D demand Generated by PRofessional effort (engineering designs/man-month)

CONPD--CONtingent Production potential Demand (units/month)

PDGPR--Potential production Demand Generated by PRofessional effort (units/man-month)

CONPDM--CONtingent Production potential Demand Maximum (units/month) (8:277)

Professional effort influencing the market is determined by the professional capability and the time necessary for that capability to have an effect on the market. The model assumes it takes 24 months for professional effort to affect the market.

L PREIM.K=PREIM.J+(DT)(1/TPREM)(PRC.J-PREIM.J) MK-6

C TPREM=24 MK-7

N PREIM=1600 MK-8

PREIM--PRofessional Effort Influencing the Market
(workers)

TPREM--Time for PRofessional Effort to influence the Market
(months)

PRC--PRofessional Capability
(workers) (8:278-279).

The actual R&D and contingent production order rates are a function of the potential demand and the effect of delays.

R RDOR.KL=(RDPD.K)(FEDEM.K)(RDEXOG.K) MK-9

A CONOR.K=(CONPD.K)(PDDEM.K)(PEXOG.K) MK-10

RDOR--R&D Order Rate
(engineering designs/month)

RDPD--R&D Potential Demand
(engineering designs/month)

FEDEM--Final Engineering design completion Delay Effect on Market
(dimensionless)

RDEXOG--R&D EXOGenous input
(dimensionless)

CONOR--CONtingent production Order Rate
(units/month)

CONPD--CONtingent Production potential Demand
(units/month)

PDDEM--Production Delivery Delay Effect on Market
(dimensionless)

PEXOG--Production EXOGenous input
(dimensionless) (8:279-280)

The effect of engineering design and production delays are calculated using the table functions below.

A	FEDEM.K=TABHL(TFEDEM,FEDDRO.K,0,3.5,0.5)	MK-11
T	TFEDEM=1/.9/.6/.45/.35/.30/.27/.25	MK-12
A	PDDEM.K=TABHL(TPDDEM,PDDRO.K,0,3.5,0.5)	MK-13
T	TPDDEM=1/.9/.8/.6/.5/.4/.35/.3	MK-14

FEDEM--Final Engineering design completion Delay Effect on the Market (dimensionless)

TFEDEM--Table for FEDEM

FEDDRO--Final Engineering Design completion Delay Ratio Observed (dimensionless)

PDDEM--Production Delivery Delay Effect on Market (dimensionless)

TPDDEM--Table for PDDEM

PDDRO--Production Delivery Delay Ratio Observed (dimensionless) (8:281-282).

The effect of the design and production delays on the market are determined by comparing the delays to their normal values, which are two months for design and thirteen months for production.

A	FEDDRO.K=FEDCDO.K/FEDCDN	MK-15
C	FEDCDN=2	MK-16
A	PDDRO.K=PDDO.K/PDDN	MK-17
C	PDDN=13	MK-18
L	FEDCDO.K=FEDCDO.J+(DT)(1/TFECDO)(FEDCD.J-FEDCDO.J)	MK-19
C	TFECDO=3	MK-20

```
N     FEDCDO=FEDCDN                                  MK-21

L     PDDO.K=PDDO.J+(DT)(1/TPDDO)
             (PDD.J-PDDO.J)                          MK-22

C     TPDDO=4                                        MK-23

N     PDDO=PDDN                                      MK-24
```

FEDDRO--Final Engineering Design completion Delay Ratio Observed (dimensionless)

FEDCDO--Final Engineering Design Completion Delay Observed (months)

FEDCDN--Final Engineering Design Completion Delay Normal (months)

FEDCD--Final Engineering Design Completion Delay (months)

PDDRO--Production Delivery Delay Ratio Observed (dimensionless)

PDDO--Production Delivery Delay Observed (months)

PDDN--Production Delivery Delay Normal (months)

TFECDO--Time for Final Engineering design Completion Delay Observation (months)

TPDDO--Time for Production Delivery Delay Observation (months)

PDD--Production Delivery Delay (months) (8:282-284).

The MYP model estimates the expected revenue from contingent orders by considering the average contingent order rate of the past twelve months, the unit price, the program life remaining, and a probability estimate that varies with program life remaining. The estimated program life in this case is twelve years, or 144 months. The model assumes a constant unit price of $10 million.

```
A    CONREV.K=(REVPR.K)(UNIPR.K)(PROREM.K)
              (SCONOR.K)                        MK-25

A    SCONOR.K=SMOOTH(CONOR.K,SORTIM)            MK-26

C    SORTIM=12                                  MK-27

A    PROREM.K=PROLIF-TIME.K                     MK-28

C    PROLIF=144                                 MK-29

C    UNIPR=10000000                             MK-30
```

CONREV--expected future CONtingent order REVenue (dollars)

REVPR--contingent REVenue PRobability (dimensionless)

SCONOR--Smoothed CONtingent Order Rate (units/month)

CONOR--CONtingent production Order Rate (units/month)

SORTIM--Smoothing ORder TIMe (months)

PROREM--PROgram time REMaining (months)

PROLIF--PROgram LIFe (months)

UNIPR--UNIt PRice (dollars)

The probability estimate used in the calculation of CONREV represents the estimated probability that the smoothed contingent order rate, SCONOR, will be maintained over the remaining life of the program. This probability estimate is a function of time: the greater the program life remaining, the lower the probability of maintaining the order rate. The TABHL function in equation MK-31 is used to maintain a minimum probability of .5.

```
A     REVPR.K=TABHL(TREVPR,PROREM.K,0,120,12)     MK-31

T     TREVPR=1/.95/.9/.85/.8/.75/.7/.65/.6/
             .55/.5                               MK-32

      REVPR--contingent REVenue PRobability
             (dimensionless)

      TREVPR--Table for REVPR
```

The expected future revenue from potential follow-on MYP contracts depends upon the number of units to be ordered, the unit price, and the contractor's confidence that the orders will, in fact, be placed. The contractor estimates that the follow-on MYP contract will be for 500 production units. The contractor's estimate of the probability of a follow-on MYP contract equals .5 early in the program, and increases linearly with time as the follow-on contract draws nearer.

```
A     FMYREV.K=(AFFLN.K)(FLWFAC.K)(UNIPR.K)       MK-33

A     AFFLN.K=(FLWCO.K)(FLWORD)                   MK-34

A     FLWCO.K=CLIP(0,1,TIME.K,84)                 MK-35

C     FLWORD=500                                  MK-36

A     FLWFAC.K=.5+MAX(TIME.K-24,0)*.4/60          MK-37

      FMYREV--expected Follow-on Multi-Year contract
              Revenue
              (dollars)

      AFFLN--Air Force FoLlow-oN
             (units)
```

FLWCO--FoLloW-oN COefficient
(dimensionless)

FLWORD--units expected in FoLloW-on ORDer
(units)

FLWFAC--contractor FoLloW-on confidence FACtor
(dimensionless)

The CLIP function in the equation for FLWCO is used to set FMYREV to zero when the potential MYP contract actually takes effect. The complex equation for FLWFAC reflects the increasing probability of a follow-on MYP contract as the program progresses.

The firm estimates potential revenue from its primary Government customer by considering the present order rate, the contract time remaining, the unit price, and a confidence factor. The contract time remaining is calculated by comparing the present time value with the expiration time of the present contract; MYP contracts end at the 84 and 144 month points. The contractor's estimate of the probability of the first MYP contract is .5 until the contract is actually awarded. The probability estimate then becomes .95. The MYP order rate is introduced via a TABLE function.

Although the variable names below refer to MYP, the equations are designed to allow for annual contracting profiles.

```
A     MYREV.K=(MYOR.K)(MYREM.K)(UNIPR.K)
              (MYFAC.K)                          MK-38

A     MYREM.K=MYDUR.K-TIME.K                     MK-39

A     MYDUR.K=CLIP(144,84,TIME.K,84)             MK-40
```

```
A    MYFAC.K=.5+STEP(.45,24)                         MK-41

A    MYOR.K=TABLE(TMYOR,TIME.K,0,144,12)             MK-42

T    TMYOR=0/10/10/10/10/10/10/10/10/
           10/10/10/10/10                            MK-43
```

MYREV--expected Multi-Year contract REVenue (dollars)

MYREM--Multi-Year contract time REMaining (months)

UNIPR--UNIt PRice (dollars)

MYFAC--Multi-Year confidence FACtor (dimensionless)

MYDUR--Multi-Year contract DURation (months)

MYOR--Multi-Year contract Order Rate (units/month)

TMYOR--Table for MYOR

The CLIP function above reflects the expiration time of each MYP contract. The STEP function in MK-41 shows the increase in the confidence factor when the first MYP contract is awarded. Each MYP contract calls for an order rate of ten units per month.

The expected future program revenue is the sum of the expected revenues from the primary Government customer (MYREV), other customers (CONREV), and potential follow-on MYP contracts (FMYREV).

```
A    FUTREV.K=MYREV.K+FMYREV.K+CONREV.K              MK-44
```

FUTREV--expected FUTure program REVenue (dollars)

MYREV--expected Multi-Year contract REVenue (dollars)

FMYREV--expected Follow-on Multi-Year contract
REVenue
(dollars)

CONREV--expected future CONtingent order REVenue
(dollars)

This completes the market sector formulation.

Financial Sector

The financial sector of the MYP model ensures that the production and design sectors are provided with sufficient operating funds. It also decides upon appropriate levels of investment in plant modernization and other productivity enhancements. Brechtel (8:285-288) discusses funding of design and production.

The heart of the financial sector modification is an investment model based upon average discounted cash flows for modernization projects (30). If the cost of investment capital is less than the quotient of average discounted cash flow divided by the cost of the project, then the MYP model considers this a desirable investment from the standpoint of cash flow. Actual investment in desirable projects depends upon contract cancellation ceilings, existing debt, corporate willingness to take risk, and incentive payments for modernization.

This investment model represents a compromise between accepted analysis techniques and model simplicity. The primary drawback of the above investment model is that it is not one of the two widely used capital expenditure models, internal rate of return and net present value (20:39-43). The researchers chose their investment model based upon its ease of translation to the DYNAMO language. Net present value or internal rate of return calculations in the MYP model would have involved much more computation, and hence more computer time.

The financial sector formulation is diagrammed in Figure 3.10. The discussion of financial sector equations will deal first with concepts used by Brechtel (Figure 3.10a) followed by modifications used in the MYP model (Figure 3.10b).

The financial sector initially estimates the funds necessary for R&D and production based upon the work backlog.

A	ECCRDE.K=(ETRDE.K)(RPED)(MCRDE)	F-1
C	RPED=.01	F-2
C	MCRDE=1	F-3
A	ECCPE.K=(ETPE.K)(RPPU)(MCPE)	F-4
C	RPPU=10	F-5
C	MCPE=1	F-6

ECCRDE--Estimated Cost to Complete R&D Effort (million dollars)

ETRDE--Estimate of Total R&D Effort (engineering designs/month)

RPED--Revenue Per Engineering Design (million dollars/engineering design)

MCRDE--Months to Complete R&D Effort (months)

ECCPE--Estimated Cost to Complete Production Effort (units/month)

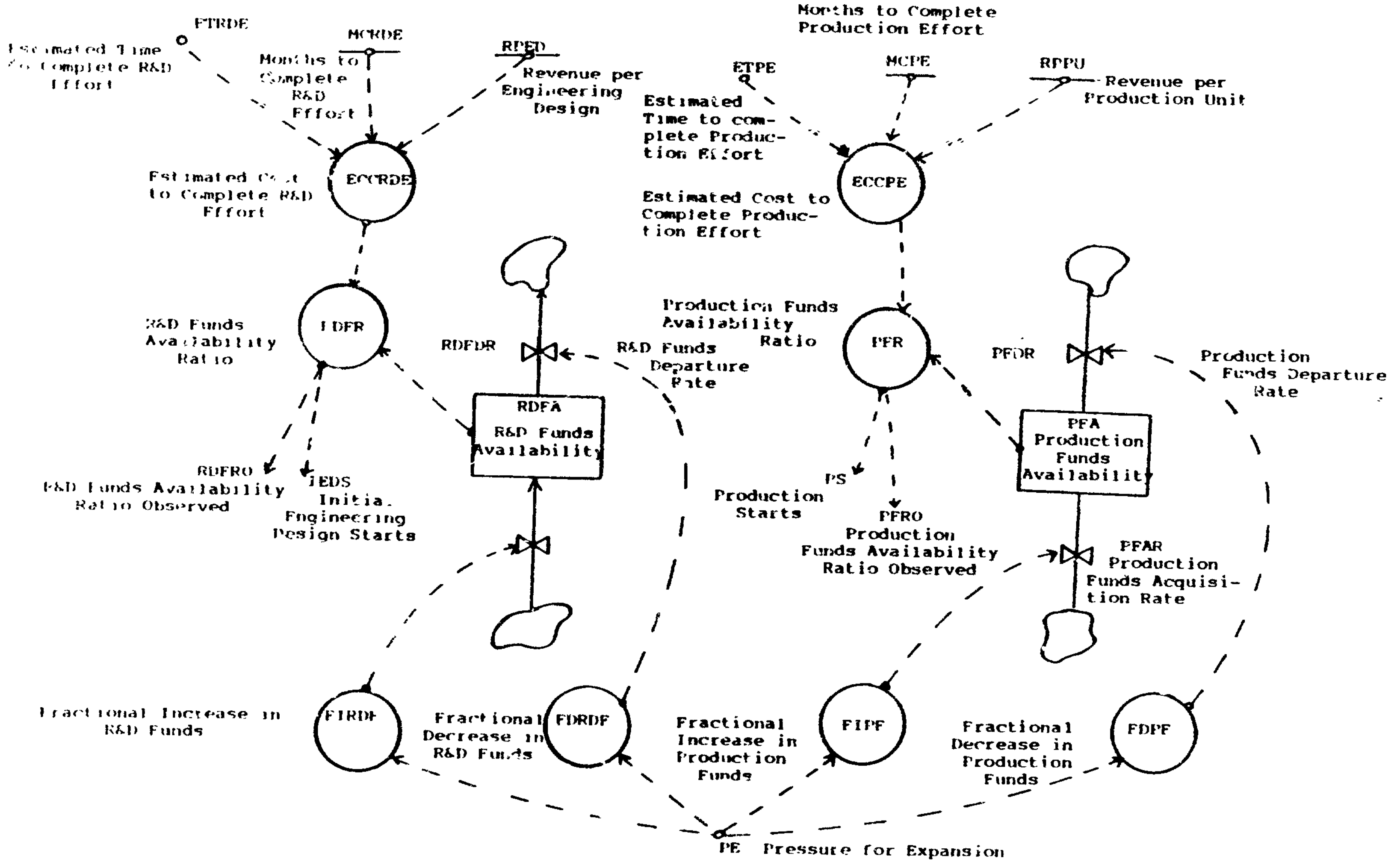


Figure 3.10a

Financial Sector Model Structure, I

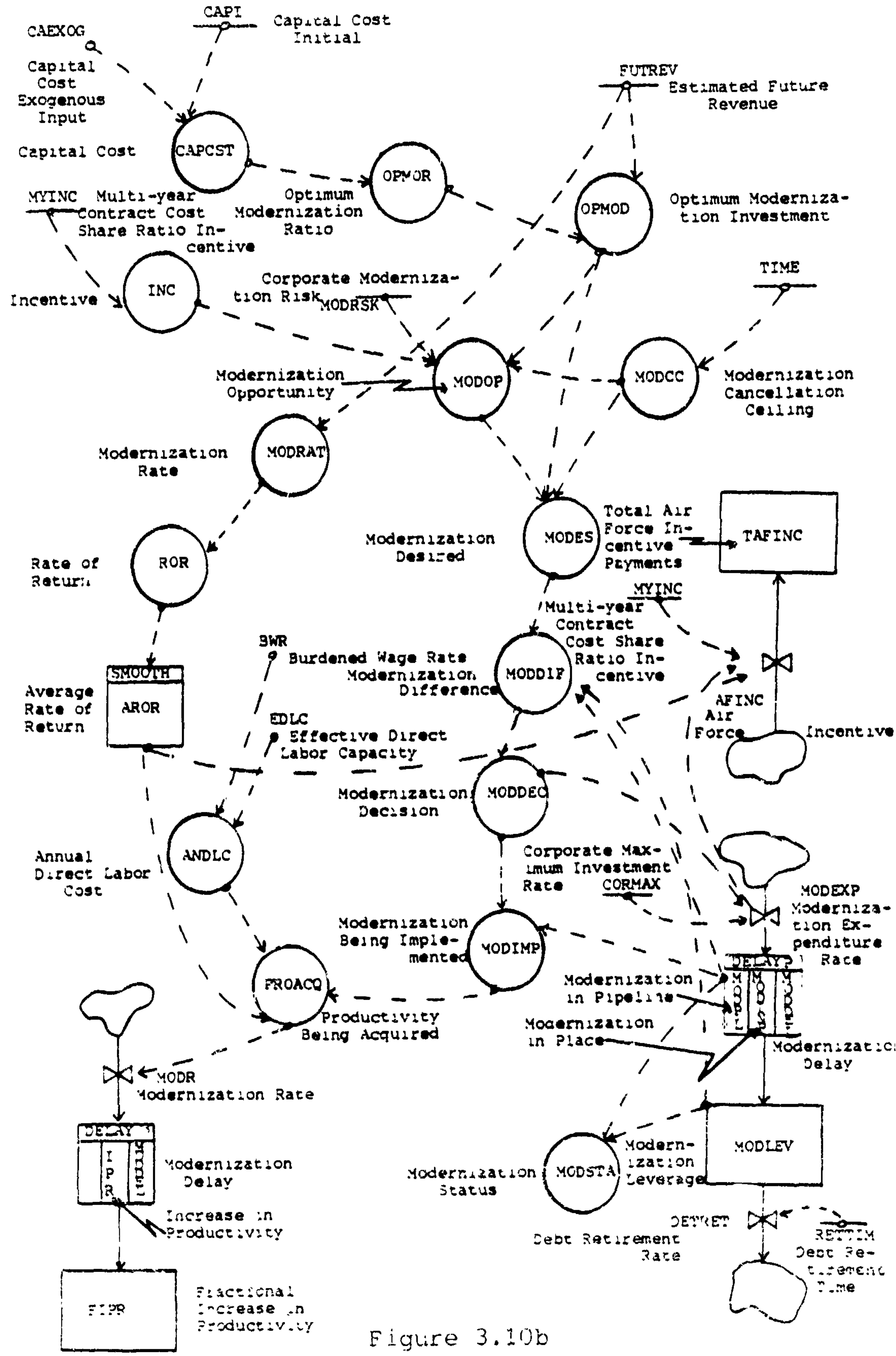


Figure 3.10b

Financial Sector Model Structure, I

ETPE--Estimate of Total Production Effort
(units/month)

RPPU--Revenue Per Production Unit
(million dollars/unit)

MCPE--Months to Complete Production Effort
(months) (8:287-288).

The model then determines the availability of funds. The initial value of R&D funds available is $10 million, and initial production funds availability is $100 million.

L	RDFA.K=RDFA.J+(DT)(RDFAR.JK-RDFDR.JK)	F-7
N	RDFA=RDFI	F-8
C	RDFI=10	F-9
L	PFA.K=PFA.J+(DT)(PFAR.JK-PFDR.JK)	F-10
N	PFA=PFI	F-11
C	PFI=100	F-12

RDFA--R&D Funds Availability
(million dollars)

RDFAR--R&D Funds Acquisition Rate
(million dollars/month)

RDFDR--R&D Funds Departure Rate
(million dollars/month)

RDFI--R&D Funds Initial
(million dollars)

PFA--Production Funds Availability
(million dollars)

PFAR--Production Funds Acquisition Rate
(million dollars/month)

PFDR--Production Funds Departure Rate
(million dollars/month)

PFI--Production Funds Initial
(million dollars) (8:289-290).

The acquisition of operating funds is determined by the firm's overall pressure-for-expansion.

R	RDFAR.KL=(RDFA.K)(FIRDF.K)	F-13
R	PFAR.KL=(PFA.K)(FIPF.K)	F-14
A	FIRDF.K=TABHL(TFIRDF,PE.K,-1,5,1)	F-15
T	TFIRDF=.005/.01/.02/.05/.1/.2/.3	F-16
A	FIPF.K=TABHL(TFIPF,PE.K,-1,5,1)	F-17
T	TFIPF=.005/.01/.02/.05/.1/.2/.3	F-18

RDFAR--R&D Funds Acquisition Rate
(million dollars/month)

RDFA--R&D Funds Availability
(million dollars)

FIRDF--Fractional Increase of R&D Funds
(1/month)

PFAR--Production Funds Acquisition Rate
(million dollars/month)

PFA--Production Funds Availability
(million dollars)

FIPF--Fractional Increase of Production Funds
(1/month)

FIRDF--Fractional Increase of R&D Funds
(1/month)

TFIRDF--Table for FIRDF
(1/month)

TFIPF--Table for FIPF
(1/month)

PE--Pressure for Expansion
(pressure units) (8:290-291).

TABHL functions are used to account for the limit on funds acquisition rate, despite extreme values for pressure-for-expansion. The same rationale applies to the equations discussed in the next paragraph.

As above, decreases in operating funds are also driven by pressure-for-expansion.

R	RDFDR.KL=(RDFA.K)(FDRDF.K)	F-19
R	PFDR.KL=(PFA.K)(FDPF.K)	F-20
A	FDRDF.K=TABHL(TFDRDF,PE.K,-5,1,1)	F-21
T	TFDRDF=.3/.2/.1/.05/.02/.01/.005	F-22
A	FDPF.K=TABHL(TFDPF,PE.K,-5,1,1)	F-23
T	TFDPF=.3/.2/.1/.05/.02/.01/.005	F-24

RDFDR--R&D Funds Departure Rate (million dollars/month)

RDFA--R&D Funds Availability (million dollars)

FDRDF--Fractional Decrease of R&D Funds (1/month)

PFDR--Production Funds Departure Rate (million dollars/month)

PFA--Production Funds Availability (million dollars)

FDPF--Fractional Decrease of Production Funds (1/month)

FDRDF--Fractional Decrease of R&D Funds (1/month)

TFDPF--Table for FDPF

TFDRDF--Table for FDRDF

PE--Pressure for Expansion (pressure units) (8:291-292).

The next group of equations determines whether funds will constrain R&D and production, and if so, how much.

A	RDFR.K=RDFA.K/ECCRDE.K	F-25
A	RDFRM.K=MAX(RDFR.K,.3)	F-26

A   RDFRC.K=CLIP(1.0,RDFRM.K,RDFRM.K,1.0)   F-27

A   PFR.K=PFA.K/ECCPE.K   F-28

A   PFRM.K=MAX(PFR.K,.3)   F-29

A   PFRC.K=CLIP(1.0,PFRM.K,PFRM.K,1.0)   F-30

RDFR--R&D Funds availability Ratio
(dimensionless)

RDFA--R&D Funds Availability
(million dollars)

ECCRDE--Estimated Cost to Complete R&D Effort
(million dollars)

RDFRM--R&D Funds availability Ratio Minimum
(dimensionless)

RDFRC--R&D Funds availability Ratio Clipped
(dimensionless)

PFR--Production Funds availability Ratio
(dimensionless)

PFA--Production Funds Availability
(million dollars)

ECCPE--Estimated Cost to Complete Production
Effort
(million dollars)

PFRM--Production Funds availability Ratio
Minimum
(dimensionless)

PFRC--Production Funds availability Ratio
Clipped
(dimensionless) (3:292-293).

The MYP model determines an optimum modernization investment level by considering the cost of capital, the annual discounted cash flows from the projects, and the estimated future revenue. The DYNAMO formulation assumes that optimum investment is directly proportional to the estimated future revenue. The formulation also assumes that modernization opportunities are independent of previous modernization projects. For example, if the model implements a $10 million program with a 20 percent rate of return at year one, the model assumes an identical opportunity will arise at the 36 month point, once the first investment is fully implemented. In actual model operation within plausible parameter ranges, such repeat investments are not actually made due to other constraints.

In the equations below, the cost of capital averages ten percent and the annual rates of return for available investment projects range from 0 to 25 percent. The TABLE function defining OPMOR assumes a linear relationship between investment rate of return and investment level.

A	CAPCST.K=CAPI+CAEXOG.K	F-31
C	CAPI=.10	F-32
A	OPMOR.K=TABLE(TOPMOR,CAPCST.K,0,.25,.05)	F-33
T	TOPMOR=.0167/.0133/.01/.0067/.0033/0	F-34
A	OPMOD.K=(OPMOR.K)(FUTREV.K)	F-35

CAPCST--CAPital CoST (percent)

CAPI--CAPital cost Initial (percent)

CAEXOG--CApital cost EXOGenous input (percent)

OPMOR--OPtimal MOdernization Ratio (dimensionless)

TOPMOR--Table for OPMOR

OPMOD--OPtimal MODernization investment level (dollars)

FUTREV--estimated FUTure REVenue
(dollars)

Once the optimum investment level is determined, the model calculates the actual investment level warranted by the contract cancellation ceiling, contract cost-sharing ratio, and the company's willingness to take investment risks. The model assumes that if the optimum modernization level exceeds the contract cancellation ceiling, then the firm will invest to at least the cancellation ceiling level. Investment beyond the cancellation ceiling is then influenced by cost-sharing ratio and the corporate risk factor.

The equations below reflect a cost-share ratio of 70-30. This cost-share ratio is converted to investment incentive through a table function. The firm is represented as being willing to invest 10 percent of the optimum investment level without the benefit of cancellation ceilings, so MODRSK equals .1 (24). The capital cancellation ceiling profile is input through a table function, and was based upon interviews with members of the Office of the Secretary of Defense staff. The maximum cancellation ceiling in this profile is $10 million.

```
A    INC.K=TABHL(TINC,MYINC.K,0,1.0,.2)              F-36

T    TINC=0/.5/.7/.9/1/1                             F-37

C    MYINC=.3                                        F-38

C    MODRSK=.1                                       F-39

A    MODOP.K=MODCC.K+(MODRSK)(INC.K)
          (OPMOD.K-MODCC.K)                          F-40
```

A MODCC.K=TABLE(TMODCC,TIME.K,0,144,3) F-41

T TMODCC=10E6/10E6/10E6/10E6/10E6/10E6/10E6/
10E6/10E6/10E6/10E6/10E6/90E6/
90E6/90E6/90E6/75E6/75E6/75E6/75E6/
50E6/50E6/50E6/50E6/20E6/20E6/20E6/
20E6/100E6/100E6/100E6/100E6/90E6/
90E6/90E6/90E6/75E6/75E6/75E6/75E6/
50E6/50E6/50E6/50E6/20E6/20E6/20E6/
20E6/20E6 F-42

A MODES.K=CLIP(MODOP.K,OPMOD.K,OPMOD.K,
MODCC.K) F-43

INC--INCentive from cost-share ratio (dimensionless)

TINC--Table for INC

MYINC--Multi-Year contract cost-sharing INCentive (dimensionless)

MODRSK--corporate willingness to incur MODernization RiSK (dimensionless)

MODCC--contract MODernization Cancellation Ceiling (dollars)

OPMOD--OPtimal MODernization investment (dollars)

MODOP--MODernization OPportunity (dollars)

MODES--MOdernization DESired (dollars)

TMODCC--Table for MODCC

The model then compares the modernization desired with modernization already implemented and corporate funding limitations to determine the new funding necessary for modernization investment. The model assumes that the contractor's corporate policy limits modernization investment to $25 million per year ($2.1 million per month). This value, CORMAX, was based upon interviews with managers of the modeled contractor.

A	MODDIF.K=MODES.K-MODPL.K-MODLEV.K	F-44
A	MODREQ.K=MAX(MODDIF.K,0)	F-45
A	MODPRO.K=MODREQ.K/DT	F-46
R	MODEXP.KL=MIN(MODPRO.K,CORMAX)	F-47
C	CORMAX=21E5	F-48
N	MODEXP=0	F-49
A	MODDEC.K=(MODEXP.JK)(DT)	F-50

MODDIF--MODernization DIFference (dollars)

MODES--MOdernization DESired (dollars)

MODPL--MODernization in PipeLine (dollars)

MODLEV--MODernization LEVerage (dollars)

MODREQ--MODernization investment REQuested (dollars)

MODPRO--MODernization rate PROposed (dollars/month)

MODEXP--MODernization EXPenditure rate (dollars/month)

CORMAX--CORporate MAXimum investment rate (dollars/month)

MODDEC--MODernization DECision (dollars)

The MAX function in F-45 assures that investment spending will be non-negative. The MIN function in F-47 maintains investment spending at or below the corporate maximum.

The MYP model assumes that modernization investment funds are spent over a 24-month period, at the end of which the total amount of the investment is incurred as a liability. The MYP model assumes this liability is paid off at the rate of ten percent per year.

R	MODINP.K=DELAYP(MODEXP.JK,MODDEL,MODPL.K)	F-51
N	MODPL=0	F-52
C	MODDEL=18	F-53
L	MODLEV.K=MODLEV.J+(DT)(MODINP.JK-DETRET.JK)	F-54
N	MODLEV=0	F-55
R	DETRET.KL=MODLEV.K/RETTIM	F-56
C	RETTIM=120	F-57
A	MODIMP.K=MODREQ.K+MODPL.K	F-58
A	MODSTA.K=MODIMP.K+MODLEV.K	F-59

MODINP--MODernization IN Place (dollars)

MODEXP--MODernization EXPenditure (dollars)

MODDEL--MODernization DELay (months)

MODPL--MODernization in PipeLine (dollars)

MODLEV--MODernization LEVerage (dollars)

DETRET--DEbT RETirement rate (dollars/month)

RETTIM--RETirement TIMe period (months)

MODIMP--MODernization being IMPLemented (dollars)

MODSTA--MODernization STAtus (dollars)

Once the modernization investment decision has been made, the MYP model calculates the improvement in productivity that will result. This is accomplished via a three-step process: (1) determine the rate of return of the latest investment, (2) calculate the annual direct labor cost, and (3) arrive at the productivity increase that will realize the rate of return.

The DYNAMO formulation determines the annual rate of return of the latest investment by using a table function very similar to that used to find the optimum investment level. In this case, however, investment level is the independent variable, and rate of return is the dependent variable. Rate of return is assigned an initial value of .25 for averaging purposes.

```
A    MODRAT.K=MODIMP.K/FUTREV.K                        F-60
A    ROR.K=TABLE(TROR,MODRAT.K,0,.0165,.0033)          F-61
T    TROR=.25/.2/.15/.1/.05/0                          F-62
A    AROR.K=SMOOTH(ROR.K,.5)                           F-63
N    ROR=.25                                           F-64
```

ROR--Rate of Return
(percent)

TROR--Table for ROR

MODRAT--MODernization to revenue RATio
(dimensionless)

MODIMP--MODernization being IMPlemented
(dollars)

FUTREV--estimated FUTure REVenue
(dollars)

AROR--Average Rate Of Return
(percent)

The MYP model then calculates the quantity that represents the annual burdened direct labor cost. The model assumes (via the CLIP function in F-66) that for the first two program years the firm uses an estimated annual burdened direct labor cost of $300 million; after that point, the firm uses present labor force data to make the labor cost calculation. The burdened direct labor rate includes an allocated share of indirect labor and general and administrative expenses.

A	ANDLCI.K= (BWR)(43)(EDLC.K)*52	F-65
A	ANDLC.K=CLIP(ANDLCI.K,300E6,TIME.K,24)	F-66

ANDLCI--ANnual Direct Labor Cost Initial
(dollars)

BWR--Burdened Wage Rate
(dollars/hour-worker)

EDLC--Effective Direct Labor Capacity
(workers)

ANDLC--ANnual Direct Labor Cost clipped
(dollars)

The fractional increase in productivity resulting from the investment decision is now calculated and injected into the pipeline to the plant. The MYP model expresses productivity increases from modernization as a multiplier of plant capacity. The model formulation uses a delay time of 24 months from investment decision to actual effect on plant productivity.

A	PROACQ.K=(AROR.K)(MODDEC.K)/ANDLC.K	F-67

R MODR.KL=PROACQ.K/DT F-68

N MODR=0 F-69

R IPR.KL=DELAY3(MODR.JK,MODDEL) F-70

L FIPR.K=FIPR.J+(DT)(IPR.JK) F-71

N FIPR=1.0 F-72

PROACQ--PROductivity being ACQuired (dimensionless)

AROR--Average Rate Of Return (percent)

MODDEC--MODernization DECision (dollars)

ANDLC--ANnual Direct Labor Cost clipped (dollars)

MODR--MODernization Rate (dollars/week)

IPR--Increase in PRoductivity (dimensionless.month)

FIPR--Fractional Increase in PRoductivity (dimensionless)

The next portion of the financial sector accounts for any Government incentive payments necessary to proceed with plant modernization. Such incentive is necessary when the contract cost-share ratio causes negative investment cash flow to the firm for even the most productive investments. In these cases, it is necessary for the Government to provide the contractor with incentive payments to prevent negative cash flow over the five year business horizon of the firm. The MYP model assumes the Government will provide 100 percent of proposed incentive payments.

A CFSF.K=(CAPCST.K-MYINC.K*AROR.K)
(MODEXP.JK*DT)*5 F-73

R AFINC.KL=MAX(CFSF.K,0)/DT F-74

L TAFINC.K=TAFINC.J+(DT)(AFINC.JK) F-75

N TAFINC=0 F-76

CFSF--Cash Flow Short Fall
(dollars)

CAPCST--CAPital CoST
(percent)

MYINC--MultiYear contract cost sharing INCentive
(percent)

AROR--Average Rate of Return
(percent)

MODEXP--MODernization EXPenditure
(dollars/month)

AFINC--Air Force INCentive payment
(dollars/month)

TAFINC--Total Air Force INCentive payment
(dollars)

The MAX function of F-74 is designed to preclude negative incentive payments.

This completes the financial sector formulation.

Production Sector

The production sector of the MYP model combines labor, plant capacity, and material to build the finished product of the firm. The production rate is driven by production backlog and is constrained by material inventory, funding, engineering design completion, and production capacity. The flow diagram of the production sector is shown in Figure 3.11a and 3.11b.

The MYP model modifies Brechtel's model by accounting for the impact of plant modernization and by making

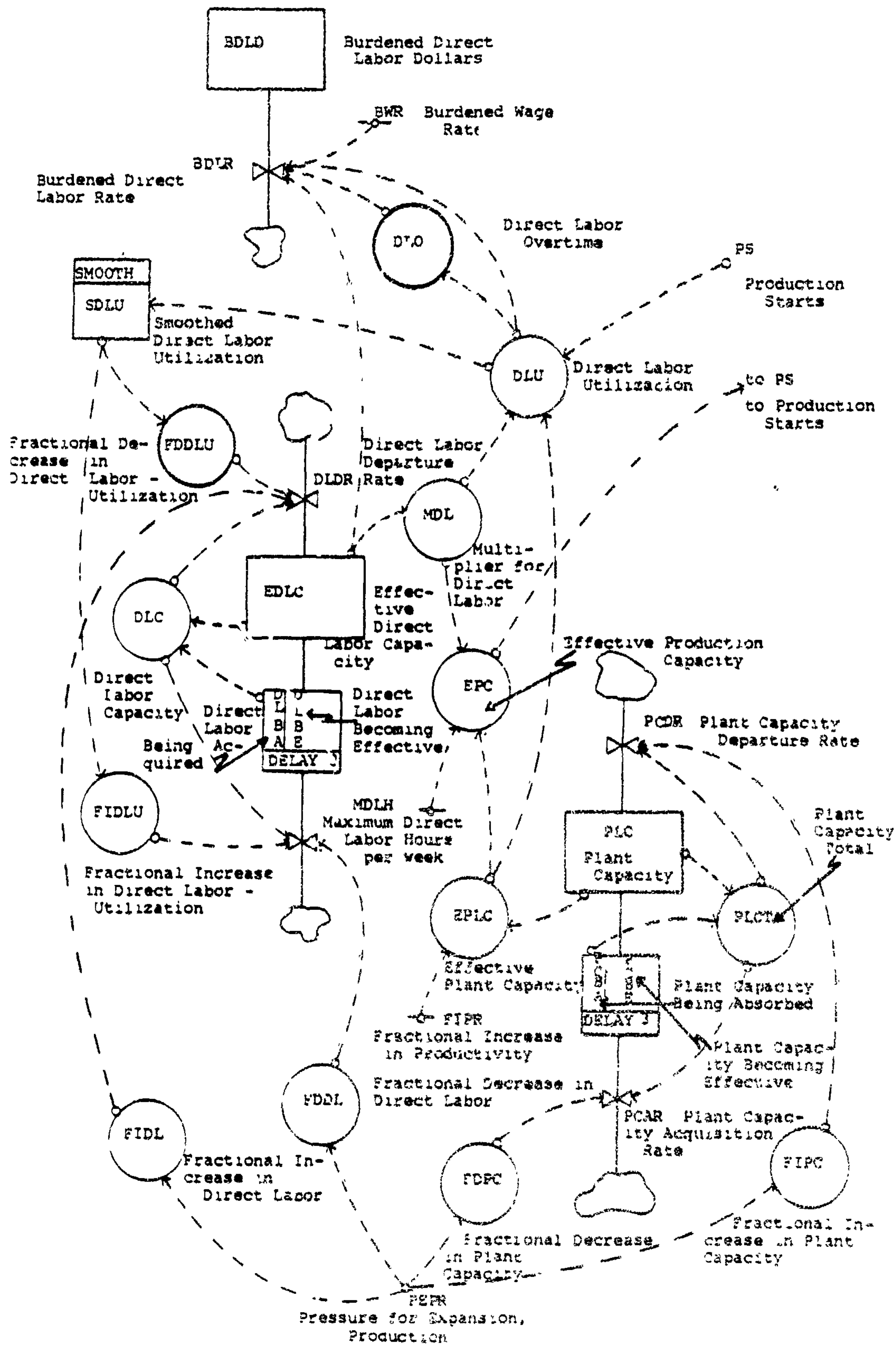


Figure 3.11a

Production Sector Model Structure, I

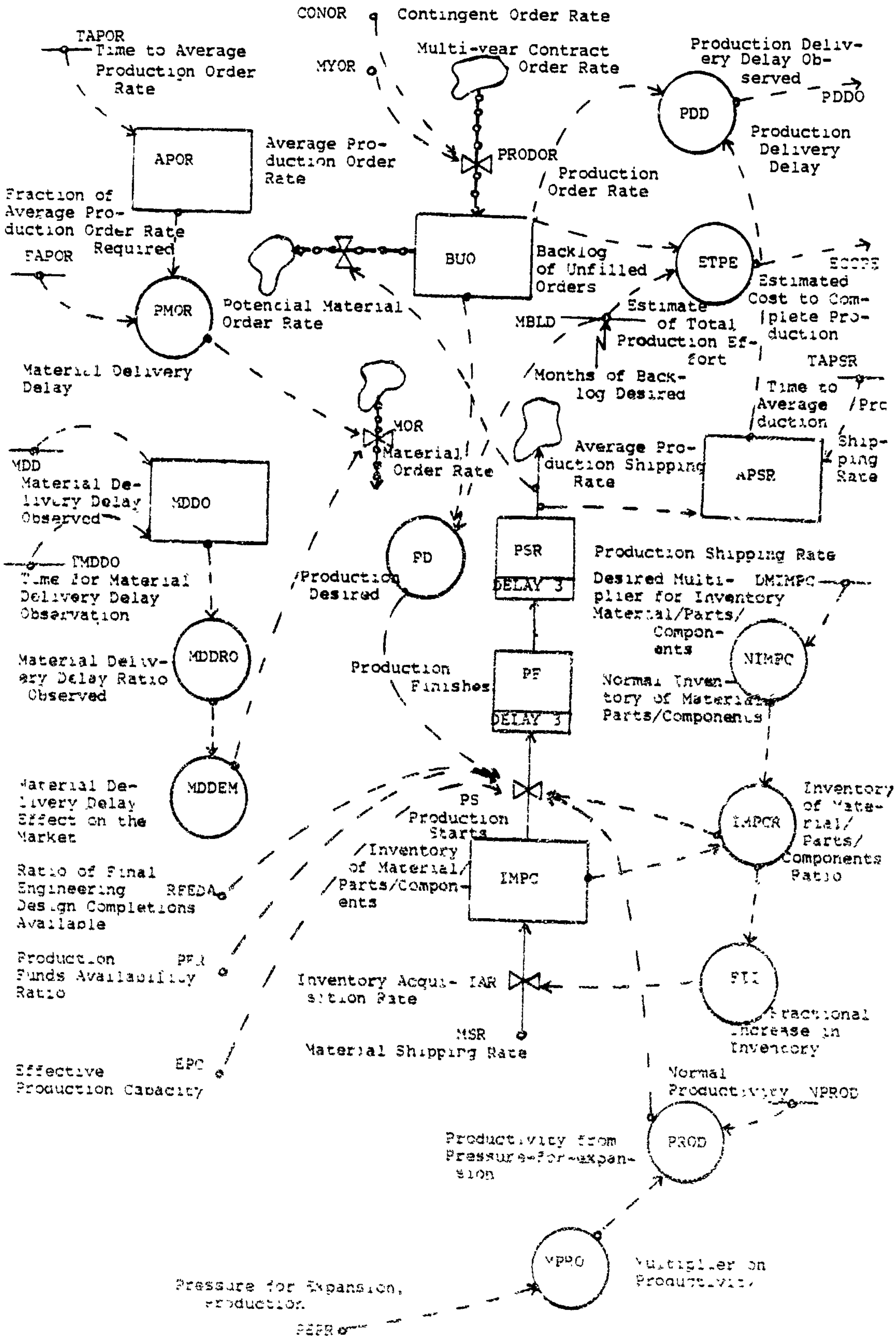


Figure 3.11b

Production Sector Model Structure, II

production sector growth more dependent upon production backlog. The MYP model also accumulates labor cost to aid in policy evaluation.

The effective direct labor capacity represents those workers who are trained and are working on the production program. However, labor force decisions take into account those workers being recruited and trained. The model assumes a maximum direct labor force of 9000, and a training/recruiting period of three months. The initial labor force size is 2000 workers.

```
L     EDLCI.K=EDLC.J+(DT)(DLBE.JK-DLDR.JK)          P-1
A     EDLC.K=MIN(EDLCI.K,9000)                       P-2
N     EDLCI=2000                                     P-3
R     DLBE.KL=DELAY3(DLAR.JK,DADL)                   P-4
C     DADL=3                                         P-5
L     DLBA.K=DLBA.J+(DT)(DLAR.JK-DLBE.JK)            P-6
N     DLBA=100                                       P-7
```

EDLCI--Effective Direct Labor Capacity Intermediate (workers)

EDLC--Effective Direct Labor Capacity (workers)

DLBE--Direct Labor Becoming Effective (workers)

DLDR--Direct Labor Departure Rate (workers/month)

DLAR--Direct Labor Acquisition Rate (workers/month)

DADL--Direct labor Acquisition DeLay (months)

DLBA--Direct Labor Being Absorbed
(workers)

The MIN function in P-2 prevents a work force of more than 9000.

Plant capacity is defined as the units per month that could be produced in a single shift operation with a 4400 worker direct labor force averaging a 43 hour work week. This definition assumes a constant technology level. Effective plant capacity refers to plant capacity multiplied by the productivity increases of modernization. The model assumes an 18-month delay in acquiring new plant capacity and an initial plant capacity of 18 units per month.

L	PLC.K=PLC.J+(DT)(PCBE.JK-PCDR.JK)	P-8
N	PLC=18	P-9
R	PCBE.KL=DELAY3(PCAR.JK,DAPC)	P-10
C	DAPC=18	P-11
L	PCBA.K=PCBA.J+(DT)(PCAR.JK-PCBE.JK)	P-12
N	PCBA=1	P-13
A	EPLC.K=(PLC.K)(FIPR.K)	P-14

PLC--Plant Capacity
(units/month)

PCBE--Plant Capacity Becoming Effective
(units/month-month)

PCDR--Plant Capacity Departure Rate
(units/month-month)

PCAR--Plant Capacity Acquisition Rate
(units/month-month)

DAPC--Delay for Acquiring Plant Capacity
(months)

PCBA--Plant Capacity Being Absorbed
(units)

EPLC--Effective PLant Capacity
(units/month)

FIPR--Fractional Increase in PRoductivity
(productivity units)

Production capacity results from the combination of labor and plant capacity. The DYNAMO model converts the labor force into a multiplier of plant capacity. The TABLE function for MDL is designed so that labor is most efficient when organized into 4400 worker shifts.

```
A    EPC.K=(EPLC.K)(MDLH)(MDL.K)                         P-15

C    MDLH=50                                             P-16

A    MDL.K=TABLE(TMDL,EDLC.K,0,8800,1100)                P-17

T    TMDL=0/.0025/.0075/.017/.023/.028/.033/
          /04/.047                                       P-18
```

EPC--Effective Production Capacity
(units/month)

EPLC--Effective PLant Capacity
(units/month)

MDLH--Maximum Direct Labor Hours per worker per week
(hours)

MDL--Multipler for Direct Labor
(1/hours)

TMDL--Table for MDL

Direct labor utilization shows how much work the average production worker actually performed in a given period. It is calculated by comparing actual production starts to effective production capacity and expressing work done in hours per worker.

A DLU.K=PS.JK/(EPLC.K*MDL.K) P-19

DLU--Direct Labor Utilization
(hours/week)

PS--Production Starts
(units/month)

EPLC--Effective PLant Capacity
(units/month)

MDL--Multiplier for Direct Labor
(week/hours)

The burdened direct labor cost per month is the product of the effective labor force, burdened wage rate, overtime per worker (direct labor utilization - 40 hours per week), and the average weeks in a month (4.33).

A DLUD.K=DLU.K-40 P-20

A DLO.K=MAX(DLUD.K,0) P-21

R BDLR.KL=4.33(EDLC.K)(BWR)
(40+1.5*DLO.K)/DT P-22

C BWR=35 P-23

L BDLD.K=BDLD.J+(DT)(BDLR.JK) P-24

N BDLD=0 P-25

DLUD--Direct Labor Utilization Difference
(hours/worker-week)

DLU--Direct Labor Utilization
(hours/worker-week)

DLO--Direct Labor Overtime
(hours/worker-week)

BDLR--Burdened Direct Labor Rate
(dollars/month)

EDLC--Effective Direct Labor Capacity
(workers)

BWR--Burdened Wage Rate
(dollars/hour-worker)

BDLD--Burdened Direct Labor Dollars
(dollars)

The MAX function in P-21 prevents negative overtime from being used in wage computations.

The model then ascertains the impact of direct labor utilization on the size of the direct labor force. Average work weeks of less than 38 hours will tend to decrease the force size, while work weeks of more than 43 hours will tend to cause an increase in the work force. The model uses a six-month labor utilization average to make the labor force decision.

A	SDLU.K=SMOOTH(DLU.K,SDLTIM)	P-26
C	SDLTIM=6	P-27
A	FIDLU.K=TABHL(TFIDLU,SDLU.K,42,60,3)	P-28
T	TFIDLU=.005/.007/.014/.022/.029/.035/.04	P-29
A	FDDLU.K=TABHL(TFDDLU,SDLU.K,33,45,2)	P-30
T	TFDDLU=.03/.029/.025/.017/.007/0/0	P-31

SDLU--Smoothed Direct Labor Utilization
(hours/week)

DLU--Direct Labor Utilization
(hours/week)

SDLTIM--Smoothing of Direct Labor over TIMe
(months)

FIDLU--Fractional Increase in Direct Labor due to Utilization
(dimensionless)

TFIDLU--Table for FIDLU

FDDLU--Fractional Decrease in Direct Labor due to Utilization
(dimensionless)

TFDDLU--Table for FDDLU

TABHL functions are used in all production capacity decisions, because the firm can only absorb a given proportion of new capacity, no matter how great the need.

The size of the direct labor force is also influenced by the pressure-for-expansion acting upon the production sector. Unlike Brechtel's formulation, in which only the aggregate firm's pressure-for-expansion affected production capacity (8:313), the MYP model gives equal weight to the more immediate consideration of production backlog. The firm uses a six-month average of pressure-for-expansion in its labor force decision.

A	PEDL.K=SMOOTH(PEPR.K,INDEDL)	P-32
C	INDEDL=6	P-33
A	FIDL.K=TABHL(TFIDL,PEDL.K,-1,5,1)	P-34
T	TFIDL=.005/.007/.014/.022/.029/.035/.04	P-35
A	FDDL.K=TABHL(TFDDL,PEDL.K,-5,1,1)	P-36
T	TFDDL=.09/.087/.076/.05/.02/.007/.005	P-37

PEDL--Pressure-for-Expansion acting upon Direct Labor
(pressure units)

PEPR--Pressure-for-Expansion acting upon PRoduction
(pressure units)

INDEDL--INput pressure DElay Direct Labor
(months)

FIDL--Fractional Increase in Direct Labor from pressure-for-expansion
(1/month

TFIDL--Table for FIDL

FDDL--Fractional Decrease in Direct Labor from pressure-for-expansion (1/month)

TFDDL--Table for FDDL

The actual rates of direct labor acquisitions and departures are determined by the total work force (those actually working plus those workers being recruited and trained) and the joint influence of pressure-for-expansion and direct labor utilization.

A DLC.K=EDLC.K+DLBA.K P-38

R DLAR.KL=(DLC.K)(FIDL.K+FIDLU.K) P-39

R DLDR.K=(DLC.K)(FDDL.K+FDDLU.K) P-40

DLC--Direct Labor Capacity (workers)

EDLC--Effective Direct Labor Capacity (workers)

DLBA--Direct Labor Being Absorbed (workers)

DLAR--Direct Labor Acquisition Rate (workers/month)

FIDL--Fractional Increase in Direct Labor due to pressure-for-expansion (1/month)

FIDLU--Fractional Increase in Direct Labor due to Utilization (1/month)

DLDR--Direct Labor Departure Rate (workers/month)

FDDL--Fractional Decrease in Direct Labor due to pressure-for-expansion (1/month)

FDDLU--Fractional Decrease in Direct Labor due to Utilization
(1/month)

The decision to change plant capacity is based only upon the pressure-for-expansion affecting production. The plant capacity decision further differs from the labor decision in that an 18-month pressure-for-expansion average is used.

A	PEPC.K=SMOOTH(PEPR.K,INDELP)	P-41
C	INDELP=13	P-42
A	FIPC.K=TABHL(TFIPC,PEPC.K,-1,5,1)	P-43
T	TFIPC=.0005/.0007/.0014/.0022/.0029/.0035 .004	P-44
A	FDPC.K=TABHL(TFDPC,PEPC.K,-5,1,1)	P-45
T	TFDPC=.009/.0087/.0076/.005/.002/.0007/ .0005	P-46
A	PLCT.K=PLC.K+PCBA.K	P-47
R	PCAR.KL=(PLCT.K)(FIPC.K)	P-48
R	PCDR.KL=(PLCT.K)(FDPC.K)	P-49

PEPC--Pressure-for-Expansion affecting Plant Capacity
(pressure units)

PEPR--Pressure-for-Expansion affecting Production
(pressure units)

INDELP--INput pressure DELay for Production
(months)

FIPC--Fractional Increase in Plant Capacity
(1/month)

TFIPC--Table for FIPC

FDPC--Fractional Decrease in Plant Capacity
(1/month)

TFDPC--Table for FDPC

PLCT--PLant Capacity Total
(units/month)

PLC--PLant Capacity
(units/month)

PCBA--Plant Capacity Being Absorbed
(units)

PCAR--Plant Capacity Acquisition Rate
(units/month)

PCDR--Plant Capacity Departure Rate
(units/month-month)

The production sector attempts a production rate that will maintain a 13-month backlog of orders. The sector's ability to maintain such a production rate may be constrained by productivity changes arising from pressure-for-expansion, material, operating funds, engineering design completions, and effective production capacity.

A	F1.K=MIN(PROD.K,PFRC.K)	P-50
A	F2.K=MIN(F1.K,RFEDAC.K)	P-51
A	F3.K=MIN(F2.K,IMPCM.K)	P-52
A	PP.K=(EPC.K)(F3.K)	P-53
A	PD.K=BUOC.K/MBLD	P-54
R	PS.KL=MIN(PP.K,PD.K)	P-55
N	PS=10	P-56

F1--Factor 1 for production starts
(dimensionless)

PROD--PRODuctivity arising from pressure-for-expansion
(dimensionless)

PFRC--Production Funds availability Ratio Clipped
(dimensionless)

F2--Factor 2 for production starts
(dimensionless)

RFEDAC--Ratio of Final Engineering Design completions Available Clipped
(dimensionless)

F3--Factor 3 for production starts
(dimensionless)

IMPCM--Inventory of Material/Parts/Components Multiplier
(dimensionless)

PP--Production starts Possible
(units/month)

EPC--Effective Production Capacity
(units/month)

PD--Production starts Desired
(units/month)

BUOC--Backlog of Unfilled Orders Clipped
(units)

MBLD--Months of Backlog Desired
(months)

PS--Production Starts
(units/month) (8:315).

The MIN functions above serve to assure that only the multiplier of the most severe constraint acts upon the desired production rate.

Pressure-for-expansion has an impact upon the productivity of the work force.

```
A   PROD.K=(NPROD)(MPRO.K)                       P-57

C   NPROD=1                                      P-58

A   MPRO.K=TABHL(TMPRO,PEPC.K,-5,5,1)            P-59

T   TMPRO=.65/.65/.75/.85/.9/1/1.1/1.2/1.25/
          1.3/1.3                                P-60
```

PROD--PRODuctivity arising from pressure-for-expansion
(units/unit-month)

NPROD--Normal PRODuctivity
(units/unit-month)

MPRO--Multiplier on PRODuctivity
(dimensionless)

PEPC--Pressure-for-Expansion affecting Plant Capacity
(pressure units) (8:316).

The next portion of the production sector determines material requirements and the extent of the material constraint upon production. First, normal inventory is defined as that sufficient to support two months production at effective capacity. The actual inventory on hand is then compared to the normal inventory to yield the inventory ratio.

A	NIMPC.K=(DMIMPC)(EPC.K)	P-61
C	DMIMPC=2	P-62
L	IMPC.K=IMPC.J+(DT)(IAR.JK-PS.JK)	P-63
N	IMPC=EPC	P-64
A	IMPCR.K=IMPC.K/EPC.K	P-65

NIMPC--Normal Inventory of Material/Parts/Components
(units)

DMIMPC--Desired Multiplier for Inventory of Material/Parts/Components
(months)

EPC--Effective Production Capacity
(units/month)

IMPC--Inventory of Material/Parts/Components
(units)

IAR--Inventory Acquisition Rate
(units/month)

PS--Production Starts
(units/month)

IMPCR--Inventory of Material/Parts/Components Ratio
(dimensionless) (8:317-318).

The inventory acquisition rate is driven by the material shipping rate and the production sector's need for material as measured by the inventory ratio.

```
R    IAR.KL=(MSR.JK)(FII.K)                          P-66

A    FII.K=TABHL(TFII,IMPCR.K,0,3.5,.5)              P-67

T    TFII=1/.9/.6/.45/.35/.3/.27/.25                 P-68
```

IAR--Inventory Acquisition Rate
(units/month)

MSR--Material Shipping Rate
(units/month)

FII--Fractional Increase of Inventory
(dimensionless)

TFII--Table for FII

IMPCR--Inventory of Material/Parts/Components
Ratio
(dimensionless) (8:318-319).

The availability of material in inventory is an important constraint in starting production. The model expresses this constraint as a multiplier that can reduce production starts by up to 70 percent.

```
A    IMPCA.K=IMPC.K/PD.K                             P-69

A    IMPCAM.K=MAX(IMPCA.K,.3)                        P-70

A    IMPCM.K=CLIP(1,IMPCAM.K,IMPCAM.K,1)             P-71
```

IMPCA--Inventory of Material/Parts/Components
Available
(months)

IMPC--Inventory of Material/Parts/Components
(units)

PD--Production starts Desired
(units/month)

IMPCAM--Inventory of Material/Parts/Components
Available Minimum
(months)

IMPCM--Inventory of Material/Parts/Components
Multiplier
(months) (8:320).

The MYP model assumes a production time of 13 months. It also assumes a one-month delay from unit completion to shipment.

R	PF.KL=DELAY3(PS.JK,DP)	P-72
C	DP=13	P-73
N	PF=10	P-74
L	UNITSF.K=UNITSF.J+(DT)(PF.JK)	P-75
N	UNITSF=0	P-76
R	PSR.KL=DELAY3(PF.JK,DPFUN)	P-77
C	DPFUN=1	P-78
N	PSR=10	P-79

PF--Production Finishes
(units/month)

PS--Production Starts
(units/month)

DP--Delay for Production
(months)

UNITSF--UNITS Finished
(units)

PSR--Production Shipping Rate
(units/month)

DPFUN--Delay in Processing Finished Units Normal
(months) (8:321-322).

The backlog of unfilled orders is a key value in determining production rate and pressure-for-expansion. The firm attempts to maintain a backlog equivalent to 13 months production.

R	PRODOR.KL=CONOR.K+MYOR.K	P-80
L	BUO.K=BUO.J+(DT)(PRODOR.JK-PSR.JK)	P-81
N	BUO=(MBLD)(AP)	P-82
C	MBLD=13	P-83
A	BUOC.K=CLIP(BUO.K,.5,BUO.K,.5)	P-84

PRODOR--PRODuction Order Rate
(units/month)

CONOR--CONtingent Order Rate
(units/month)

MYOR--Multi-Year Order Rate
(units/month)

BUO--Backlog of Unfilled Orders
(units)

PSR--Production Shipping Rate
(units/month)

MBLD--Months of Backlog Desired
(months)

AP--Average Production rate
(units/month)

BUOC--Backlog of Unfilled Orders Clipped
(units) (8:322).

The material order rate depends upon the average production order rate of the last three months and the effect of delays in the material sector.

```
L    APOR.K=APOR.J+(DT)(1/TAPOR)
              (PRODOR.JK-APOR.J)                        P-85

C    TAPOR=3                                            P-86

N    APOR=10                                            P-87

A    PMOR.K=(APOR.K)(FAPOR)                             P-88

C    FAPOR=3                                            P-89

R    MOR.KL=(PMOR.K)(MDDEM.K)                           P-90
```

APOR--Average Production Order Rate
(units/month)

TAPOR--Time to Average Production Order Rate
(months)

PRODOR--PRODuction Order Rate
(units/month)

PMOR--Potential Material Order Rate
(units/month)

FAPOR--Fraction of Average Production Order Rate required
(dimensionless)

MOR--Material Order Rate
(units/month)

MDDEM--Material Delivery Delay Effect on the Market
(dimensionless) (8:322-325).

The effect of material delivery delay on the market allows for difficulties in procuring material from suppliers. Material delays greater than one month adversely effect the material order rate.

A MDDEM.K=TABHL(TMDDEM,MDDRO.K,0,3.5,.5) P-91

T TMDDEM=1/.9/.6/.45/.35/.3/.27/.25 P-92

A MDDRC.K=MDDO.K/MDDN P-93

C MDDN=1 P-94

MDDEM--Material Delivery Delay Effect on the Market (dimensionless)

TMDDEM--Table for MDDEM

MDDRO--Material Delivery Delay Ratio Observed (dimensionless)

MDDO--Material Delivery Delay Observed (months)

MDDN--Material Delivery Delay Normal (months) (8:325-326).

The model assumes that it takes the market three months to notice material delivery delays.

L MDDO.K=MDDO.J+(DT)(1/TMDDO)(MDD.J-MDDO.J) P-95

C TMDDO=3 P-96

N MDDO=MDDN P-97

MDDO--Material Delivery Delay Observed (months)

TMDDO--Time for Material Delivery Delay Observation (months)

MDD--Material Delivery Delay (months)

MDDN--Material Delivery Delay Normal (months) (8:326-327).

The production delivery delay is an important information input into the market sector. Production delivery delay is a function of production backlog and average production shipping rate.

A	PDD.K=BUOC.K/APSR.K	P-98
L	APSR.K=APSR.J+(DT)(1/TAPSR)(PSR.JK-APSR.J)	P-99
C	TAPSR=3	P-100
N	APSR=10	P-101

PDD--Production Delivery Delay (months)

BUOC--Backlog of Unfilled Orders Clipped (units)

APSR--Average Production Shipping Rate (units/month)

TAPSR--Time to Average Production Shipping Rate (months)

PSR--Production Shipping Rate (units/month) (8:327-328).

Finally, the production sector estimates its forecast of total production effort for the financial sector; this estimate is based upon a comparison of existing versus desired production backlog.

A	ETPE.K=BUOC.K/MBLD	P-102

ETPE--Estimate of Total Production Effort (units/month)

BUOC--Backlog of Unfilled Orders Clipped (units)

MBLD--Months of Backlog Desired (months) (8:328)

This completes the production sector formulation.

Additional Modifications

As mentioned earlier, the MYP model also includes changes to Brechtel's pressure-for-expansion sector. Brechtel's model (8) calculated one overall pressure-for-expansion value that encompassed the entire firm.

The researcher's MYP model uses a "customized" pressure-for-expansion variable for the production sector. The customized pressure-for-expansion value accounts equally for both the firm-wide pressure and the state of the production sector.

```
A    PEPR.K=(PE.K+6*PEB.K)/2                          PE-52

     PEPR--Pressure-for-Expansion, PRoduction
           (pressure units)

     PE--Pressure-for-Expansion, firm-wide
         (pressure units)

     PEB--Pressure-for-Expansion, production Backlog
          (pressure units)
```

The researchers designed a model modification that permits the evaluation of the firm's ability to respond to a production surge requirement. This modification involves changes to equations in the market and production sectors. Two step functions introduce a 20-unit surge requirement over a one-month period.

```
A    CONOR.K=(CONPD.K)(PDDEM.K)(PEXOG.K)+SURGE.K MK-10
A    SURGE.K=STEP(20,60)+STEP(-20,61)            MK-45
```

The surge equations make the surge requirement a high priority by making the surge requirement a direct input in determining production starts. The equations also account for the surge units introduced into production.

R	PS.KL=MIN(PP.K,PD.K+SL.K)	P-55
L	SL.K=SL.J+(SURGE.J-SR.J)(DT)	P-103
N	SL=0	P-104
A	SR.K=MAX(0,PS.JK-PD.K)	P-105

PS--Production Starts
(units/month)

PP--Production starts Possible
(units/month)

PD--Production starts Desired
(units/month)

SL--Surge Level
(units)

SURGE--SURGE order rate
(units/month)

SR--Surge level Reduction
(units/month)

Summary

The researchers modified three sectors of Brechtel's contractor model to allow evaluation of four predicted MYP benefits. These modifications of the market sector, financial sector, and production sector were then tested for proper use of the DYNAMO language. The next step was to evaluate model usefulness.

CHAPTER 4

MODEL EVALUATION

Introduction

In Richardson and Pugh's outline of the steps in the system dynamics approach, model formulation is immediately followed by analysis of model behavior and model evaluation (31:16). These steps include the familiar concepts of sensitivity analysis, model verification, and model validation.

Forrester and Senge have integrated the above steps into an overall model validation procedure (18). They define validation as "the process of establishing confidence in the soundness and usefulness of a model [18:210]." The researchers used Forrester and Senge's outline in the confidence building process for this research project.

The researchers conducted tests of the model structure, model behavior, and policy implications. These tests were accomplished via interviews with managers of the modeled contractor, examination of model structure, and analysis of simulation results. This chapter will discuss model evaluation by considering the results of the researchers' examination of model structure, model behavior, and policy implications.

Model Structure

Forrester and Senge (18) propose five tests for establishing confidence in model structure. First, the <u>structure verification test</u> compares the structure of the model with the structure of the real system. Likewise, the <u>parameter verification test</u> compares model parameters to actual system parameters. The third test, <u>extreme conditions</u>, evaluates the ability of the model structure to deal with extreme variable values. The <u>boundary adequacy test</u> is designed to determine if the model structure is adequate to the model purpose. Last, a <u>dimensional consistency test</u> involves examining the DYNAMO equations to ensure correct dimensional algebra (18:211-216). The researchers conducted all five tests, which will be discussed in the above order.

<u>Structure-Verification Test</u>. The researchers verified MYP model structure by interviewing managers from the modeled contractor using the interview guide in Appendix G. Section II of the interview guide concentrates on model structure and is organized into questions about the market sector, financial sector, and production sector.

The researchers interviewed one contractor representative about the market sector. The manager indicated agreement or strong agreement with all interview guide questions dealing with the market sector structure.

Two contractor managers answered questions about the financial sector. Both managers agreed with the basic sector structure, but both also stated that technical modernization incentive payments should be incorporated into the financial sector structure. The researchers included this concept into the model, as previously discussed in Chapter 3.

Four managers were interviewed about the production sector. The managers provided the researchers with more accurate information on the firm's direct labor requirements; this interview-derived information was incorporated into the production sector of the model. No other necessary structure changes were identified in the interview process.

Parameter-Verification Test. The researchers also used the contractor interviews to verify the accuracy of several model parameters. The interview findings provided the model with an accurate figure for the Burdened Wage Rate (BWR) and also identified parameters for special attention during sensitivity analysis. These parameters, corporate willingness to take risk and time necessary to hire and train new workers, were points of disagreement or uncertainty among the interviewees. The result of this sensitivity analysis is discussed later in this chapter.

Extreme-Conditions Test. The researchers conducted the extreme-conditions test on the MYP model modifications by determining the effect of extreme level variable values on rate equations. This procedure is valuable in discovering model flaws and expanding the useful range of the model (18:214).

The extreme-condition test revealed one area of concern. Zero or negative inventory will not bring production to a halt; it will only reduce production by 70 percent. The researchers felt that a 70 percent reduction in production is a reasonable approximation for a production halt, since the purpose of the researchers' MYP model was not to evaluate plant shutdowns.

Boundary-Adequacy Test. Forrester and Senge maintain that a successful boundary-adequacy test results when the modeler is unable to develop a plausible hypothesis requiring additional model structure (18:215). The researchers could not identify any other structure necessary to evaluate the MYP benefits of plant modernization, labor stability, and surge capability. It can be argued that the present MYP model does not extensively account for certain cost types, such as overhead and administration. The researchers maintain, however, that the model is sufficient to evaluate MYP's ability to reduce cost, in the aggregate.

Dimensional Consistency Test. The researchers checked all equations in the modified sector (production, financial, and market) to ensure dimensional consistency. This check confirmed the proper use of variable dimensions.

Model Behavior

The researchers subjected model behavior to five of Forrester and Senge's tests. First, behavior tests substantiated the ability of the model to reproduce past system behavior. Behavior prediction tests, likewise, explored the model's capability to forecast system behavior. Third, searching for behavior anomalies helped the researchers uncover flaws in model structure. Introducing extreme policies into the model strengthened the researchers' confidence in the model's ability to respond to a wide range of MYP options. Finally, the researchers investigated the model's sensitivity to parameter changes.

Behavior-Reproduction. Brechtel demonstrated the ability of his contractor model to reproduce the modeled firm's behavior over a period of 20 years (8). The MYP model modifications do not impair this capability; the researchers' MYP model was used to enhance portions of Brechtel's proven model structure.

Figure 4.1 is a graphical representation of a ten-year system simulation. In this experiment, the researchers input an annual contracting profile through an order rate that varied from 19 to 10 units per month in a three-year long cycle. On the graph, where production starts are represented by the letter P and labor force by the letter L, production and labor display a significant instability--with the same cycle period as the order rate. Here, the model reproduces the contractor behavior which has led to the push for MYP.

Behavior-Prediction. Figure 4.2 is graphical output from another ten-year simulation. For this experiment, two

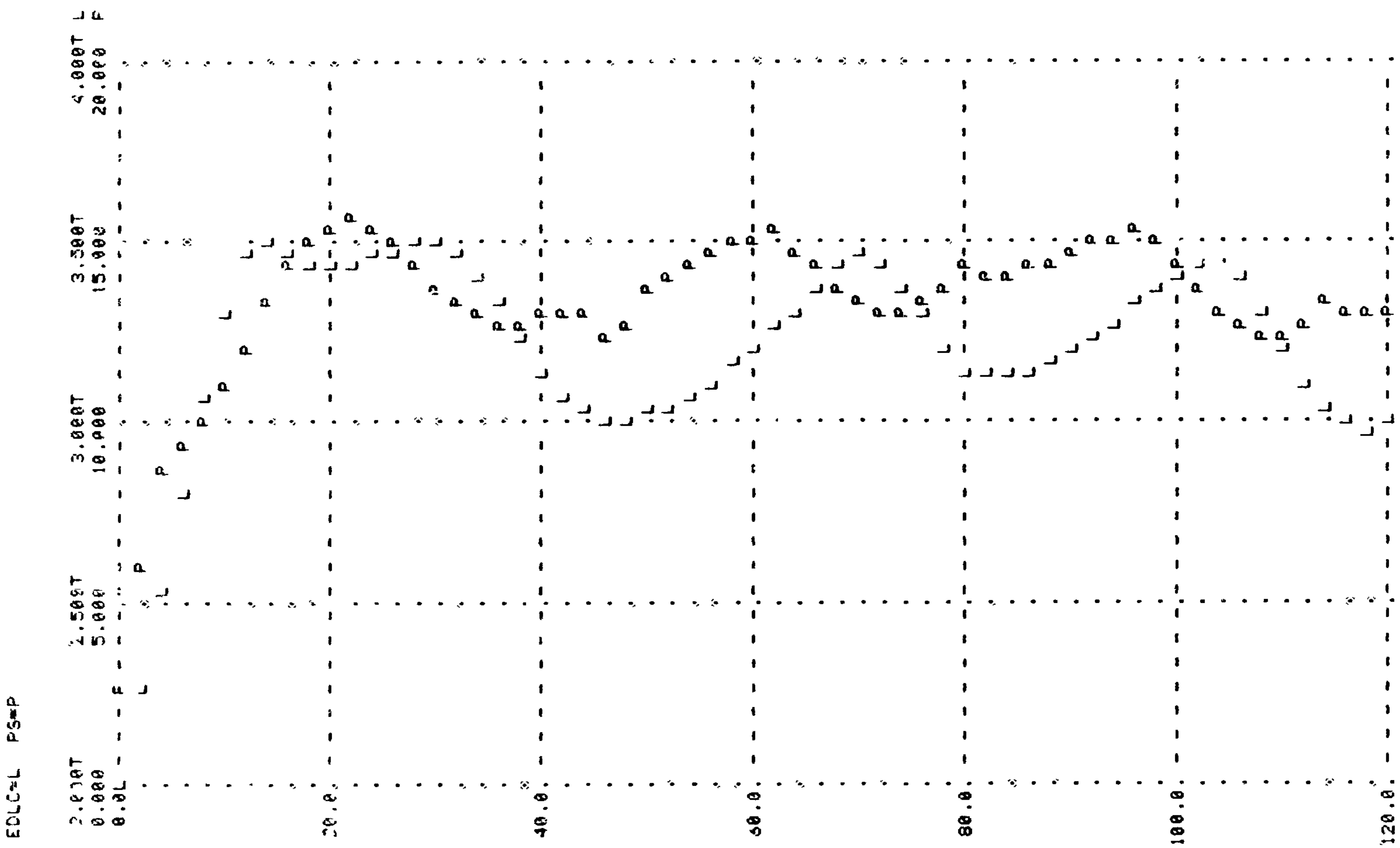


Figure 4.1

Annual Profile Model Behavior, Labor and Production

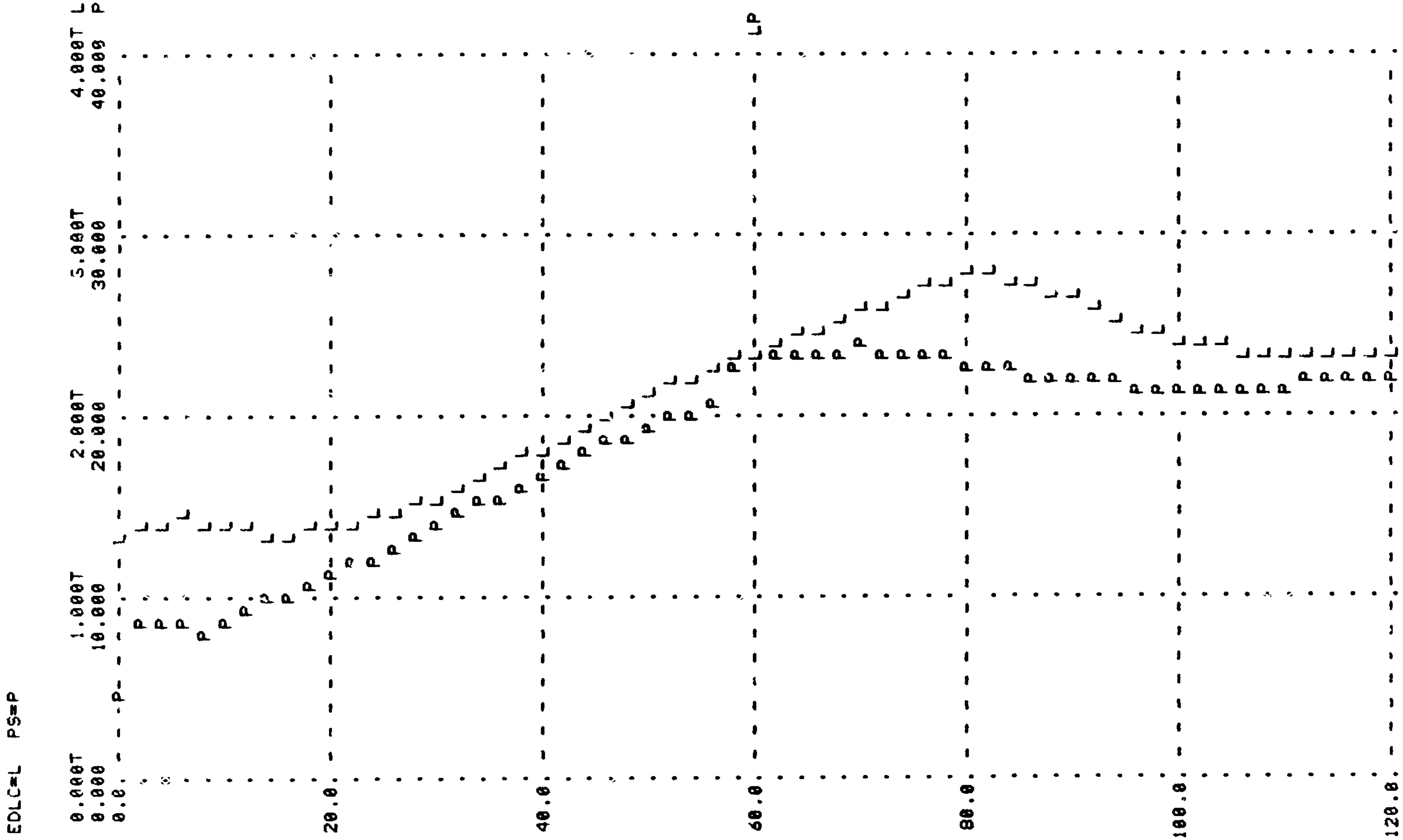


Figure 4.2

MYP Profile Model Behavior, Labor and Production consecutive five-year MYP contracts (awarded at the 24 and 84 month points) maintained a constant primary customer order rate of 10 units per month. Contingent order rate rose as high as 12 units/month within sixty months of the start of production. Note the smoother build-up of labor force (L) and production rate (P) as compared to the annual profile (Figure 4.1). Figure 4.3 shows the modernization liability curve (symbol I) for the simulation. Notice the large investment increase at month 24, the start of the first MYP contract. A smaller increase in investment occurs at month 84, the beginning of the second MYP contract.

Using Section III of the interview guide (Appendix G), the researchers questioned three contractor managers about the behavior reflected by the graphs of labor and modernization investment. The managers all expressed agreement with the general behavior of the labor and modernization curves, although they had reservations about the sharp spikes in investment at the MYP contract start points. These investment spikes were reduced in the model by accounting for the corporate limit on annual modernization spending obtained in the interview process.

The interviewees disagreed with the market sector behavior demonstrated in Figure 4.4. The managers felt that the build-up of the contingent order rate (represented by the letter F; G is the MYP order rate) was too gradual. Changing the value of the parameter PDGPR--Potential Production

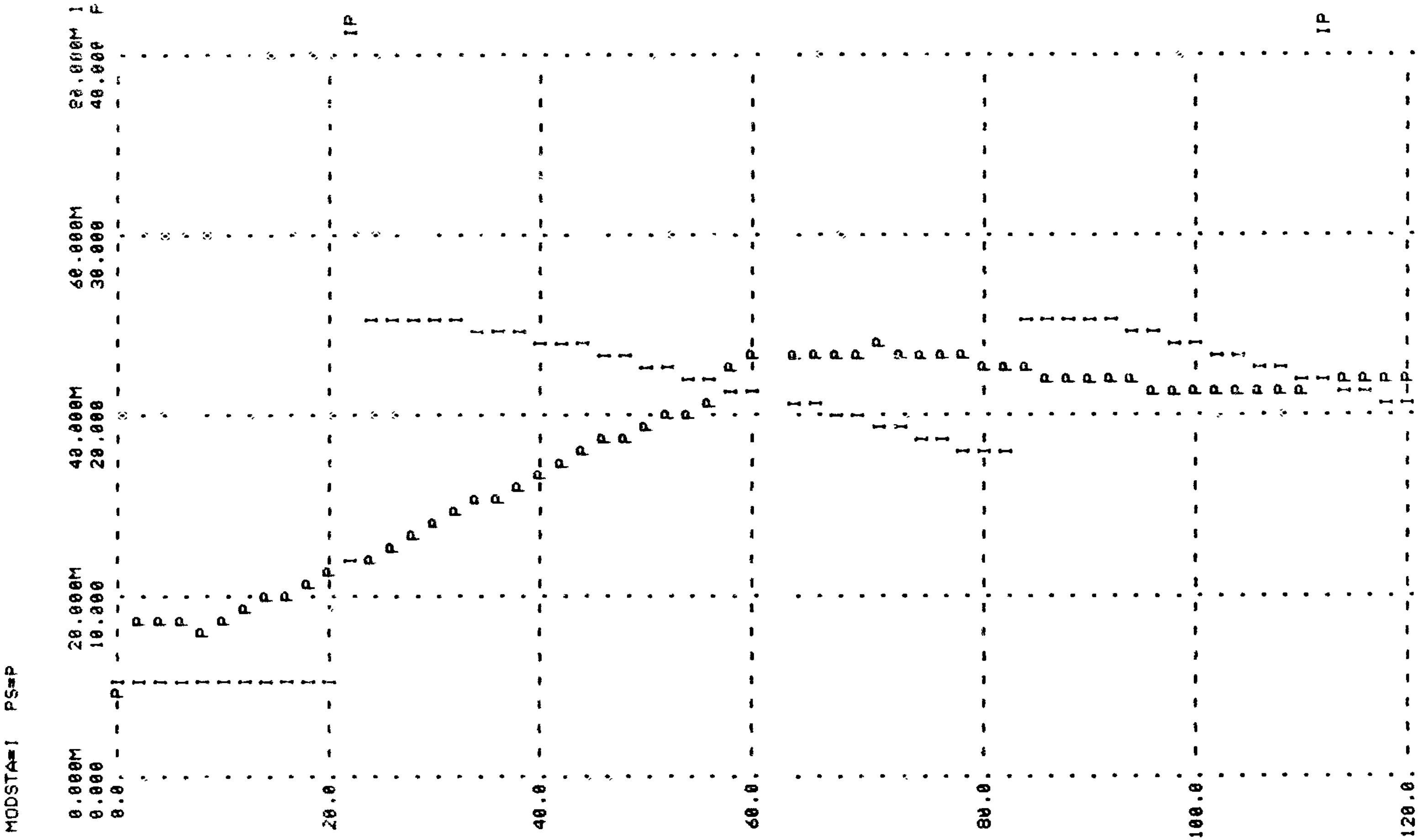


Figure 4.3

MYP Profile Model Behavior, Investment and Production

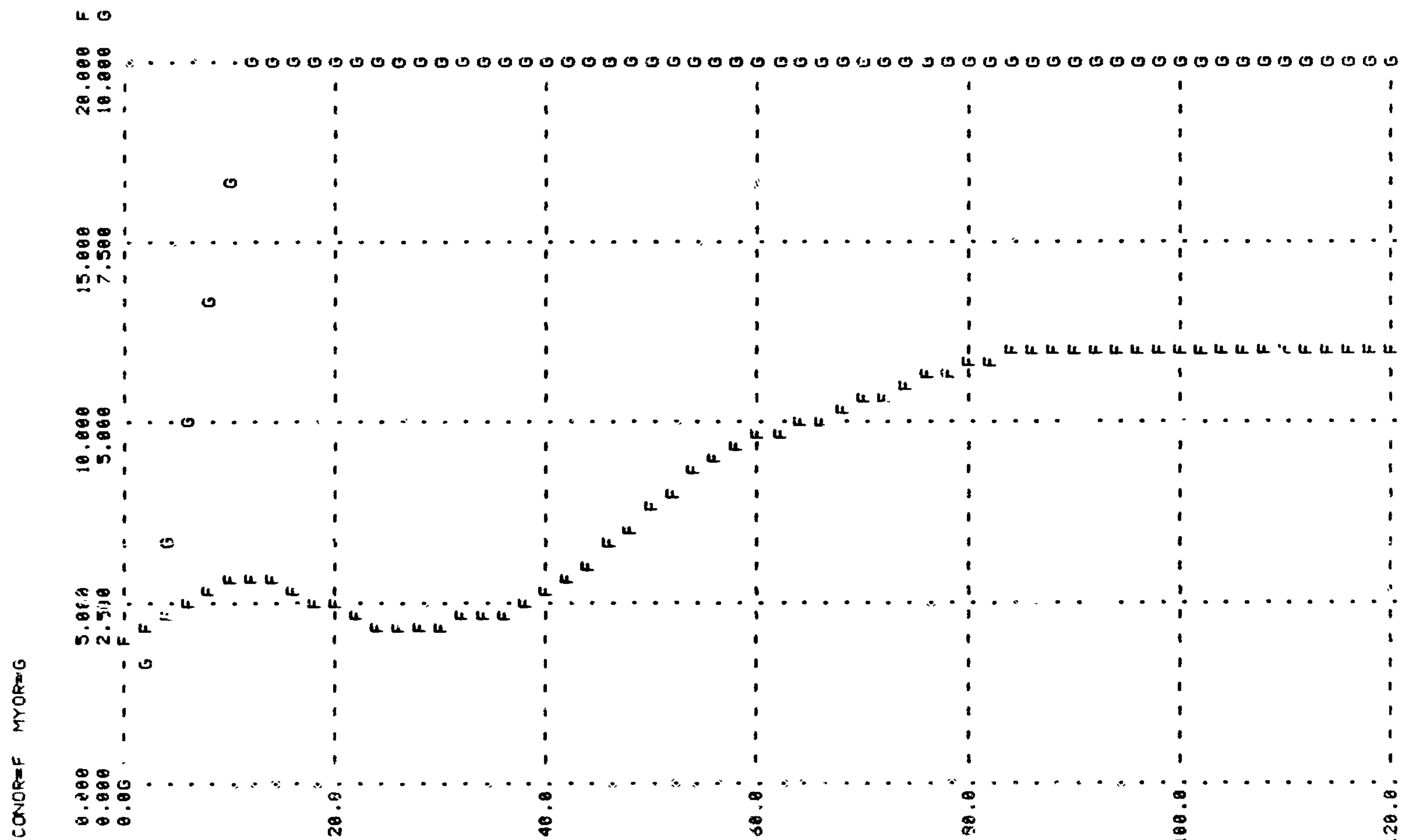


Figure 4.4

Prel[illegible]ary Model Behavior, Contingent Orders

Demand Generated by Professional Effort--from .003 to .005 resulted in the market behavior shown in Figure 4.5; here, contingent order rate build up is 24 months faster than in the curve to which the managers objected (Figure 4.4). Since the researchers developed the revised market behavior (Figure 4.5) after the contractor interviews, contractor reaction to the results shown in Figure 4.5 was not obtained in this study.

The interviewees' reaction to the simulation results shows the model is generally compatible with what the contractor thinks will happen under an MYP contract. The interviews demonstrated the plausibility of MYP model predictions, but only actual MYP experience can prove or disprove prediction accuracy.

Extreme Policy. The extreme policy test attempts to build confidence in the model by evaluating model behavior when the model is subject to policy extremes (18:221). The researchers conducted this extreme policy test by subjecting the model to a variety of investment policies and contract cancellation ceilings.

As an example, the researchers tested model behavior by setting MODEXP, the rate determining modernization investment, equal to zero. Although no profound change in model behavior was expected, the researchers did expect an increase in labor force requirements. This was the case; the labor force was about five to eight percent bigger with no

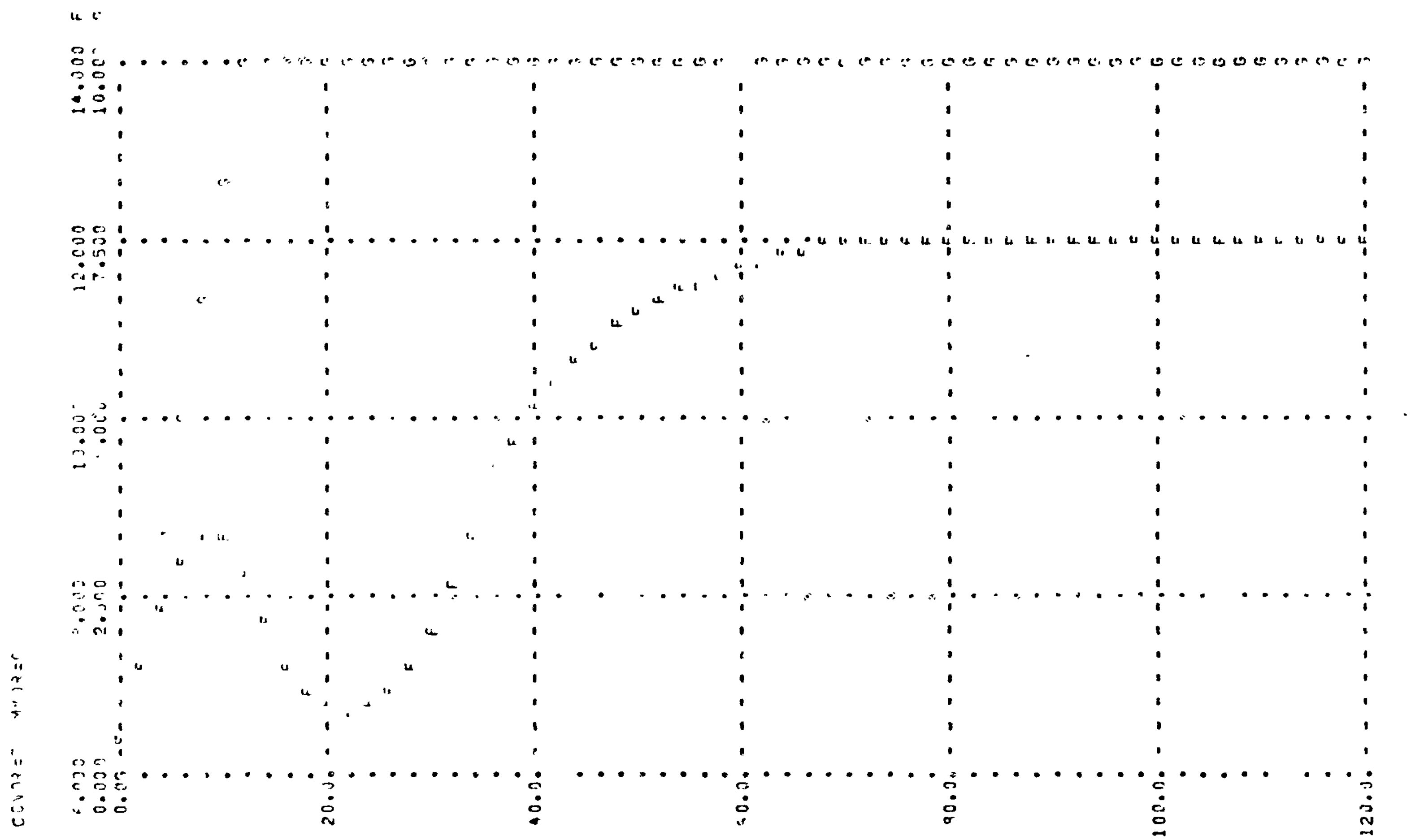


Figure 4.5

Revised Model Behavior, Contingent Orders modernization investment. Also, labor force size peaked some four months later with the change, and production rate build-up was slightly more erratic. Similar extreme policy tests with other policy variables provided similar support for overall model predictability.

Behavior Sensitivity. The researchers conducted sensitivity analyses on a variety of parameters and table functions. Of particular interest were the table function describing investment opportunity (TOPMOR), the table function describing the firm's contingent market evaluation (TREVPR), the time required to acquire new workers (DADL), and the time used to evaluate changes in labor requirements (SDLTIM and INDEDL).

The researchers found that investment level was sensitive to changes in investment opportunities. However, the behavior of modernization investment and the rest of the key response variables was essentially unchanged.

The model was insensitive to changes in the shape of table function TREVPR. Changing TREVPR from its original linear shape to the S-shaped curve suggested by an interviewee resulted in no change in investment level.

Changing the time required to acquire direct labor from six to three months had no major effect on the model. There was little numerical sensitivity, and the only behavioral sensitivity was a two months earlier peak in the work force level.

The most significant (and surprising) result of sensitivity analysis was model reaction to a change in the smoothing constants for direct labor force decisions (SDLTIM and INDEDL). Reducing the two constants from six to three months caused smoother but more rapid work force changes. Since the researchers could not determine which value (three or six months) was more accurate, the researchers conducted all policy tests using both values.

Policy Implications

Forrester and Senge discuss several tests of policy implications. Unfortunately, two tests--system improvement and changed-behavior-prediction--are based upon the actual implementation of recommendations from simulation study. Although these two tests are certainly relevant to long term use of the MYP model, they have little immediate utility in model validation (18:224-225).

The researchers did subject policy inputs to sensitivity analysis. As previously mentioned, each policy experiment was conducted with two values for SDLTIM and INDEDL, the labor policy smoothing constants. Sensitivity analysis in the policy testing phase also included examination of the effect of different values of corporate willingness to take risk. The researchers found numerical sensitivity only for the MYP model.

Conclusion

Several authors (18:29) repeat the theme that model validation is a continuous process, and that a model should never be pronounced "validated." If this approach is necessary for system dynamics models in general, the researchers believe it to be particularly appropriate for the MYP model.

Since the MYP model is designed to evaluate new policy, rather than to understand the effects of an existing policy, user confidence in the model must depend upon comparison of model output with actual future system behavior. Prudent use of the MYP model must be based upon this realization. As the results from MYP implementation become available, the MYP model should be updated to maintain its usefulness. Before unquestionable conclusions can be made about the MYP model's utility, additional MYP model validation in follow-on research is necessary.

The researchers believe that model testing has demonstrated the model structure and behavior to be consistent with the actual system. Also, extreme policy and parameter values have had predictable effects on simulation results. The researchers' MYP model can be a promising instrument with which to evaluate MYP benefits.

CHAPTER 5

RESULTS/ANALYSIS

As outlined in Chapter 2, the research methodology was designed around two complementary approaches. The researchers surveyed 34 firms to determine contractor opinions about 8 presumed MYP benefits. A computer model was also developed to further evaluate four MYP benefits by studying the impact of MYP on a single aerospace contractor.

This chapter presents the results of this research. In this chapter, survey results are reported first, followed by a discussion of simulation findings.

SURVEY RESULTS

The researchers distributed eighty-eight survey questionnaires, but due to reproduction of the questionnaire by one firm (call it Firm X) a total of 103 survey instruments were distributed. Of the 103 questionnaires, 62 were returned, for a return rate of 60.2 percent. The response from Firm X represented 27.4 percent of the survey respondents.

Because of this large input from Firm X, the researchers tabulated two data files to determine the effect of the large response by Firm X. The first data file consisted of 61 cases; one questionnaire was rejected because it was completed by a military Education with Industry student. The second data file did not include the seventeen cases from Firm X for a total of 44 cases. Identical analyses were performed using both data files; the results from the two data sets were not significantly different. Therefore the substantial input from Firm X did not bias survey results. Accordingly, all sixty-one valid responses were used for data analysis purposes.

The demographics of the research sample are summarized in Appendix H. Over one-third (36 percent) of the responses came from executive managers; greater than nine-tenths (93.4 percent) of the respondents were at least middle managers. Of the survey group, 93.4 and 78.9 percent have at least ten years experience in the defense industry and with their firms, respectively. Just over half of the sample, 54.1 percent, claimed actual MYP contract experience within the last five years.

The data analysis was performed using two different methods. In the first method, the researchers analyzed the sample as one group. For the second method, the sample was divided into two groups: those who claimed MYP contract experience within the last five years, and those who did not. The results are summarized in Appendices I and J.

Analysis of the Entire Population

Appendix I groups the survey results according to each projected MYP benefit. Appendix I is organized as follows. For each predicted benefit, the first column lists the question numbers that applies to that particular benefit. The second column lists the calculated t-values for questions from Sections III and IV of the survey. The third column is the two-tailed probability value calculated by SPSS for questions in Section IV. This probability is the significance of the t-value; the researchers chose 0.05 as the significance level for hypothesis testing. The mean response for each question is listed in the fourth column. In Section IV of the questionnaire, questions 22 through 33 had two answer scales each, so both means are listed in the fourth column. The first value is the mean of the responses for situation one, annual contracting. The second value is the mean of the responses for situation two, MYP contracting. For example, Question 30 (under advanced material buys) lists the means as 19.125/51.339. The value 19.125 indicates approximately 19 percent of the materials will be purchased as advanced buys under an annual contract, while the value 51.339 indicates approximately 51 percent of the materials will be purchased as advanced material buys under an MYP contract.

The D values, listed in the fifth column of Appendix I, are the differences between the two means and therefore will only be listed for Questions 22 through 33 of the survey. The D values indicate the magnitude and direction of the differences between the mean responses. The next to last column of Appendix I indicates the number of responses (6] possible) for each particular question. The last column reflects whether the null hypothesis was accepted (an A), or rejected (an R). A rejection of the null hypothesis indicated that MYP had an impact upon that predicted benefit. No statistical tests were performed for Section II of the survey; therefore, a dash (-) appears in the last column for these questions.

Next, the survey results for each projected benefit are discussed.

<u>Modernization of Plant Facilities</u>. The survey sample was of the opinion that MYP will help increase the technology level of the production facilities. The mean of Question 14 fell between the slightly disagree and disagree responses, indicating that the sample did not agree with the researchers' statement that an "MYP contract would decrease modernization of production capability." The results of Question 33 indicate that MYP contracting would result in the technology level of the firms' production facilities being approximately two years (1.836) more advanced than under annual contracting. The null hypothesis of Question 33 was rejected.

<u>Stabilized Work Force</u>. The mean response for Question 13 fell between the slightly agree and the agree responses, indicating the sample agreed with the statement that MYP will help stabilize production manpower loading.

<u>Lower Production Costs</u>. The survey data indicated that MYP should lower production costs. The means of

Questions 8 and 11 reflect the opinion of the sample that MYP will reduce average unit cost over the life of the contract, and that MYP will reduce labor costs. Question 11 was one of the question reverse worded to guard against the acquiescence of response sets, i.e.,"firewalling" (21:451-452). The researchers can only state that the sample disagrees with the statement "MYP will increase contract administration costs." The means of Questions 18 through 21 indicated the sample believes MYP will reduce four types of costs: (1) a mean estimate of a 6.5 percent decrease for direct labor cost per unit produced; (2) for manufacturing overhead cost per unit produced, a mean decrease of 4.3 percent was estimated; (3) the mean estimate for contract administration cost decreased 7.6 percent; and (4) material and subassembly cost per unit was down 9.3 percent. The null hypothesis pertaining to lower production costs was rejected.

Advanced Material Buys. The mean responses to Question 30 and 31 indicated the sample believes that under MYP the percentage of material and subassemblies purchased as advanced buys would increase by an estimated 32.2 and 28.4, respectively. The null hypothesis was rejected for Questions 30 and 31.

The researchers also investigated the importance of advanced material progress payments to the contractors. Questions 34 and 35 posed a situation in which advanced material buys would only be reimbursed in the event of contract cancellation; in other words, there would be no advanced material buy progress payments. The responses to Questions 34 and 35 were paired with the MYP responses of Questions 30 and 31 for paired sample t-tests.

The results showed that advanced material buys would not be increased without advanced material buy progress payments. There was essentially no difference in mean responses between the MYP with no progress payments and annual contracting scenarios of Questions 30 and 31. The null hypotheses were rejected, since the means of the MYP responses were not equal to the means of the MYP with no advanced material buy progress payments responses.

Improved Surge Capability. The survey questionnaire contained three questions directed at the issue of MYP's impact on surge capability. Responses to two questions reflected strong support for the prediction that production surge capability will be enhanced by MYP. However, the response to the third question indicated only marginal support by the sample for improved surge capability.

The sample believed that MYP will reduce the time required to surge from a peacetime to a wartime production rate by a mean estimate of 5.4 months (Question 24). Those sampled believed wartime production could be supported 4.1 months longer under MYP than under annual contracting with the material and subassemblies on hand (Question 32).

Without advanced material progress payments (Question 36), the survey group felt that wartime production rates could be supported only 2 months longer under MYP than under annual contracting.

When asked about the statement that surge capability would be improved under MYP, the respondents gave only slight support for the statement. The mean response fell between the neutral and the slightly agree responses. The remaining three questions (27, 28, and 29) were directed more toward surge constraints rather than surge capability.

Again, the sample felt that MYP will lessen the effect of the three constraints: material and subassemblies, direct labor, and the technology level of the production facilities. Although the difference in the means was significant, MYP does not substantially alleviate any of the three constraints. For materials (Question 27), the means fell on either side of the "a major constraint" response. The labor means fell just past "a minor constraint" response. The last set of means -- technology -- fell on either side of the "a minor constraint" response.

Increased Competition. The sample felt that MYP may increase competition among their subcontractors while not affecting the surveyed firms likelihood to bid for more defense contracts. This is supported by the neutral response to the statement (Question 15) that widespread use of MYP will increase the respondent's firm's likelihood to compete for more defense contracts. Question 16 applies the same statement to vendors competing for a firm's subcontracted effort. The mean to Question 16 reflects a slight agreement to the latter statement that competition may be increased for subcontracts.

The results were mixed for the other questions (22, 23, 25 and 26) in this area of competition, but overall those surveyed do not believe that MYP will increase competition.

When asked what percentage of bids the respondent's firm would respond to under an MYP versus annual contract, the difference was only one percent (Question 22). However, the sample estimated that 64 percent of subcontractors would bid for defense work in an MYP environment, as opposed to 54 percent in an annual contracting environment. The results compare quite favorably to those responses of Questions 15 and 16, which implied MYP would not affect competition for the surveyed firms but would increase competition for their subcontractors. The means for Questions 25 and 26 indicated that the type of contract did not affect the responses made by the sample population. When asked if the firm would not compete for a production contract due to a lack of anticipated profit (Question 25), both mean responses were neutral. When asked if the firm would not compete for a production contract because the firm anticipated being locked-in to a long term contract, both means indicated a disagreement to the statement. This disagreement appears to indicate that the sampled firms would not be more hesitant to compete for long term contracts.

The overall results concerning increased competition indicate that there is no significant difference between MYP and annual contracting in the effects upon the surveyed contractors' likelihood to compete. However, there did appear to be a significant difference in the degree of increased competition among subcontractors.

Increased Standardization. The sample disagreed with the statement that MYP will decrease standardization. The mean response (Question 9) fell between the slightly disagree and disagree responses.

Improved Productivity. Those sampled agreed that MYP will increase productivity. The mean response (Question 13) fell between the slightly agree and the agree responses.

Analysis of MYP Experience

The researchers analyzed the data to determine the effect of MYP experience on survey responses. Appendix J lists the results of this analysis. A description of Appendix J follows.

Column 1 shows the question being analyzed. The second and third columns show the t-value and two tailed probability (calculated by SPSS), respectively. Again, the researchers used a significance level of 0.05. The number of cases, from each group, is shown in the last column. The first number is the number of respondents from Group 1 (MYP experience), and the second value is the number in Group 2 (no MYP experience). The maximum size of each group is 33/28, respectively. For example, question 27B has a significance level of .016; 28 people from Group 1 and 26 people from Group 2 responded to this question. The "B" attached to the question number indicates that the MYP response (second answer scale) was used for this analysis. An "A" would indicate the response under the annual contracting situation was used.

The survey responses were significantly different for five questions: 9, 15, 20, 27B, and 31B. The means for Question 9 indicated that those respondents with MYP experience expressed slightly more disagreement with the statement "implementation of MYP will decrease standardization." Question 15 averaged a neutral response overall but was rated differently between the two groups. Those experienced in MYP slightly agreed that MYP contracting would result in their firm competing for more defense contracts, while Group 2 (no MYP experience) slightly disagreed with the statement. Those with MYP experience felt contract administration costs would decrease by 9.8 percent, while the non-experienced group averaged a mean response of a 5 percent decrease. For Question 27B, Group 1 (MYP experience) thought materials and subassemblies would be more of a major constraint in an emergency production surge than Group 2 (no

MYP experience). When asked the percentage of subassemblies that would be purchased as advanced buys, the experienced MYP group estimated 53.226 percent, while the other group averaged a mean of 39.2 percent.

Survey Comments

In this section the researchers will present the comments that some of the sample wrote on their questionnaires. Some of the comments were directed at specific questions, other comments concerned the survey in general.

Most of the survey comments were directed at the situations presented in Sections III and IV of the questionnaire (Appendix B). Ten percent of the respondents believed the situations were too general. One of the respondents added that due to the lack of specifics, many of the survey questions were "indeed academic." The researchers would like to point out that the situations were designed to be general. If a situation was too specific, it would have hindered the generalization of the research results.

The modified situation of MYP was also commented on by survey respondents. One respondent stated:

> In my opinion this is now the same as an annual contracting situation except for the administration benefits of one contract versus five. All benefits derived from the quantity buys and escalation avoidance are passed on to the customer. This situation asks the prime and/or subcontractor to subsidize customer with cost of money, inventory, and risk.

The above comment supports the survey results pertaining to the importance of advanced material buy progress payments.

Improved surge capability and increased competition were two areas that caused problems for the respondents. These problems were identified by the number of comments received and the number of respondents who did not answer the questions in the above two areas.

Question 24 caused some ten percent of those who commented on this survey to state that surge time depends on the nature of the product or just the circumstances in general. The researchers agree that surge response depends on the circumstances but felt that a general response to Question 24 could have been given.

A large number of comments were directed towards Questions 22 and 23 (increased competition). The comments for the two questions were similar in nature, therefore the researchers will review the specific comments received for Question 22.

The majority of the respondents who commented felt that the type of contract would not affect the firm's decision to bid. The respondents indicated that the decision would be based on factors such as: the product; the compatibility with existing product lines; the firm's interest and capabilities; the capacity of the plant; or the risk involved and the probability of capturing the contract. The researchers understand that the above two questions could be misconstrued since the type of contract may not be (and is not) considered an important factor for such decisions. The researchers wanted to determine if MYP could make a difference. The statistical analysis supported the null hypothesis that MYP would make no difference in competition. As one respondent put it: "The only thing worse than a government contract, is not having one."

SIMULATION RESULTS

The researchers used simulation to evaluate four predicted MYP benefits: increased plant modernization, improved labor stability, increased surge capability, and reduced production cost. For each predicted benefit, the researchers compared the behavior of key model variables in an annual versus an MYP environment. In most cases, the effect of policy variations and different financial environments on MYP benefits were also investigated.

Since the modeled contractor was awarded an MYP contract at a point relatively early in the contractor's current production program, there was little historical data upon which to base annual contracting order rate profiles. Therefore, the production order rates used in the annual profiles of this chapter were designed by the researchers to represent plausible annual contracting scenarios. These scenarios were based upon the program histories of similar weapon systems (8:22). The reader is reminded that the simulation results are preliminary because additional validation for the MYP model is necessary.

The simulation results are presented by discussing each benefit individually. The discussion includes the specific modeling steps used in conducting the experiments, as well as the numerical and graphical outcomes of illustrative simulation runs. The MYP benefit evaluation will conclude with a discussion of implications of the simulation results.

The researchers have used numerical results in the text only so that the effect of different policies may be compared. The MYP model was not intended to be used to predict specific results, so the numbers presented should not be taken for actual predictions. Rather, the numerical results are meant to represent model behavior.

Plant Modernization

MYP is predicted to increase plant modernization by providing contractors with a stable business base. Large contract cancellation ceilings can also provide incentive for investment in manufacturing technology (40:32).

The researchers designed plant modernization simulation experiments to isolate the effects of business base and large cancellation ceilings upon modernization investment. Annual and MYP order profiles were run with contract capital cancellation ceilings of both $10 million and $100 million.

The annual contracting profiles used the following production order rates, listed by year.

Year 1 -- 16 units/month   Year 6 -- 25 units/month

Year 2 -- 20 units/month	Year 7 -- 25 units/month
Year 3 -- 20 units/month	Year 8 -- 10 units/month
Year 4 -- 10 units/month	Year 9 -- 10 units/month
Year 5 -- 10 units/month	Year 10 -- 10 units/month

(The contingent order rate, CONOR, was set equal to zero.)

When the modernization cancellation ceiling was set at $10 million, modernization investment after 10 years totaled $21.8 million. The researchers then introduced a $100 million cancellation ceiling at month 24; the ceiling decreased linearly to $10 million by month 96. After introducing the $100 million cancellation ceiling, modernization investment totaled $111 million after 10 years. The cumulative investment curve for this latter annual scenario is shown by the dashed line in Figure 5.1.

A constant order rate of 20 units/month served as the MYP profile for modernization evaluation. A constant $10 million cancellation ceiling yielded a cumulative investment of $25 million, an increase of some 14 percent over the annual profile. The $100 million cancellation ceiling profile resulted in a total of $129 million of investment, 16 percent more than the annual situation. The cumulative investment curve of the MYP, $100 million cancellation ceiling-profile is displayed by the solid line in Figure 5.1.

Figure 5.2 presents the cumulative Government incentive payments necessary to provide the contractor with sufficient cash flow to make modernization investment feasible.

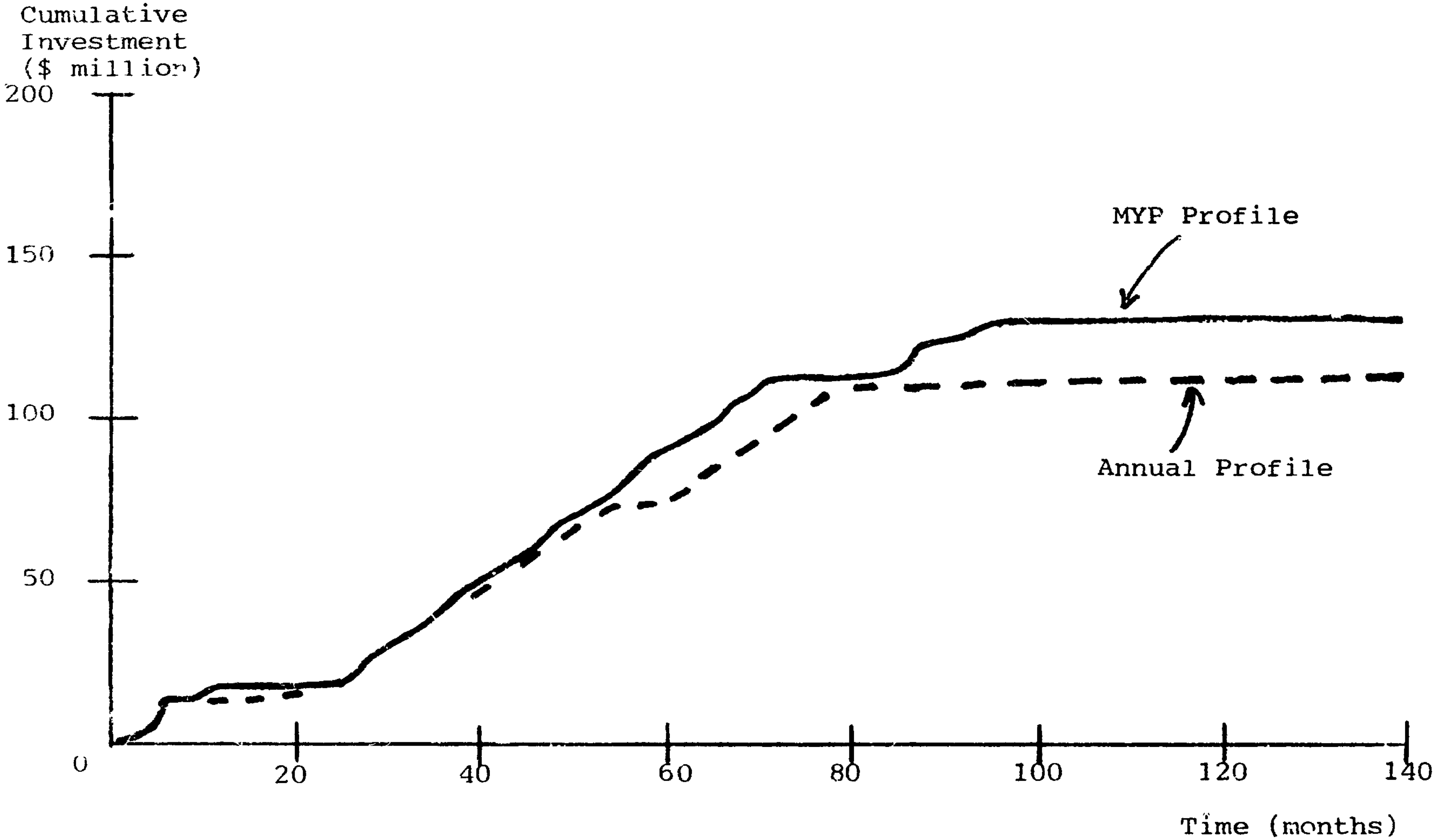


Figure 5.1

Cumulative Investment, $100 Million Cancellation Ceiling

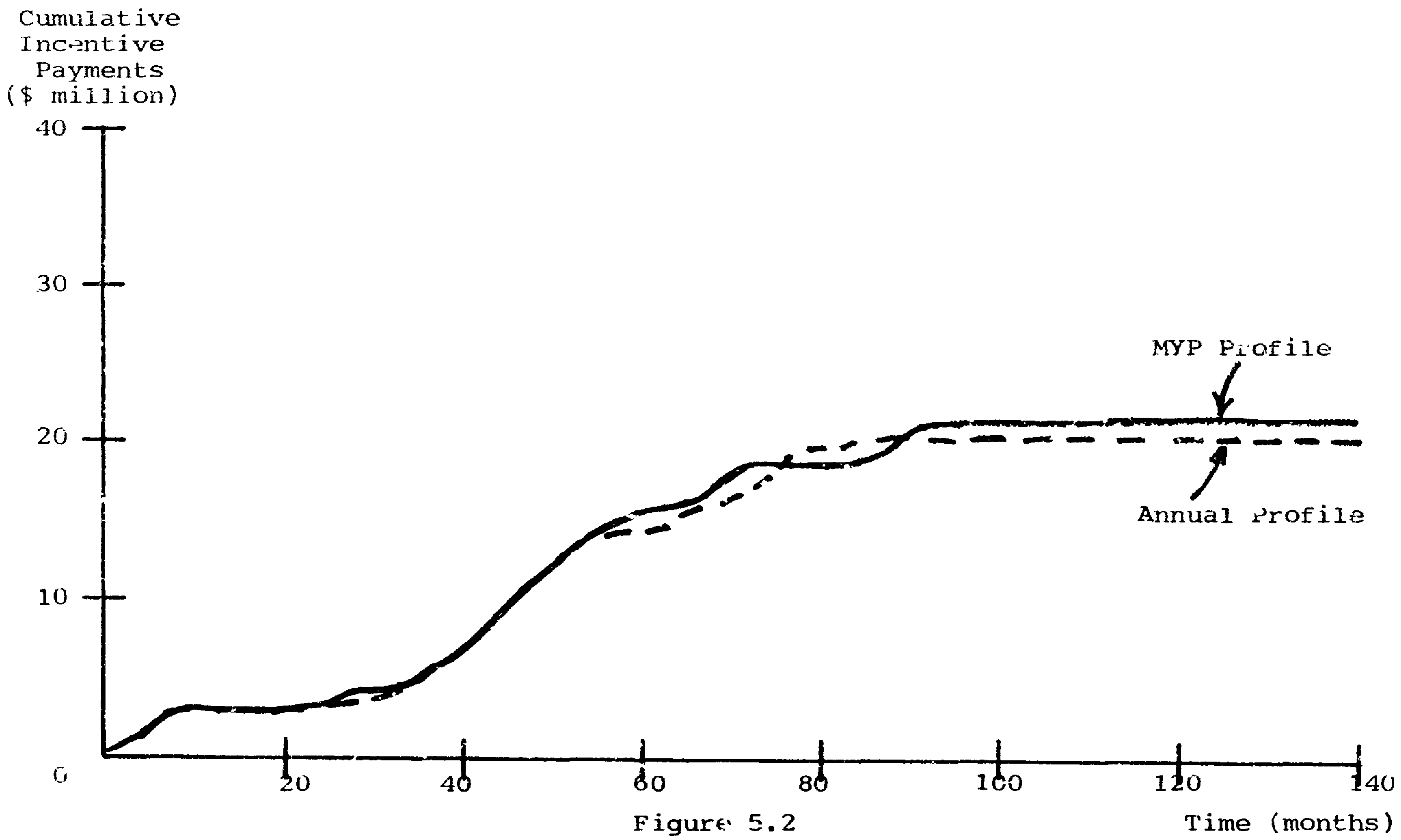


Figure 5.2

Cumulative Incentive Payments, Cost of Capital = 10%

As in Figure 5.1, the dashed line represents the annual profile, and the solid line is the result of the MYP profile. Note that about $21 million was required in the MYP profile.

Decreasing the cost of capital from an average of ten percent to an average of five percent dramatically reduced required incentive payments (Figure 5.3); note that cumulative incentive payments for both annual and MYP profiles were reduced to below $1.5 million. The capital cost decrease had a less dramatic effect on investment level, causing an increase of only $7 million in cumulative investment for the MYP profile.

The simulation results indicated that the effect of a firm's willingness to take investment risk will be more evident with smaller cancellation ceilings. When the contract cancellation ceiling was $100 million, increasing the corporate willingness to take risk (MODRSK) from .1 to .3 had little effect upon cumulative investment for both the annual and MYP scenarios. However, when the cancellation ceiling was $10 million, the increase in willingness to take risk resulted in 40 percent more investment under both MYP and annual profiles. These results imply that the financial aggressiveness of the contractor may be a factor in negotiating contract cancellation ceilings.

The researchers also investigated the effect of a different cost-sharing ratio upon investment. All the previous simulations in this study used a 70-30 Government-contractor cost-sharing ratio. A 80-20 share ratio caused

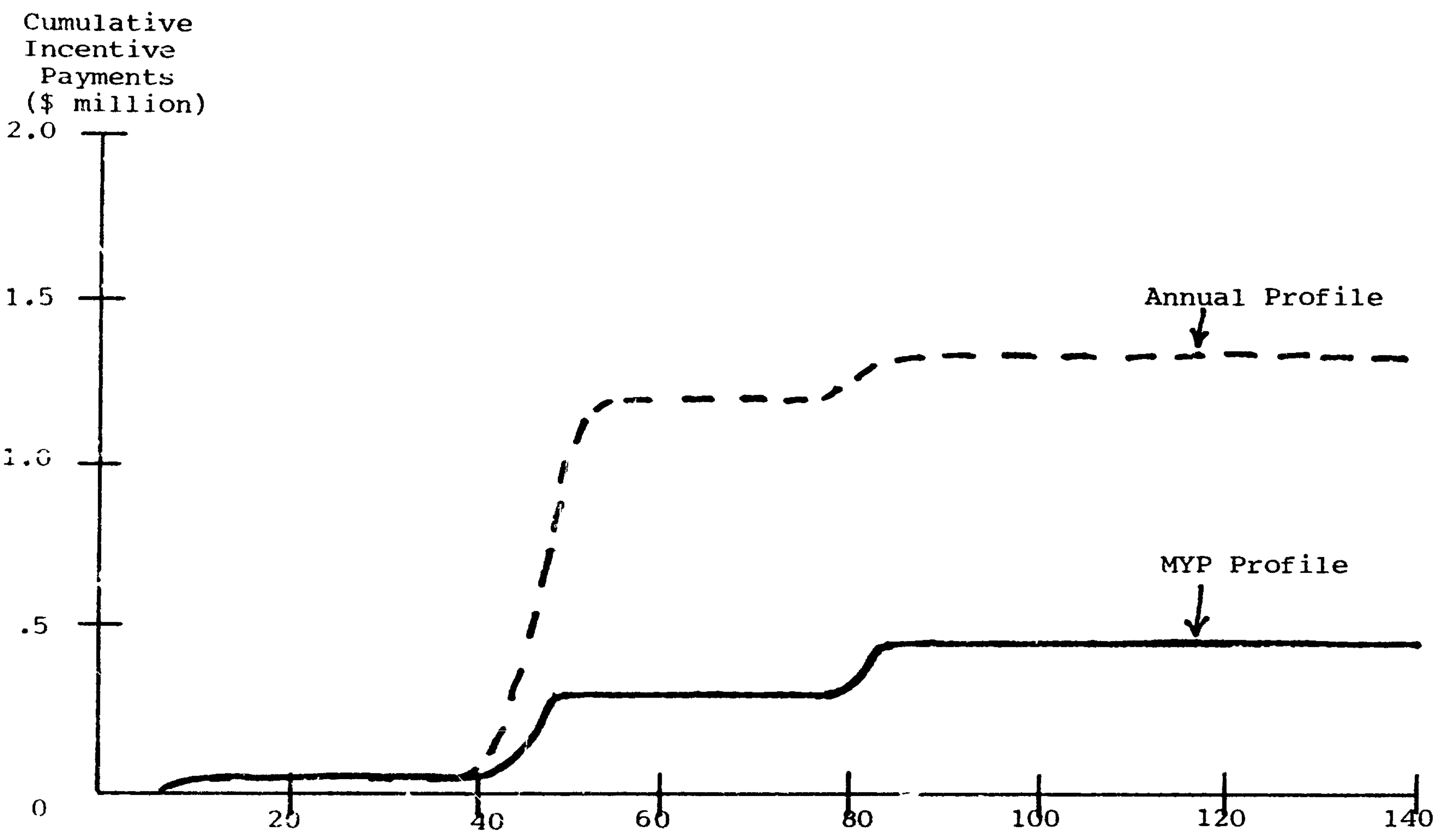


Figure 5.3

Cumulative Incentive Payments, Cost of Capital = 5%

little difference in investment levels, but, like capital cost, necessary incentive payments were markedly changed. Total required incentive payments were increased some $14 million with a $100 million cancellation ceiling and about $5 million with the smaller ($10 million) cancellation ceiling.

These simulation results indicated that the characteristic of MYP that contributes most to plant modernization may likely be large cancellation ceilings for capital investment (with accompanying incentive payments). However, the more stable business base provided by MYP did result in significantly increased investment, compared to the annual profiles. This research implies that while the stable business base of MYP may have some positive influence on plant modernization, large plant modernization programs will require large contract cancellation ceilings.

Work Force

The researchers tested for work force stability by comparing labor strength curves for MYP versus annual contracting scenarios. These work force tests included investigation of the effect of the size of the non-primary customer market (contingent market) and the effect of contractor labor policies.

The first experiment was an annual contracting profile with a maximum contingent market of five units per month. The primary customer (such as the U.S. Air Force in the F-16 program) had an order rate that averaged 15 units per month. The actual order rates, listed by year, are shown below:

Year 1 -- 14 units/month	Year 7 -- 12 units/month
Year 2 -- 16 units/month	Year 8 -- 19 units/month
Year 3 -- 11 units/month	Year 9 -- 12 units/month
Year 4 -- 11 units/month	Year 10 -- 16 units/month
Year 5 -- 20 units/month	Year 11 -- 18 units/month
Year 6 -- 19 units/month	Year 12 -- 15 units/month

This simulation run resulted in the labor force curve shown in Figure 5.4.

Figure 5.5 was the result of an experiment with a maximum potential contingent order rate of 15 units per month and an average primary customer order rate of 10 units per month. Relative order quantities, from year to year, were the same for this experiment as for the first experiment. The labor force size curve of Figure 5.5 was smoother in nature for this experiment, as compared to Figure 5.4.

The MYP experiment used a constant order rate (MYOR) of 10 units per month, and a contingent order potential (CONPDM) of 15 units per month. Figure 5.6 summarizes the result of this simulation. Labor force rises with production rate, then steadies at approximately 5100 workers by month 50.

The researchers also conducted experiments using labor force decision times (SDLTIM and INDFDL) of three months rather than six months. Although there was a slight smoothing of the labor force and production start curves, the basic nature of each experiment result was unchanged.

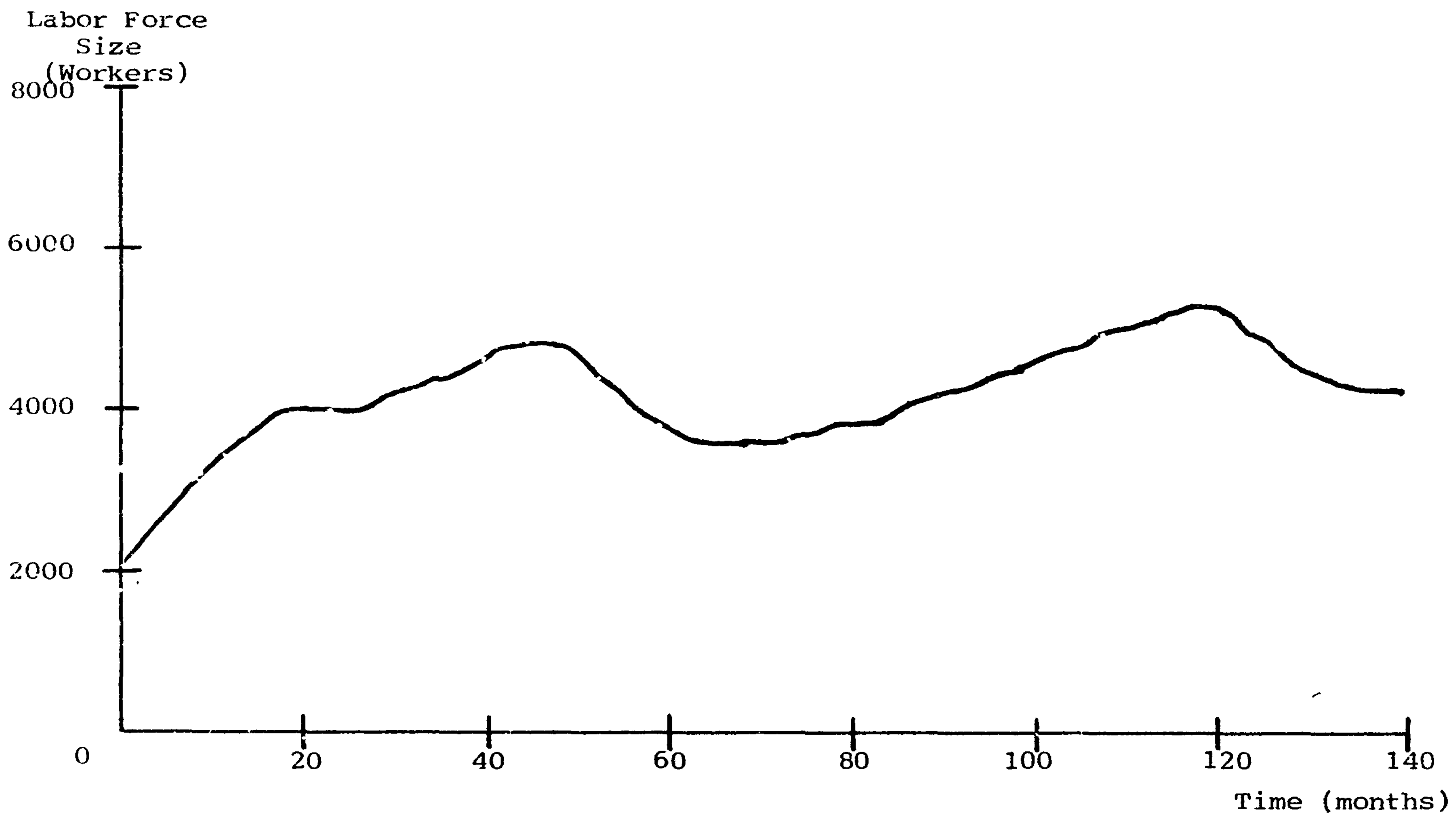


Figure 5.4

Labor Force, Annual Profile with Small Outside Market

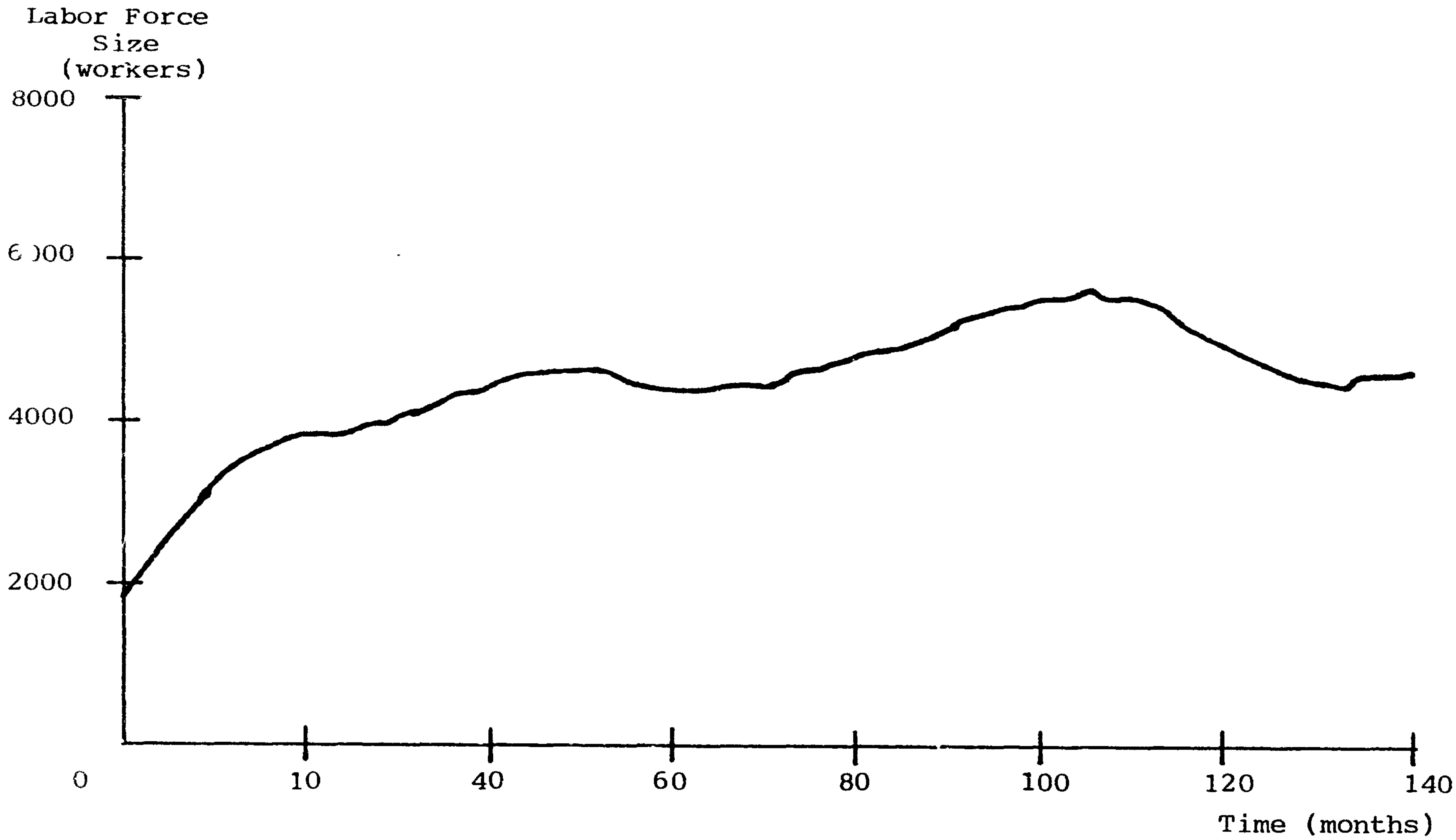


Figure 5.5

Labor Force, Annual Profile with Large Outside Market

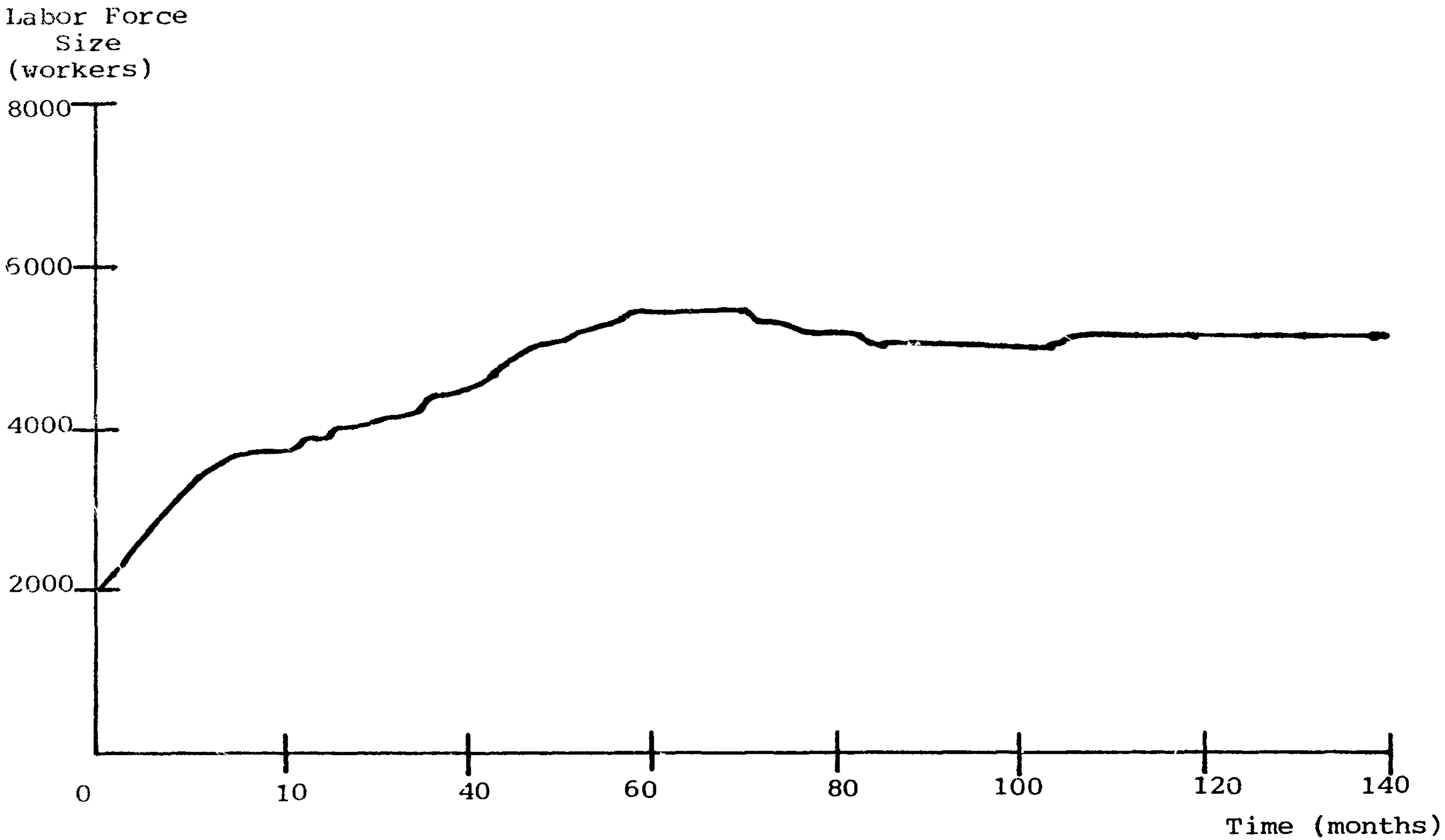


Figure 5.6

Labor Force, MYP Profile

The ability of constant order rates to steady a contractor's labor force strength seems apparent from the simulation results. As will be discussed later, this constant order rate has a direct impact on production expenses. It is also important to note the effect of a large contingent market (foreign military sales, other military services, etc.) on a firm's production rate/labor stability. The smoother nature of the curves in Figure 5.5 as compared to Figure 5.4 suggests that the labor force steadying effect of MYP would be less pronounced for a firm with a large outside market for its product.

Production Costs

MYP proponents believe that MYP will lower production costs through greater work force stability, plant modernization, and lower material costs through advanced buys (7:121). Although the MYP model was unable to evaluate the cost savings of advanced material buys, the researchers were able to study the potential of MYP to reduce costs through production stability and technological productivity enhancements. The simulation study was designed to isolate the impacts of stability and modernization.

The first simulation experiment with production costs was a repeat of the first labor force stability experiment: an annual contracting profile with an average order rate of 15 units per month; a maximum outside order rate of 5 units per month; and a maximum capital cancellation ceiling of $10 million. After 120 months, 2,048 units were finished with a burdened labor cost of $3,092 billion, or $1.51 million per unit.

The second production cost experiment was an MYP profile of 10 units per month with a maximum cancellation ceiling of $10 million and a maximum outside market of 15 units per month. At month 120, the model had recorded 2,276 production finishes at a total burdened labor cost of $3.361 billion. The average burdened labor cost per unit was $1.48 million.

The last planned experiment involved a 10 year MYP scenario with a 10 units/month order rate and an outside market potential of 15 units/month. The intent of this experiment was to gauge the effect of large modernization investment, so a $50 million capital ceiling was used. After 10 years, 2,248 aircraft were produced with a cumulative burdened labor cost of $3,254 billion, an average of $1.45 million per unit.

At this point, the researchers chose to repeat the first experiment, this time with a maximum contingent order potential of 15 units per month (this is the same scenario as experiment two of the labor stability evaluation). This simulation yielded 2,246 aircraft with $3.32 billion in labor costs. The average labor cost per unit of $1.48 million per unit was identical to the MYP scenario with the same ($10 million) cancellation ceiling.

These simulation results support the earlier finding that MYP may have less impact on a program with a large outside market. At the same time, MYP had a significant cost advantage over annual contracting when the scenario involved a smaller outside market. Finally, enhanced modernization resulting from a moderately large cancellation ceiling ($50 million) further reduced labor costs.

Once again, the researchers point out that these research results do not take advanced material buys into account. Interviews with managers of the modeled firm indicated that cost savings of more than five percent per aircraft are expected from advanced material buy savings alone. No analysis of MYP cost savings can be complete without considering advanced material procurement.

Surge Capability

MYP has been proposed as a step to increase the ability of defense contractors to surge production rates when defense requirements warrant. This enhanced surge capability is expected to result from reduced component and material lead times, enhanced manufacturing technology, and a stable production rate (40).

Although former Under Secretary of Defense for Research and Engineering William J. Perry defined surge capability as the ability to "double the production rate . . . in three or six months [40:121]," the researchers settled upon a less ambitious operational definition of surge capability. Based upon interviews with Aeronautical System Division System Program Office managers who monitor the modeled contractor, the researchers defined surge capability as the time necessary to enter 20 additional high priority units into production; this would, for example be equivalent to one fighter squadron.

The researchers conducted two surge experiments on both annual and MYP scenarios. In all cases, the requirement for 20 additional units was levied upon the contractor within a one month period. Little evidence was found for reduced material lead times resulting from MYP, so surge experiments used normal material lead times.

Figure 5.7 is graphical output from the first surge experiment. This was an annual profile with a maximum outside order rate of 15 units per month. The annual order input rates averaged about 10 units per month, with the following yearly values:

Year 1 -- 10 units/month	Year 7 -- 10 units/month
Year 2 -- 10 units/month	Year 8 -- 6 units/month
Year 3 -- 6 units/month	Year 9 -- 11 units/month
Year 4 -- 6 units/month	Year 10 -- 10 units/month
Year 5 -- 12 units/month	Year 11 -- 7 units/month
Year 6 -- 14 units/month	Year 12 -- 7 units/month.

On the graph, the dashed line represents the number of surge units waiting to enter production. The surge was ordered at month 60, hence the jump in surge units from 0 to 20. The first surge unit enters production at month 82 under the

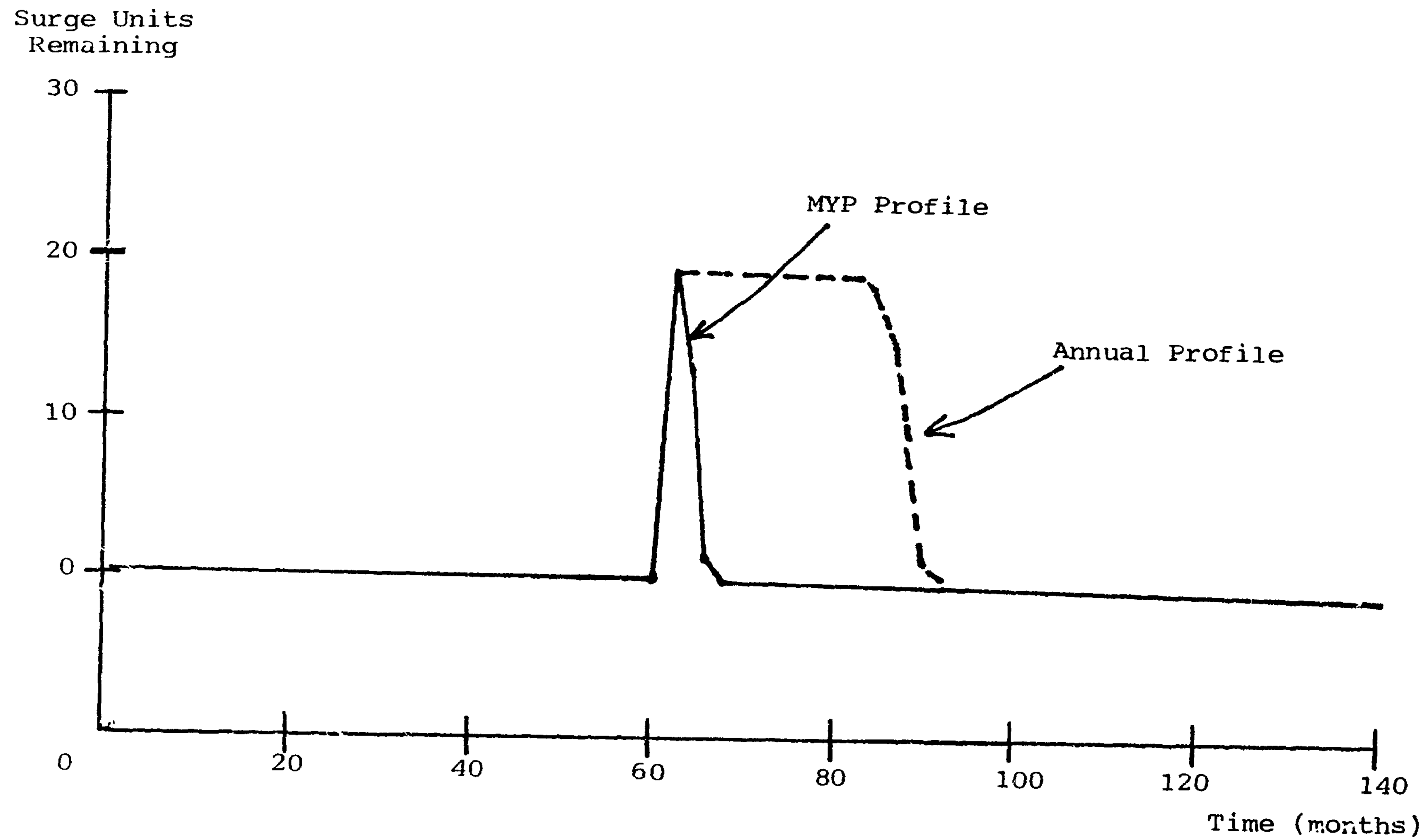


Figure 5.7

Surge at Month 60

annual profile, and all units have entered production by month 92. Since the modeled firm's production time is 13 months, all 20 units would have been completed by month 105, a 45-month wait following surge implementation.

The researchers then made an identical surge input into an MYP profile. This profile was based on an MYP contract order rate of 10 units per month and an outside market potential of 15 units per month. These simulation results are represented in Fugure 5.7 by the solid line. The surge units began entering production immediately, with all units having entered production ny month 68. In other words, all units would have been completed by month 81, a waiting time of 21 months from surge implementation.

Figure 5.8 shows the result of an annual scenario receiving a surge input at month 80; again, the annual profile is represented by the dashed line. Since the previous annual scenario received the surge input when order rates were increasing, the researchers timed this surge requirement for an order rate decrease. The first surge units entered production at month 86, and the last unit was complete at month 107, a waiting time of 27 months.

The last surge experiment was an MYP profile with a 20 units surge at month 80. As the solid line in Figure 5.8 shows, surge performance was the same as in the previous MYP scenario (Figure 5.7).

The researchers found that reducing in-plant material inventory (NIMPC) from two month's to one month's production

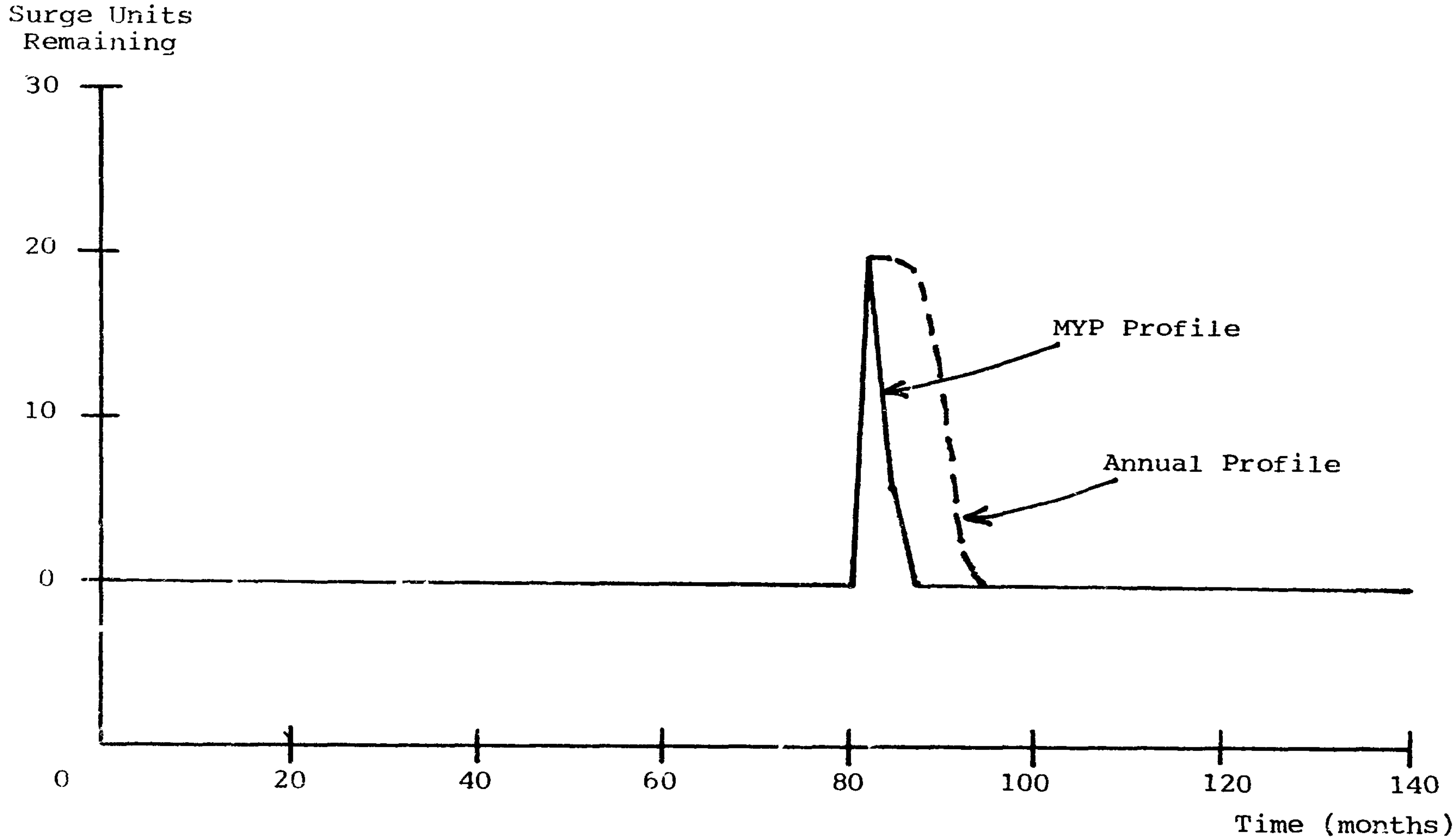


Figure 5.8

Surge at Month 80

requirements had no effect on the 20-unit surge. Further inventory reductions did begin to constrain surge capability.

The simulation results support the contention that MYP will enhance a firm's ability to increase production in a national emergency by encouraging a stable production schedule. This stable production schedule provided a margin of labor capacity that allowed the immediate introduction of surge units into production.

SUMMARY

These simulation results supporting the four MYP benefits must be considered in light of the fact that the researchers' MYP model is not yet fully validated. However, the combination of the simulation results and the survey results do provide some evidence about the impact of MYP, as is discussed in the next chapter.

CHAPTER 6

FINDINGS, OBSERVATIONS, AND RECOMMENDATIONS

Introduction

This research effort was based upon a dual methodology in which the researchers used a survey of Government contractors and a simulation model to evaluate eight predicted benefits of multi-year procurement. Previous chapters have described the survey, the simulation model, model validation, and research results. This concluding chapter presents a summary of the research findings, the researchers' observations about the research, and proposed directions for further research into MYP.

Findings

This research effort found substantial support for seven of the eight predicted MYP benefits. Six of the predicted MYP benefits were fully supported by the survey results; the seventh predicted MYP benefit (i.e., improved surge capability) was fully supported by results from the simulation model. As mentioned previously, the reader is cautioned that the simulation model used in this research is not fully validated. So, the reader must interpret the simulation results accordingly. However, since the survey results also provided slight support for the MYP benefit "improved surge capability," the researchers considered the survey and simulation results to jointly indicate full support for this seventh MYP benefit. For the other MYP benefit areas, the simulation results were generally consistent with the survey results. Negligible support was found for the expected increase in competition for defense work due to MYP. Figure 6.1 summarizes the research results.

The researchers found strong evidence that MYP will have a favorable impact on the modernization of plant facilities. The surveyed managers felt that manufacturing technology would be significantly more advanced in an environment where MYP was widely used. Simulation study indicated that large capital cancellation ceilings would greatly expand plant investment, while the stable business base provided by MYP would have a smaller, but still significant, impact on investment.

Model results supported the results obtained from the survey sample that MYP would have a stabilizing effect on a firm's work force level. Simulation showed that MYP's impact may be greater for programs for which there is a small outside market.

The contention that MYP will reduce production costs was also supported. The survey sample's mean estimates of cost savings were substantial: 6.5 percent savings in direct labor, 8 percent for material, and 4.5 percent for overhead

PREDICTED MYP BENEFIT	SURVEY RESULT	MODEL RESULT
Modernization of Plant Facilities	Support	Support
Stabilized Work Force	Support	Support
Lower Production Costs	Support	Slight Support
Advanced Material Buys	Support	Not Applicable
Improved Surge Capability	Slight Support	Support
Increased Competition	Negligible Support	Not Applicable
Increased Standardization	Support	↓
Improved Productivity	Support	↓

Figure 6.1

Summary of Results

per unit. Modeling results showed smaller savings, but the model results did indicate that MYP would reduce labor cost.

Simulation results were clearer in evaluating MYP's impact on production surge capability. MYP greatly reduced the time necessary for the modeled contractor to produce 20 additional units on a surge basis. The survey group supported these results by agreeing that production rate increases to wartime levels would be faster in an MYP environment.

The managers completing the questionnaire (Appendix B) felt quite strongly about the necessity for advanced material progress payments in encouraging advanced material buys. The percentage of material to be bought in advance was virtually identical for annual contracting and MYP without advanced material progress payments, about 18 percent in both cases. When the MYP contract was accompanied by material progress payments, a mean estimate of some 50 percent of material needs would be filled with advanced material buys.

The one predicted MYP benefit for which only negligible support was generated was increased competition. The consensus of the survey sample was that their firms would not be more likely to compete for a defense contract under MYP than under annual contracting. However, the sample felt that roughly 20 percent more subcontractors would bid for work on MYP programs than would bid for annually contracted programs. The researchers believe that the nature of the sample could have been a factor in the foregoing research results. This issue will be discussed in the next section.

Observations

The research methodology of two complementary approaches allowed the researchers insight into the unique strengths and limitations of each research approach. This section presents an evaluation of the value of the survey and the simulation model to this study of MYP.

Survey. Because the researchers were unable to distribute the survey questionnaire to firms that are vendors and suppliers for defense contracts (i.e., lower tier contractors), the survey results reflected the opinions of larger firms whose involvement in defense programs is sufficient to warrant Government representation at their plants (14). Therefore, it is likely that the firms surveyed will compete for defense work under most circumstances. Since the disenchantment of lower tier vendors and suppliers has been identified as a key factor in the deterioration of the defense industrial base (19:126), the willingness of these vendors and suppliers to compete in the defense marketplace is an important issue that should be addressed in more depth than was possible in this research effort.

This research was designed to validate the benefits of MYP to the Department of Defense. Accordingly, the survey was oriented toward those issues of concern to the Government. The researchers received a letter from an Education With Industry student that outlined the concerns of industry about MYP contracts. The letter states that these contractor concerns are "the real issues and problems of MYP. . ." Those issues and problems included:

1. Minimization of risk through economic price adjustment for labor, material, profit, business base, and overhead costs;

2. Amortization of non-recurring costs;

3. Program selection for MYP;

4. Termination liability funding/cancellation ceiling price;

5. Clauses and regulations; and

6. Unforseeable risks which cause profit erosion, such as interest rates and acts of Government.

Although the survey instrument allowed the researchers access to a wide range of viewpoints and expertise, supplementing the survey with a well-designed interview program would have allowed further study of specific issues of interest, such as the advanced material buy decision and the decision to compete for defense contracts. Comments about the questionnaire by the responding contractor managers illustrated the limitations of the survey instrument in addressing complex MYP issues. Interviews would have allowed the researchers to pose questions specific enough to permit more precise responses by contractor personnel.

Model. The most conspicuous limitation of the modeling used in this research was that only four of eight MYP benefits were evaluated using a simulation model that requires more validation. Although the original intention was to include advanced material buys in the model, the researchers were unable to get enough information to adequately define the advanced buy process. Adequate treatment of advanced buys and defense contract competition would likely require a comprehensive model involving the entire market for defense contracts and material needs.

The market sector of the MYP model may not provide a complete description of the firm's outside (contingent) market. Although the market sector was adequate for this evaluation of MYP, a more rigorous modeling of the generation of production orders would be useful in future MYP model applications.

The researchers believe that the MYP model developed for this thesis effort is a useful instrument for the study of MYP and other acquisition issues. As an example of the model's fidelity, the cumulative plant modernization for a simulation experiment was $111 million with an annual contracting profile and a $100 million contract capital cancellation ceiling. The actual experience of the firm's technology modernization program, with $100 million in Air

Force investment coverage, was a cumulative investment level of $112 million. Although the model is not guaranteed to produce high numerical accuracy, this research result speaks well for the model's basic economic assumptions.

Recommendations

The rapid commitment to MYP by DOD (12) makes the understanding of the risks and benefits of MYF of obvious importance. The researchers consider this research effort to have been an early step in the accumulation of knowledge about multi-year procurement.

Over the length of this thesis work, many areas of interest and importance for future MYP research have become apparent. The researchers propose the following directions for further study:

1. The impact of MYP upon the defense industrial base depends largely upon the suppliers and vendors (40). An important research objective would be to understand the opinions and attitudes of these firms about MYP through interviews, surveys, or a combination of both.

2. As discussed earlier in this chapter, the survey instrument used in this thesis primarily addressed the concerns of the Government. A worthwhile research objective would be to find out what concerns industry about MYP, using the issues addressed in the Observations section of this chapter as a guide.

3. The next step in developing the researchers' MYP model is to conceptualize the system that encompasses advanced material buys and competition among subcontractors and vendors, and then incorporate this system conceptualization into a validated MYP model. Such a modeling project would be a major research effort, but it promises a substantial expansion of knowledge about the defense industry, as well as MYP.

4. The MYP model could be used, with little modification, to study the effects of DOD-sponsored plant modernization programs. The implications of Government policy regarding incentive payments and the effect of capital costs would be of particular importance.

5. The researchers strongly urge continued examination of the MYP model. These examinations would serve to both enhance model validity and improve model accuracy. All adaptations of the MYP model should include such an examination.

APPENDICES

APPENDIX A

LIST OF SURVEYED FIRMS

AEROJET ELECTROSYSTEMS COMPANY
Azusa CA 91702

AEROJET LIQUID ROCKET COMPANY
Sacramento CA 95813

AEROJET STRATEGIC PROPULSION COMPANY
Sacramento CA 95813

AEROJET TACTICAL SYSTEMS COMPANY
Sacramento CA 95813

AVCO LYCOMING DIVISION
Stratford CT 06497

AVCO SYSTEMS DIVISION
Wilmington MA 01887

BOEING AEROSPACE COMPANY
Seattle WA 98124

BOEING VERTOL COMPANY
Philadelphia PA 19142

CHEMICAL SYSTEMS DIVISION
Sunnyvale CA 94088

GENERAL DYNAMICS CORPORATION
Convair Division
San Diego CA 92138

GENERAL DYNAMICS CORPORATION
Fort Worth Division
Fort Worth TX 76101

GENERAL ELECTRIC COMPANY
Aircraft Engine Group
Cincinnati OH 45215

GENERAL ELECTRIC COMPANY
Re-Entry Systems Division
Philadelphia PA 19101

GRUMMAN AEROSPACE CORPORATION
Bethpage NY 11714

HERCULES INCORPORATED
Hercules Aerospace Division
Magna UT 84044

HONEYWELL, INC.
Space & Strategic Systems Operations
Avionics Division
Clearwater FL 33516

HUGHES AIRCRAFT COMPANY
El Segundo CA 90245

HUGHES AIRCRAFT COMPANY
Tucson Manufacturing Division
Tucson AZ 85734

IBM CORPORATION
Federal Systems Division
Owego NY 13827

LOCKHEED-GEORGIA COMPANY
Marietta GA 30063

LOCKHEED MISSILES & SPACE COMPANY, INC.
Sunnyvale CA 94086

MARTIN MARIETTA DENVER AEROSPACE
Denver CO 80201

MARTIN MARIETTA ORLANDO AEROSPACE
Orlando FL 32855

McDONNELL DOUGLAS CORPORATION
Douglas Aircraft Company
Long Beach CA 90846

McDONNELL DOUGLAS CORPORATION
McDonnell Douglas Astronautics Company
Huntington Beach CA 92647

McDONNELL DOUGLAS CORPORATION
McDonnell Aircraft Company
St Louis MO 63166

NORTHROP CORPORATION
Hawthorne CA 90250

PRATT AND WHITNEY AIRCRAFT GROUP
Manufacturing Division
East Hartford CT 06108

ROCKWELL INTERNATIONAL
Collins Communications Systems Division
Richardson TX 75081

VOUGHT CORPORATION
Dallas TX 75265

PRATT AND WHITNEY AIRCRAFT GROUP
Government Products Division
West Palm Beach FL 33402

RCA MISSILE AND SURFACE RADAR
Moorestown NJ 08054

ROCKWELL INTERNATIONAL
Electronic Systems Group
Anaheim CA 92803

WESTINGHOUSE ELECTRIC CORPORATION
Defense Electronics Systems Center
Baltimore MD 21203

APPENDIX B

MULTI-YEAR PROCUREMENT QUESTIONNAIRE

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY (ATC)
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433

29 APR 1982

REPLY TO ATTN OF: LSB (Maj Rasch, Autovon: 785-4549)

SUBJECT: Multiyear Procurement Questionnaire

TO: Education With Industry Students

1. The attached questionnaire is part of an Air Force Institute of Technology research project studying multiyear procurement concepts. The purpose of this questionnaire is to gather information concerning contractor opinions about multiyear procurement concepts.

2. This survey is authorized by AU survey control number AU SCN 82-23. Your participation is voluntary, and your anonymity is guaranteed, so please answer frankly. The report that results from this research will be available through the Defense Technical Information Center.

3. The success of this research effort is totally dependent on your cooperation. Your views are needed to be sure to avoid misleading conclusions. Please return the completed questionnaires by 21 May 1982. Please take a few minutes from your schedule to share your knowledge with us.

ALAN R. STOUT, Lt Col, USAF
Acting Dean
School of Systems and Logistics

1 Atch
Questionnaire

AU SCN 82-23 (Expires 1 May 83)

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY (ATC)
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433

REPLY TO ATTN OF: CI

5 April 1982

SUBJECT: Survey of Education With Industry Students

TO: LS

I fully support the multiyear procurement survey proposed by Maj Rasch's research team at AFIT/LS. The researchers have briefed me on their methodology and expected results.

JAMES H. HAVEY, JR., Colonel, USAF
Dean
Civilian Institution Programs

AIR FORCE—A GREAT WAY OF LIFE

SPECIAL NOTES

1. Please circle the appropriate response on the questionnaire itself.

2. Section I questions refer to the company level at which you are currently working.

3. All references to "your firm" refer to the contractor location to which you are currently assigned.

4. Address the completed questionnaires to:

   Major Ronald H. Rasch
   AFIT/LSB
   Wright-Patterson AFB, Oh. 45433

SECTION I

In this section, you are asked questions concerning your background and experience.

1. Select the answer below that most nearly describes your area of responsibility in the firm.

   a. Manufacturing/Operations Management
   b. Financial Management
   c. Contracts
   d. Engineering/Research and Development
   e. Personnel/Management
   f. Program Management
   g. Marketing
   h. Other, ____________________(please specify)

2. Which choice below best describes your position within the firm?

   a. Executive Management
   b. Middle Management
   c. Foreman/Line Supervisor
   d. Other, ____________________(please specify)

3. How many years have you been in your present position?

   a. Less than 1 year
   b. 1 to 3 years
   c. 3 to 5 years
   d. 5 to 7 years
   e. 7 to 10 years
   f. 10 to 15 years
   g. 15 to 25 years
   h. over 25 years

4. How many years have you been employed by your firm?

   a. Less than 1 year
   b. 1 to 3 years
   c. 3 to 5 years
   d. 5 to 7 years
   e. 7 to 10 years
   f. 10 to 15 years
   g. 15 to 25 years
   h. over 25 years

5. How many years have you been employed in the defense industry?

a. Less than 1 year
b. 1 to 3 years
c. 3 to 5 years
d. 5 to 7 years
e. 7 to 10 years
f. 10 to 15 years
g. 15 to 25 years
h. over 25 years

6. In your job, which of the following activities consumes the most time?

a. Planning
b. Supervising
c. Dealing with Government Representatives
d. Production/Manufacturing
e. Budgeting
f. Other, ____________________ (please specify)

Multiyear procurement (MYP) allows the Department of Defense to award production contracts of several years duration (up to five years), as opposed to the mandatory annual contracts currently in use. A multiyear procurement contract can include provisions for advance buys of material and subassemblies to reduce costs; it can also include contract cancellation provisions that allow reimbursement of the contractor for both recurring and nonrecurring costs.

7. Have you worked on a multiyear procurement contract within the last five years?

a. Yes   b. No

SECTION II

The following questions relate to multiyear procurement issues. Please answer each of the ten statements below by circling one of seven responses. These seven responses are displayed on the answer scale that follows each statement.

8. For my firm's defense contracts, implementation of MYP will reduce average unit cost at the life of a program.

1 2 3 4 5 6 7

Strongly disagree — Neutral — Strongly agree

9. For my firm's defense contracts, implementation of MYP will decrease standardization.

1 2 3 4 5 6 7

Strongly disagree — Neutral — Strongly agree

10. For my firm's defense contracts, implementation of MYP will increase contract administration costs.

1 2 3 4 5 6 7

Strongly disagree — Neutral — Strongly agree

11. For my firm's defense contracts, an MYP contract will result in reduced labor costs.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

12. For my firm's defense contracts, implementation of MYP will increase productivity.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

13. For my firm's defense contracts, implementation of MYP will help stabilize our production manpower loading.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

14. For my firm's defense contracts, an MYP contract would decrease modernization of production capability.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

15. Widespread use of MYP contracting would result in my firm competing for more defense contracts.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

16. Widespread use of MYP contracts would result in more vendors competing for my firm's subcontracted effort.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

17. MYP contracts will improve my firm's ability to rapidly increase (surge) production during a national emergency.

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

SECTION III

In this section, you are asked to compare multi-year procurement and annual contracting. All questions will be asked in the context of the situations below.

Situation I. Your firm is engaged in a long term production program for the U.S. Air Force; USAF estimates another eight years of production life. You anticipate that annual contracting will be used for the remaining production years.

Situation II. The same as Situation I, except that the USAF has offered you a MYP contract with the following provisions: a five year contract; USAF will reimburse you for materials purchased for use up to two years in the future, and the contract cancellation ceiling has provisions to cover nonrecurring costs.

The scales below represent a percentage change for each type of cost. Based on recollection of your largest (dollar-value) production contract of the last five years, please estimate the cost impact that would be the result of Situation II (MYP) compared to Situation I (annual contracting).

18. Direct labor cost per unit produced?

30% or more	15%	5%	no change	5%	15%	30% or more
		Increase			Decrease	

19. Manufacturing overhead cost per unit produced?

30% or more	15%	5%	no change	5%	15%	30% or more
	Increase			Decrease		

20. Contract administration cost?

30% or more	15%	5%	no change	5%	15%	30% or more
	Increase			Decrease		

21. Material and subassembly cost per unit?

30% or more	15%	5%	no change	5%	15%	30% or more

SECTION IV

In this section, you are again asked to compare annual contracting and MYP. Each question in this section will have two answer scales. Use the first scale to give an answer appropriate for annual contracting, and use the second scale for MYP. As an aid to comparison, Situation I and Situation II are outlined below. Please answer the questions as they relate to your firm.

Situation I. Your firm is engaged in a long term production program for the U.S. Air Force; USAF estimates another eight years of production life. You anticipate that annual contracting will be used for the remaining production years.

Situation II. The same as Situation I, except that USAF has offered you an MYP contract with the following provisions: a five year contract; USAF will reimburse you for materials purchased for use up to two years in the future; and the contract cancellation ceiling has provisions to cover nonrecurring costs.

22. What percentage of Department of Defense Request for Proposals (RFP) and Invitations for BID (IFB) would your firm respond to?

a. Annual contracting

10 or less	25	40	50	60	75	90 or more

b. Widespread MYP use

10 or less	25	40	50	60	75	90 or more

23. What percentage of qualified U.S. firms would bid for subcontracts awarded by your firm for defense programs?

a. Annual contracting

10 or less	25	40	50	60	75	90 or more

b. Widespread MYP use

10 or less	25	40	50	60	75	90 or more

24. How long would it take to surge from a peacetime to a wartime production rate?

a. Annual contract (Situation I)

4 mos or less	6	8	12	18	24	30 mos. or more

b. MYP contract (Situation II)

4 mos or less	6	8	12	18	24	30 mos. or more

25. Your firm would not compete for a production contract because it anticipates a lack of sufficient profit.

a. Annual contract (Situation I)

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

b. MYP contract (Situation II)

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

26. Your firm would not compete for a production contract because it anticipates being locked into a long term project.

a. Annual contract (Situation I)

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

b. MYP contract (Situation II)

1	2	3	4	5	6	7
Strongly disagree			Neutral			Strongly agree

27. How much of a constraint would material and subassemblies be in an emergency production surge?

a. Annual contract (Situation I)

1	2	3	4	5	6	7
no factor		a minor constraint		a major constraint		the major constraint

b. MYP contract (Situation II)

1	2	3	4	5	6	7
no factor		a minor constraint		a major constraint		the major constraint

28. How much of a constraint would direct labor be in an emergency production surge?

a. Annual contract (Situation I)

1	2	3	4	5	6	7
no factor		a minor constraint		a major constraint		the major constraint

b. MYP contract (Situation II)

1	2	3	4	5	6	7
no factor		a minor constraint		a major constraint		the major constraint

29. How much of a constraint would the technology level of your firm's production facilities be in an emergency production surge?

a. Annual contract (Situation I)

1	2	3	4	5	6	7
no factor		a minor constraint		a major constraint		the major constraint

b. MYP contract (Situation II)

1	2	3	4	5	6	7
no factor		a minor constraint		a major constraint		the major constraint

30. What percentage of material would be purchased as advance buys?

a. Annual contract (Situation I)

10 or less	25	40	50	60	75	90 or more

b. MYP contract (Situation II)

10 or less	25	40	50	60	75	90 or more

31. What percentage of subassemblies would be purchased as advance buys?

a. Annual contract (Situation I)

10 or less	25	40	50	60	75	90 or more

b. MYP contract (Situation II)

10 or less	25	40	50	60	75	90 or more

32. How many months of wartime production could you support with the material and subassemblies in inventory or readily available from suppliers?

a. Annual contract (Situation I)

½ or less	2	4	6	8	10	12 or more

b. MYP contract (Situation II)

½ or less	2	4	6	8	10	12 or more

33. The technology level of my firm's production facilities would reflect the state of the art.

a. Annual contract (Situation I)

now	2 yrs ago	4 yrs ago	6 yrs ago	8 yrs ago	10 yrs ago	12 or more years ago

b. MYP contract (Situation II)

now	2 yrs ago	4 yrs ago	6 yrs ago	8 yrs ago	10 yrs ago	12 or more years ago

In Situation II, advance material buys are encouraged and your firm is reimbursed by the government for advance purchases. What if the multiyear contract did not provide for routine reimbursement of advance material buys, but rather provided for advance buy reimbursement only in the event of contract cancellation?

34. In this case, what percentage of materials would be purchased as advance buys?

10 or less	25	40	50	60	75	90 or more

35. In this case, what percentage of subassemblies would be purchased as advance buys?

10 or less	25	40	50	60	75	90 or more

36. In this case, how many months of wartime production could you support with the materials and subassemblies in inventory or readily available for suppliers?

4 mos or less	6	8	12	18	24	30 mos. or more

APPENDIX C

STATISTICAL ANALYSIS PROGRAMS

```
RUN NAME        MYP
PRINT BACK      CONTROL
VARIABLE LIST   Q1 TO Q21,Q22A,Q22B,Q23A,Q23B,Q24A,Q24B,Q25A,Q25B,Q26A,
                Q26B,Q27A,Q27B,Q28A,Q28B,Q29A,Q29B,Q30A,Q30B,Q31A,Q31B,
                Q32A,Q32B,Q33A,Q33B,Q34,Q35,Q36
INPUT MEDIUM    DISK
N OF CASES      UNKNOWN
INPUT FORMAT    FIXED(7A1,10F1.0,4F3.0,6F2.0,10F1.0,4F2.0,2F4.1,5F2.0)
RECODE          Q1 TO Q7 ('A'=1)('B'=2)('C'=3)('D'=4)('E'=5)('F'=6)
                ('G'=7)('H'=8)('I'=9)(ELSE=0)
VAR LABELS      Q1,AREA OF RESPONSIBILITY/Q2,POSITION/Q3,YRS IN POS/
                Q4,YRS WITH FIRM/Q5,YRS IN DEFENSE/Q6,MAJOR TIME/
                Q7,WORKED MYP/Q8,AVE UNIT COST/Q9,STANDARDIZATION/
                Q10,CONTRACT ADMIN COST/Q11,LABOR COST/Q12,PRODUCTIVITY/
                Q13,MANPWR LOAD/Q14,MODN PROD CAP/Q15,FIRM'S COMP/
                Q16,VENDOR'S COMP/Q17,NAT'L EMGY SURGE/Q18,DL COST/
                Q19,MFG OH COST/Q20,CONTRCT ADMIN COST/Q21,MAT'L COST/
                Q22A,FIRM RESP-A/Q22B,FIRM RESP-M/Q23A,SUB RESP-A/
                Q23B,SUB RESP-M/Q24A,SURGE-A/Q24B,SURGE-M/Q25A,PROFIT-A/
                Q25B,PROFIT-M/Q26A,LOCK IN-A/Q26B,LOCK IN-M/
                Q27A,MAT'L CONST-A/Q27B,MAT'L CONST-M/Q28A,DL CONST-A/
                Q28B,DL CONST-M/Q29A,TECH CONST-A/Q29B,TECH CONST-M/
                Q30A,MAT'L BUY-A/Q30B,MAT'L BUY-M/Q31A,SUB BUY-A/
                Q31B,SUB BUY-M/Q32A,WAR MAT'L-A/Q32B,WAR MAT'L-M/
                Q33A,TECH LVL-A/Q33B,TECH LVL-M/Q34, MAT'L BUY/
                Q35,CC SUB BUY/Q36,CC WAR MAT'L/
MISSING VALUES  Q1 TO Q17,Q25A TO Q29B(0)/Q18 TO Q24B,Q30A TO Q36(99)
FREQUENCIES     GENERAL=ALL
OPTIONS         3,8,9
STATISTICS      1,3,5,6
READ INPUT DATA
FINISH
```

FREQUENCIES/STATISTICS PROGRAM

```
RUN NAME        MYP
PRINT BACK      CONTROL
VARIABLE LIST   Q1 TO Q21,Q22A,Q22B,Q23A,Q23B,Q24A,Q24B,Q25A,Q25B,Q26A,
                Q26B,Q27A,Q27B,Q28A,Q28B,Q29A,Q29B,Q30A,Q30B,Q31A,Q31B,
                Q32A,Q32B,Q33A,Q33B,Q34,Q35,Q36
INPUT MEDIUM    DISK
N OF CASES      UNKNOWN
INPUT FORMAT    FIXED(7A1,10F1.0,4F3.0,6F2.0,10F1.0,4F2.0,2F4.1,5F2.0)
RECODE          Q1 TO Q7 ('A'=1)('B'=2)('C'=3)('D'=4)('E'=5)('F'=6)
                ('G'=7)('H'=8)('I'=9)(ELSE=0)
VAR LABELS      Q1,AREA OF RESPONSIBILITY/Q2,POSITION/Q3,YRS IN POS/
                Q4,YRS WITH FIRM/Q5,YRS IN DEFENSE/Q6,MAJOR TIME/
                Q7,WORKED MYP/Q8,AVE UNIT COST/Q9,STANDARDIZATION/
                Q10,CONTRACT ADMIN COST/Q11,LABOR COST/Q12,PRODUCTIVITY/
                Q13,MANPWR LOAD/Q14,MODN PROD CAP/Q15,FIRM'S COMP/
                Q16,VENDOR'S COMP/Q17,NAT'L EMGY SURGE/Q18,DL COST/
                Q19,MFG OH COST/Q20,CONTRCT ADMIN COST/Q21,MAT'L COST/
                Q22A,FIRM RESP-A/Q22B,FIRM RESP-M/Q23A,SUB RESP-A/
                Q23B,SUB RESP-M/Q24A,SURGE-A/Q24B,SURGE-M/Q25A,PROFIT-A/
                Q25B,PROFIT-M/Q26A,LOCK IN-A/Q26B,LOCK IN-M/
                Q27A,MAT'L CONST-A/Q27B,MAT'L CONST-M/Q28A,DL CONST-A/
                Q28B,DL CONST-M/Q29A,TECH CONST-A/Q29B,TECH CONST-M/
                Q30A,MAT'L BUY-A/Q30B,MAT'L BUY-M/Q31A,SUB BUY-A/
                Q31B,SUB BUY-M/Q32A,WAR MAT'L-A/Q32B,WAR MAT'L-M/
                Q33A,TECH LVL-A/Q33B,TECH LVL-M/Q34, MAT'L BUY/
                Q35,CC SUB BUY/Q36,CC WAR MAT'L/
MISSING VALUES  Q1 TO Q17,Q25A TO Q29B(0)/Q18 TO Q24B,Q30A TO Q36(99)
T-TEST          GROUPS=Q7(1,2)/VARIABLES=Q8 TO Q36/
                PAIRS=Q22A WITH Q22B/Q23A WITH Q23B/Q24A WITH Q24B/
                Q25A WITH Q25B/Q26A WITH Q26B/Q27A WITH Q27B/Q28A WITH
                Q28B/Q29A WITH Q29B/Q30A WITH Q30B/Q31A WITH Q31B/
                Q32A WITH Q32B/Q33A WITH Q33B/Q34 WITH Q30B/
                Q35 WITH Q31B/Q36 WITH Q32B
READ INPUT DATA
FINISH
```

T-TEST PROGRAM

APPENDIX D

SURVEY DATA FILE

DATA/COLUMN KEY

QUESTION*	COLUMNS	MISSING VALUE
1	1	0
2	2	0
3	3	0
4	4	0
5	5	0
6	6	0
7	7	0
8	8	0
9	9	0
10	10	0
11	11	0
12	12	0
13	13	0
14	14	0
15	15	0
16	16	0
17	17	0
18	18 - 20	99
19	21 - 23	99
20	24 - 26	99
21	27 - 29	99
22A	30, 31	99
22B	32, 33	99
23A	34, 35	99
23B	36, 37	99

* For Questions 1 through 7, an "I" indicates multiple responses.

DATA/COLUMN KEY

QUESTION*	COLUMNS	MISSING VALUE
24A	38, 39	99
24B	40, 41	99
25A	42	0
25B	43	0
26A	44	0
26B	45	0
27A	46	0
27B	47	0
28A	48	0
28B	49	0
29A	50	0
29B	51	0
30A	52, 53	99
30B	54, 55	99
31A	56, 57	99
31B	58, 59	99
32A	60 - 63	99
32B	64 - 67	99
33A	68 - 69	99
33B	70 - 71	99
34	72 - 73	99
35	74 - 75	99
36	76 - 77	99

* For Questions 1 through 7, an "I" indicates multiple responses.

```
HBCFFAA6225662544-15-15-30-1575906090180644426443332560256004.003.004004
04006
FACBDBA6225562452-03-05-05-1050605060121233320055331025102502.004.004041
01004
CACGGFA6225662566-15  0-15-0599999999242444226533111050105002.004.000001
01004
HBCFFFB6315762455-15-05-15-1590906090241275325353532570105000.506.003001
01004
FBDFFAA7114774777-15-15-30-1510401050120471715353111075107502.012.006001
01004
CBCEHCB7266562655-30-15-15-1550755075060644215533336060101000.500.502021
01004
HBBHHAA6225641455-05-15-15-1575755060242455217643332540607508.012.004022
54008
CBFGHIB6216552455-03-03-15-0560755075121244115555441010101004.010.002001
01004
HCDGGBA4324575772-15-15-15-0540502560131844325354531075107510.012.002002
51006
HBFHHFA7117771477-15-05-20-1599999999241262327354531045104506.012.007031
01004
HBBBHBB6435764464-10-10-15-1550755075080422445353532575257502.010.002005
05008
GBBEEAA5424663444 99 99 99 9999999999999900000000009999999999.099.099999
99999
CBFHH0A3355554544-05-05-05-0590909090999933330000009999999999.099.099999
99999
AAFHHDA7017761474-10-05-15-1099999999120600447555111040102502.004.008041
01004
CBFGGBB7126771;22-15+05-05-0510101010181277115453521025102502.006.008041
01004
CBBEFBA7426654444-05 00-05-0590909090999935330000001010101099.099.099991
01099
FAEHHBB6223571465-15-15 00-2040405075242474137433222525252506.006.004002
52506
CBGGGFA3063331246000000-15-10000000000000554477332?1010151512.012.900001
01004
FBBGGIB6326662665-15-05-15-0510252550120644427332311060251004.012.004602
52506
HBHGHBA7117771666-15-15-15-1550605060241822116532324050254006.012.004006
04018
CBFGGIA7117762456-05 00-15-1575757590120665117532221060101004.008.008061
01004
CBFGGIA7117762456-05  0-15-1575757=90120665117=32221060101004.008.008061
01004
```

DATA FILE

```
IBBGHAB5114561255  0  0-05-0510105060;02411115333;2160106012.012.002021
01012
BADHHBB5412331464  0  0  0-15757550502412551155553310501.7004.012.006001
01004
CABGGBA5215771545-10-10-10-209999999918084322735353259025900б.012.012042
52506
CDFGFIA6115551455-05-05-15-15252560601212233327665211001040 04.008.004041
01006
CADHHIB5324661154-05-05  0-1099999999999000000009099999999999.099.099999
99999
BABDGAB5335553455-05  0  0-0550505050241244226243324060102506.012.006049
99999
CBGGGBA6246662445-10  0  0-1590909090120600227633441090109000.500.501011
01004
CABFGFB6325562455+10+05+15+1040405060181232325444431025101506.010.002001
51006
IBCGGIA6335561554-05  0-05-1090906075181244216543321075106003.010.000001
01004
CDGGHFB6426671445-15-15-30-0599999999999944116655339999999999.099.002009
99999
FBDGHAA2244353511  0  0  0  05050101004041111553353105025401 2.012.000005
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DAAAHAA6323553455-05  0  0-0599995050181866225533334060406006.008.002021
01004
CBGGGIA6214772456-05-05-05-1090909090121222114453321090109000.512.002005
05012
BBBBBIA5333553454-05  0-05-0540401010080844323444431050107502.006.004021
01004
AAAGGIA7117777405-15-15  0-1099999999999900005443641040194099.099.099999
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CBFBGCB5245563455  0  0  0-0599999999121233115534552560102500.502.006061
01004
CAAAGBB1464662416-05-05  0-0590109090180825224435222540254002.002.012121
01004
BBGGHBB5355562256-05  0  0-1090907590301811116434431075107506.012.006061
01006
IBCGGFB7425342142-05-05  0-0550505050120433224433334040404008.008.002021
01004
```

DATA FILE

```
AABHHDB5225662455-05-05-15-0590909090181844225422432560405006.012.008041
02504
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01012
HADHHAB5325662464-05-15-05-1540502540251832224355441040102502.004.006021
02504
HABFFAA7145741455  0  0  0-0540405050301844447533331040109000.504.000001
01004
FBBDDEB5334554445  0-05  0-056075>07518064343=;53434075507506.012.006026
06012
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99999
AACHHBA7346562472-05  0  0-6599995090999942117732335090759002.002.004025
09099
BABHHFB6225563455-05-05-05-0550505060301863227443321050109006.012.006021
01006
BCGGGBA5225562366  0+05+05  090907590301846113322445070507506.006.002024
04006
GBEGGAB4454555454+05+05+05-0510102525061244444455771040104000.506.004041
01004
CBFHHBB7245552465-05-05-05-1090909090241544136443114090105504.012.000004
01024
FBDGGAA6116572267-05  0-30-1590509050301266367433112550255006.010.002029
01006
HAFFGIA4335553335-05  0-05-0590909090242425146333446090609002.010.002001
01004
BABHHBA5345563555-05  0  0-0575605075121244565444441040105009.506.002021
01004
CABFGAB5333353424  0-05-05-0510102540181200116533221040102500.504.006061
01004
*EOR
```

DATA FILE

APPENDIX E

MYP MODEL LISTING

```
*       GOVERNMENT AEROSPACE CONTRACTOR--MULTI-YEAR PROCUREMENT
NOTE
NOTE       1.   STUDY OF THE CORPORATE GROWTH PROCESS
NOTE       2.   ORIGINAL RESOURCE ACQUISITION MODEL
           3.   MULTI-YEAR PROCUREMENT MODIFICATIONS
NOTE
NOTE
NOTE       MARKET SECTOR
NOTE
A       RDPD.K=(PREIM.K)(PRDGPR)                                   MK-1
C       PRDGPR=2                                                   MK-2
A       CONPD.K=MIN(PREIM.K*PDGPR,CONPDM)                          MK-3
C       PDGPR=.005                                                 MK-4
C       CONPDM=15                                                  MK-5
L       PREIM.K=PREIM.J+(DT)(1/TPREM)(PRC.J-PREIM.J)               MK-6
C       TPREM=24                                                   MK-7
N       PREIM=1600                                                 MK-8
R       RDOR.KL=(RDPD.K)(FEDEM.K)(RDEXOG.K)                        MK-9
A       CONOR.K=(CONPD.K)(PDDEM.K)(PEXOG.K)                        MK-10
A       FEDEM.K=TABHL(TFEDEM,FEDDRO.K,0,3.5,0.5)                   MK-11
T       TFEDEM=1/.9/.6/.45/.35/.30/.27/.25                         MK-12
A       PDDEM.K=TABHL(TPDDEM,PDDRO.K,0,3.5,0.5)                    MK-13
T       TPDDEM=1/.9/.8/.6/.5/.4/.35/.3                             MK-14
A       FEDDRO.K=FEDCDO.K/FEDCDN                                   MK-15
C       FEDCDN=2                                                   MK-16
A       PDDRO.K=PDDO.K/PDDN                                        MK-17
C       PDDN=13                                                    MK-18
L       FEDCDO.K=FEDCDO.J+(DT)(1/TFECDO)(FEDCD.J-FEDCDO.J)         MK-19
C       TFECDO=3                                                   MK-20
N       FEDCDO=FEDCDN                                              MK-21
L       PDDO.K=PDDO.J+(DT)(1/TPDDO)(PDD.J-PDDO.J)                  MK-22
C       TPDDO=4                                                    MK-23
N       PDDO=PDDN                                                  MK-24
A       CONREV.K=(REVPR.K)(UNIPR.K)(PROREM.K)(SCONOR.K)            MK-25
A       SCONOR.K=SMOOTH(CONOR.K,SORTIM)                            MK-26
C       SORTIM=12                                                  MK-27
A       PROREM.K=PROLIF-TIME.K                                     MK-28
C       PROLIF=144                                                 MK-29
C       UNIPR=10000000                                             MK-30
A       REVPR.K=TABHL(TREVPR,PROREM.K,0,120,12)                    MK-31
T       TREVPR=1/.95/.9/.85/.8/.75/.70/.65/.60/.55/.50             MK-32
A       FMYREV.K=(AFFLN.K)(FLWFAC.K)(UNIPR.K)                      MK-33
A       AFFLN.K=(FLWCO.K)(FLWORD)                                  MK-34
A       FLWCO.K=CLIP(0,1,TIME.K,84.0)                              MK-35
C       FLWORD=500                                                 MK-36
A       FLWFAC.K=.5+MAX(TIME.K-24,0)*.4/60                         MK-37
A       MYREV.K=(MYOR.JK)(MYREM.K)(UNIPR.K)(MYFAC.K)               MK-38
A       MYREM.K=MYDUR.K-TIME.K                                     MK-39
A       MYDUR.K=CLIP(144,84,TIME.K,84)                             MK-40
A       MYFAC.K=.5+STEP(.45,24.0)                                  MK-41
A       MYOR.K=TABLE(TMYOR,TIME.K,0,144,12)                        MK-42
T       TMYOR=0/10/10/10/10/10/10/10/10/10/10/10/10                MK-43
A       FUTREV.K=MYREV.K+FMYREV.K+CONREV.K                         MK-44
```

```
NOTE
NOTE     FINANCIAL SECTOR
NOTE
A    ECCRDE.K=(ETRDE.K)(RPED)(MCRDE)                         F-1
C    RPED=.01                                                F-2
C    MCRDE=1                                                 F-3
A    ECCPE.K=(ETPE.K)(RPPU)(MCPE)                            F-4
C    RPPU=10                                                 F-5
C    MCPE=1                                                  F-6
L    RDFA.K=RDFA.J+(DT)(RDFAR.JK-RDFDR.JK)                   F-7
N    RDFA=RDFI                                               F-8
C    RDFI=10                                                 F-9
L    PFA.K=PFA.J+(DT)(PFAR.JK-PFDR.JK)                       F-10
N    PFA=PFI                                                 F-11
C    PFI=100                                                 F-12
R    RDFAR.KL=(RDFA.K)(FIRDF.K)                              F-13
R    PFAR.KL=(PFA.K)(FIPF.K)                                 F-14
A    FIRDF.K=TABHL(TFIRDF,PE.K,-1,5,1)                       F-15
T    TFIRDF=.005/.01/.02/.05/.1/.2/.3                        F-16
A    FIPF.K=TABHL(TFIPF,PE.K,-1,5,1)                         F-17
T    TFIPF=.005/.01/.02/.05/.1/.2/.3                         F-18
R    RDFDR.KL=(RDFA.K)(FDRDF.K)                              F-19
R    PFDR.KL=(PFA.K)(FDPF.K)                                 F-20
A    FDRDF.K=TABHL(TFDRDF,PE.K,-5,1,1)                       F-21
T    TFDRDF=.3/.2/.1/.05/.02/.01/.005                        F-22
A    FDPF.K=TABHL(TFDPF,PE.K,-5,1,1)                         F-23
T    TFDPF=.3/.2/.1/.05/.02/.01/.005                         F-24
A    RDFR.K=RDFA.K/ECCRDE.K                                  F-25
A    RDFRM.K=MAX(RDFR.K,.3)                                  F-26
A    RDFRC.K=CLIP(1.0,RDFRM.K,RDFRM.K,1.0)                   F-27
A    PFR.K=PFA.K/ECCPE.K                                     F-28
A    PFRM.K=MAX(PFR.K,.3)                                    F-29
A    PFRC.K=CLIP(1.0,PFRM.K,PFRM.K,1.0)                      F-30
A    CAPCST.K=CAPI+CAEXOG.K                                  F-31
C    CAPI=.10                                                F-32
A    OPMOR.K=TABHL(TOPMOR,CAPCST.K,0,.25,.05)                F-33
T    TOPMOR=.0167/.0133/.01/.0067/.0033/0                    F-34
A    OPMOD.K=(OPMOR.K)(FUTREV.K)                             F-35
A    INC.K=TABLE(TINC,MYINC.K,0,1.0,.2)                      F-36
T    TINC=0/.5/.7/.9/1/1                                     F-37
C    MYINC=.3                                                F-38
C    MODRSK=.1                                               F-39
A    MODOP.K=MODCC.K+(MODRSK)(INC.K)(OPMOD.K-MODCC.K)        F-40
A    MODCC.K=TABHL(TMODCC,TIME.K,0,144,3)                    F-41
T    TMODCC=10E6/10E6/10E6/10E6/10E6/10E6/10E6/10E6/
X    100E6/100E6/100E6/100E6/90E6/90E6/90E6/90E6/
X    75E6/75E6/75E6/75E6/50E6/50E6/50E6/59E6/
X    20E6/20E6/20E6/20E6/100E6/100E6/100E6/100E6/
X    90E6/90E6/90E6/90E6/75E6/75E6/75E6/75E6/
X    50E6/50E6/50E6/50E6/20E6/20E6/20E6/20E6/20E6            F-42
A    MODES.K=CLIP(MODOP.K,OPMOD.K,OPMOD.K,MODCC.K)           F-43
A    MODDIF.K=MODES.K-MODPL.K-MODLEV.K                       F-44
A    MODREQ.K=MAX(MODDIF.K,0.0)                              F-45
A    MODPRO.K=MODREQ.K/DT                                    F-46
```

```
R       MODEXP.KL=MIN(MODPRO.K,CORMAX)                               F-47
C       CORMAX=21E5                                                  F-48
N       MODEXP=0                                                     F-49
A       MODDEC.K=(MODEXP.JK)(DT)                                     F-50
R       MODINP.KL=DELAYP(MODEXP.JK,MODDEL,MODPL.K)                   F-51
N       MODPL=0                                                      F-52
C       MODDEL=18                                                    F-53
L       MODLEV.K=MODLEV.J+(DT)(MODINP.JK-DETRET.JK)                  F-54
N       MODLEV=0                                                     F-55
R       DETRET.KL=MODLEV.K/RETTIM                                    F-56
C       RETTIM=120                                                   F-57
A       MODIMP.K=MODREQ.K+MODPL.K                                    F-58
A       MODSTA.K=MODIMP.K+MODLEV.K                                   F-59
A       MODRAT.K=MODIMP.K/FUTREV.K                                   F-60
A       ROR.K=TABHL(TROR,MODRAT.K,0,.0165,.0033)                     F-61
T       TROR=.25/.20/.15/.10/.05/0                                   F-62
A       AROR.K=SMOOTH(ROR.K,.5)                                      F-63
N       ROR=.25                                                      F-64
A       ANDLCI.K=(BWR)(43)(EDLC.K)(52)                               F-65
A       ANDLC.K=CLIP(ANDLCI.K,300E6,TIME.K,24)                       F-66
A       PROACQ.K=(AROR.K)(MODDEC.K)/ANDLC.K                          F-67
R       MODR.KL=PROACQ.K/DT                                          F-68
N       MODR=0                                                       F-69
R       IPR.KL=DELAY3(MODR.JK,MODDEL)                                F-70
L       FIPR.K=FIPR.J+(DT)(IPR.JK)                                   F-71
N       FIPR=1.0                                                     F-72
A       CFSF.K=(CAPCST.K-MYINC.K*AROR.K)(MODEXP.JK*DT)(5)            F-73
R       AFINC.KL=MAX(CFSF.K,0)/DT                                    F-74
L       TAFINC.K=TAFINC.J+(DT)(AFINC.JK)                             F-75
N       TAFINC=0                                                     F-76
NOTE
NOTE       DESIGN (ENGINEERING) SECTOR
NOTE
L       EDEC.K=EDEC.J+(DT)(DECBE.JK-DECDR.JK)                        DE-1
N       EDEC=DECI                                                    DE-2
C       DECI=1000                                                    DE-3
R       DECBE.KL=DELAY3(DECAR.JK,DDEC)                               DE-4
C       DDEC=4                                                       DE-5
L       DECBA.K=DECBA.J+(DT)(DECAR.JK-DECBE.JK)                      DE-6
N       DECBA=100                                                    DE-7
R       DECAR.KL=(DEC.K)(FIDEC.K)                                    DE-8
A       DEC.K=EDEC.K+DECBA.K                                         DE-9
A       FIDEC.K=TABHL(TFIDEC,PE.K,-1,5,1)                            DE-10
T       TFIDEC=.005/.007/.026/.053/.062/.062/.063                    DE-11
R       DECDR.KL=(DEC.K)(FDDEC.K)                                    DE-12
A       FDDEC.K=TABHL(TFDDEC,PE.K,-5,1,1)                            DE-13
T       TFDDEC=.09/.087/.076/.05/.03/.007/.005                       DE-14
A       FA.K=MIN(DEPROD.K,RDFRC.K)                                   DE-15
R       IEDS.KL=(EDEC.K)(FA.K)                                       DE-16
A       DEPROD.K=(NDEPRO)(MDEPRO.K)                                  DE-17
C       NDEPRO=3                                                     DE-18
A       MDEPRO.K=TABHL(TMDEPR,PE.K,-5,5,1)                           DE-19
T       TMDEPR=.65/.65/.75/.85/.9/1/1.1/1.2/1.25/1.3/1.3             DE-20
R       IEDC.KL=DELAY3(IEDS.JK,DIEDC)                                DE-21
```

```
C       DIEDC=2                                              DE-22
L       BURDO.K=BURDO.J+(DT)(RDOR.JK-PFEDC.JK)               DE-23
N       BURDO=(MRDBLD)(AFEDCR)                               DE-24
C       MRDBLD=12                                            DE-25
A       BURDOC.K=CLIP(BURDO.K,1000,BURDO.K,1000)             DE-26
L       ARDOR.K=ARDOR.J+(DT)(1/TARDOR)(RDOR.JK-ARDOR.J)      DE-27
C       TARDOR=3                                             DE-28
N       ARDOR=RDOR                                           DE-29
A       EDCH.K=(RDOR.JK)(FREDCH)                             DE-30
C       FREDCH=.10                                           DE-31
A       NEDCH.K=(ARDOR.K)(FEDCHN)                            DE-32
C       FEDCHN=.10                                           DE-33
A       EDCHR.K=EDCH.K/NEDCH.K                               DE-34
R       FEDC.KL=IEDC.JK-EDCH.K                               DE-35
A       RFEDA.K=FEDC.JK/IEDC.JK                              DE-36
A       RFEDAM.K=MAX(RFEDA.K,.3)                             DE-37
A       RFEDAC.K=CLIP(1.0,RFEDAM.K,RFEDAM.K,1.0)             DE-38
R       PFEDC.KL=DELAY3(FEDC.JK,DPFEDN)                      DE-39
C       DPFEDN=1                                             DE-40
A       FEDCD.K=BURDOC.K/AFEDCR.K                            DE-41
L       AFEDCR.K=AFEDCR.J+(DT)(1/TAFECR)(PFEDC.JK-AFEDCR.J)  DE-42
C       TAFECR=3                                             DE-43
N       AFEDCR=3000                                          DE-44
A       ETRDE.K=BURDOC.K/MRDBLD                              DE-45
NOTE
NOTE       PRODUCTION (MANUFACTURING) SECTOR
NOTE
L       EDLCI.K=EDLC.J+(DT)(DLBE.JK-DLDR.JK)                 P-1
A       EDLC.K=MIN(EDLCI.K,9000)                             P-2
N       EDLCI=2000                                           P-3
R       DLBE.KL=DELAY3(DLAR.JK,DADL)                         P-4
C       DADL=3                                               P-5
L       DLBA.K=DLBA.J+(DT)(DLAR.JK-DLBE.JK)                  P-6
N       DLBA=100                                             P-7
L       PLC.K=PLC.J+(DT)(PCBE.JK-PCDR.JK)                    P-8
N       PLC=18                                               P-9
R       PCBE.KL=DELAY3(PCAR.JK,DAPC)                         P-10
C       DAPC=18                                              P-11
L       PCBA.K=PCBA.J+(DT)(PCAR.JK-PCBE.JK)                  P-12
N       PCBA=1                                               P-13
A       EPLC.K=(PLC.K)(FIPR.K)                               P-14
A       EPC.K=(EPLC.K)(MDLH)(MDL.K)                          P-15
C       MDLH=50                                              P-16
A       MDL.K=TABLE(TMDL,EDLC.K,0,8800,1100)                 P-17
T       TMDL=0/.0025/.0075/.017/.023/.028/.033/.04/.047      P-18
A       DLU.K=PS.JK/(EPLC.K*MDL.K)                           P-19
A       DLUD.K=DLU.K-40                                      P-20
A       DLO.K=MAX(DLUD.K,0.0)                                P-21
R       BDLR.KL=4.33*(EDLC.K)(BWR)(40+1.5*DLO.K)/DT          P-22
C       BWR=35                                               P-23
L       BDLD.K=BDLD.J+(DT)(BDLR.JK)                          P-24
N       BDLD=0                                               P-25
A       SDLU.K=SMOOTH(DLU.K,SDLTIM)                          P-26
C       SDLTIM=6                                             P-27
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```
A     FIDLU.K=TABHL(TFIDLU,SDLU.K,42,60,3)                        P-28
T     TFIDLU=.005/.007/.014/.022/.029/.035/.04                    P-29
A     FDDLU.K=TABHL(TFDDLU,SDLU.K,33,45,2)                        P-30
T     TFDDLU=.03/.029/.025/.017/.007/0/0                          P-31
A     PEDL.K=SMOOTH(PEPR.K,INDEDL)                                P-32
C     INDEDL=6                                                    P-33
A     FIDL.K=TABHL(TFIDL,PEDL.K,-1,5,1)                           P-34
T     TFIDL=.005/.007/.014/.022/.029/.035/.04                     P-35
A     FDDL.K=TABHL(TFDDL,PEDL.K,-5,1,1)                           P-36
T     TFDDL=.09/.087/.076/.05/.02/.007/.005                       P-37
A     DLC.K=EDLC.K+DLBA.K                                         P-38
R     DLAR.KL=(DLC.K)(FIDL.K+FIDLU.K)                             P-39
R     DLDR.KL=(DLC.K)(FDDL.K+FDDLU.K)                             P-40
A     PEPC.K=SMOOTH(PEPR.K,INDELP)                                P-41
C     INDELP=18                                                   P-42
A     FIPC.K=TABHL(TFIPC,PEPC.K,-1,5,1)                           P-43
T     TFIPC=.005/.0007/.0014/.0022/.0029/.0035/.004               P-44
A     FDPC.K=TABHL(TFDPC,PEPC.K,-5,1,1)                           P-45
T     TFDPC=.009/.0087/.0076/.005/.002/.0007/.0005                P-46
A     PLCT.K=PLC.K+PCBA.K                                         P-47
R     PCAR.KL=(PLCT.K)(FIPC.K)                                    P-48
R     PCDR.KL=(PLCT.K)(FDPC.K)                                    P-49
A     F1.K=MIN(PROD.K,PFRC.K)                                     P-50
A     F2.K=MIN(F1.K,RFEDAC.K)                                     P-51
A     F3.K=MIN(F2.K,IMPCM.K)                                      P-52
A     PP.K=(EPC.K)(F3.K)                                          P-53
A     PD.K=BUOC.K/MBLD                                            P-54
R     PS.KL=MIN(PP.K,PD.K)                                        P-55
N     PS=10                                                       P-56
A     PROD.K=(NPROD)(MPRO.K)                                      P-57
C     NPROD=1                                                     P-58
A     MPRO.K=TABHL(TMPRO,PEPC.K,-5,5,1)                           P-59
T     TMPRO=.65/.65/.75/.85/.9/1/1.1/1.2/1.25/1.3/1.3             P-60
A     NIMPC.K=(DMIMPC)(EPC.K)                                     P-61
C     DMIMPC=2                                                    P-62
L     IMPC.K=IMPC.J+(DT)(IAR.JK-PS.JK)                            P-63
N     IMPC=EPC                                                    P-64
A     IMPCR.K=IMPC.K/EPC.K                                        P-65
R     IAR.KL=(MSR.JK)(FII.K)                                      P-66
A     FII.K=TABHL(TFII,IMPCR.K,0,3.5,0.5)                         P-67
T     TFII=1/.9/.6/.45/.35/.30/.27/.25                            P-68
A     IMPCA.K=IMPC.K/EPC.K                                        P-69
A     IMPCAM.K=MAX(IMPCA.K,.3)                                    P-70
A     IMPCM.K=CLIP(1.0,IMPCAM.K,IMPCAM.K,1.0)                     P-71
R     PF.KL=DELAY3(PS.JK,DP)                                      P-72
C     DP=13                                                       P-73
N     PF=10                                                       P-74
L     UNITSF.K=UNITSF.J+(DT)(PF.JK)                               P-75
N     UNITSF=0                                                    P-76
R     PSR.KL=DELAY3(PF.JK,DPFUN)                                  P-77
C     DPFUN=1                                                     P-78
N     PSR=10                                                      P-79
R     PRODOR.KL=CONOR.K+MYOR.K                                    P-80
L     BUO.K=BUO.J+(DT)(PRODOR.JK-PSR.JK)                          P-81
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N       BUO=(MBLD)(AP)                                          P-82
C       MBLD=[illegible]                                        P-83
A       BUOC.K=CLIP(BUO.K,.5,BUO.K,.5)                          P-84
L       APOR.K=APOR.J+(DT)(1/TAPOR)(PRODOR.JK-APOR.J)           P-85
C       TAPOR=3                                                 P-86
N       APOR=10                                                 P=87
A       PMOR.K=(APOR.K)(FAPOR)                                  P-88
C       FAPOR=3                                                 P-89
R       MOR.KL=(PMOR.K)(MDDEM.K)                                P-90
A       MDDEM.K=TABHL(TMDDEM,MDDRO.K,0,3.5,0.5)                 P-91
T       TMDDEM=1/.9/.6/.45/.35/.30/.27/.25                      P-92
A       MDDRO.K=MDDO.K/MDDN                                     P-93
C       MDDN=1                                                  P-94
L       MDDO.K=MDDO.J+(DT)(1/TMDDO)(MDD.J-MDDO.J)               P-95
C       TMDDO=3                                                 P-96
N       MDDO=MDDN                                               P-97
A       PDD.K=BUOC.K/APSR.K                                     P-98
L       APSR.K=APSR.J+(DT)(1/TAPSR)(PSR.JK-APSR.J)              P-99
C       TAPSR=[illegible]                                       P-100
N       APSR=10                                                 P-101
A       ETPE.K=BUOC.K/MBLD                                      P-102
NOTE
NOTE       MATERIAL SECTOR
NOTE
L       EMPC.K=EMPC.J+(DT)(MPCBE.JK-MPCDR.JK)                   MT-1
N       EMPC=MPCI                                               MT-2
C       MPCI=20                                                 MT-3
R       MPCBE.KL=DELAY3(MPCAR.JK,DAMPC)                         MT-4
C       DAMPC=4                                                 MT-5
L       MPCBA.K=MPCBA.J+(DT)(MPCAR.JK-MPCBE.JK)                 MT-6
N       MPCBA=2                                                 MT-7
R       MPCAR.KL=(MPC.K)(FIMPC.K)                               MT-8
A       MPC.K=EMPC.K+MPCBA.K                                    MT-9
A       PEMPC.K=SMOOTH(PE.K,INDELM)                             MT-10
C       INDELM=12                                               MT-11
A       FIMPC.K=TABHL(TFIMPC,PEMPC.K,-1,5,1)                    MT-12
T       TFIMPC=.005/.007/.014/.022/.029/.035/.04                MT-13
R       MPCDR.KL=(MPC.K)(FDMPC.K)                               MT-14
A       FDMPC.K=TABHL(TFDMPC,PEMPC.K,-5,1,1)                    MT-15
T       TFDMPC=.09/.087/.076/.05/.02/.007/.005                  MT-16
R       MPS.KL=((EMPC.K)(RFEDAC.K))/WDF                         MT-17
N       MPS=15                                                  MT-18
C       WDF=1                                                   MT-19
R       MPF.KL=DELAY3(MPS.JK,DMP)                               MT-20
C       DMP=20                                                  MT-21
R       MSR.KL=DELAY3(MPF.JK,DPFMN)                             MT-22
N       MPF=15                                                  MT-23
C       DPFMN=1                                                 MT-24
L       BUPO.K=BUPO.J+(DT)(MOR.JK-MSR.JK)                       MT-25
N       BUPO=(MMBLD)(AMP)                                       MT-26
C       MMBLD=20                                                MT-27
A       BUPOC.K=CLIP(BUPO.K,10,BUPO.K,10)                       MT-28
A       MDD.K=BUPOC.K/AMSR.K                                    MT-29
L       AMSR.K=AMSR.J+(DT)(1/TAMSR)(MSR.JK-AMSR.J)              MT-30
```

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C       TAMSR=3                                                   MT-31
N       AMSR=5                                                    MT-32
NOTE
NOTE       PROFESSIONAL SECTOR
NOTE
R       PRAR.KL=(PRE.K)(FIP.K)                                    PF-1
A       PRE.K=EPRE.K+PEBA.K                                       PF-2
A       FIP.K=FIPE.K+FIAP.K                                       PF-3
A       FIPE.K=TABHL(TFIPE,PE.K,-1,5,1)                           PF-4
T       TFIPE=.005/.007/.014/.022/.029/.035/.04                   PF-5
A       FIAP.K=FPRD.K/TAPR                                        PF-6
C       TAPR=16                                                   PF-7
A       FPRD.K=(1/PRE.K)(PRED.K-PRE.K)                            PF-8
A       PRED.K=(DRDEC)(DEC.K)+(DRPRC)(EPC.K)+(DRMPC)(MPC.K)       PF-9
N       DRDEC=(3150)/DEC                                          PF-10
N       DRPRC=(900)/EPC                                           PF-11
N       DRMPC=(450)/MPC                                           PF-12
R       PRDE.KL=(FDPR.K)(EPRE.K)                                  PF-13
R       PRDA.KL=(FDPR.K)(PEBA.K)                                  PF-14
A       FDPR.K=TABHL(TFDPR,PE.K,-5,1,1)                           PF-15
T       TFDPR=.09/.087/.076/.05/.02/.007/.005                     PF-16
L       EPRE.K=EPRE.J+(DT)(PEBE.JK-PRDE.JK)                       PF-17
N       EPRE=PEEI                                                 PF-18
C       PEEI=4200                                                 PF-19
R       PEBE.KL=PEBA.K/DAPE                                       PF-20
L       F[illegible]K=PEBA.J+(DT)(PRAR.JK-PEBE.JK-PRDA.JK+0)      PF-21
N       P[illegible]00                                            PF-22
A       DA[illegible].K=TABHL(TDAPE,PRE.K,0,6300,700)             PF-23
T       TDAPE=3/4/5/6/9/12/17/20/22/24                            PF-24
A       PREA.K=(EPRE.K)(PREF.K)                                   PF-25
A       PREF.K=TABHL(TPREF,FPRA.K,0,.8,.1)                        PF-26
T       TPREF=1/.95/.9/.75/.6/.45/.35/.28/.25                     PF-27
A       FPRA.K=PEBA.K/PRE.K                                       PF-28
A       PRC.K=PREA.K-PRER.K                                       PF-29
A       PRER.K=(FIP.K)(PRE.K)(RCE)                                PF-30
C       RCE=0.5                                                   PF-31
NOTE

NOTE       PRESSURE-FOR-EXPANSION SECTOR
NOTE
A       PERDB.K=TABXT(TPERDB,RDBLRO.K,0,4,.5)                     PE-1
T       TPERDB=-1/-.5/.5/2/3.2/3.7/4/5/6                          PE-2
A       PEB.K=TABHL(TPEB,BLRO.K,0,4,.5)                           PE-3
T       TPEB=-1/-.5/.5/2/3.2/3.7/3.9/4/4                          PE-4
A       PEMB.K=TABHL(TPEMB,MBLRO.K,0,4,.5)                        PE-5
T       TPEMB=-1/-.5/-.1/.3/1/1.5/1.8/2/2                         PE-6
L       RDBLRO.K=RDBLRO.J+(DT)(1/TRBLRO)(RDBLR.J-RDBLRO.J)        PE-7
C       TRBLRO=3                                                  PE-8
N       RDBLRO=RDBLR                                              PE-9
L       BLRO.K=BLRO.J+(DT)(1/TBLRO)(BLR.J-BLRO.J)                 PE-10
C       TBLRO=3                                                   PE-11
N       BLRO=BLR                                                  PE-12
L       MBLRO.K=MBLRO.J+(DT)(1/TMBLRO)(MBLR.J-MBLRO.J)            PE-13
C       TMBLRO=3                                                  PE-14
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N      MBLRO=MBLR                                                PE-15
A      RDBLR.K=MRDBL.K/MRDBLD                                    PE-16
A      BLR.K=MBL.K/MBLD                                          PE-17
A      MBLR.K=MMBL.K/MMBLD                                       PE-18
A      MRDBL.K=BURDOC.K/AFEDCR.K                                 PE-19
A      MBL.K=BUOC.K/FPC.K                                        PE-20
A      MMBL.K=BUPOC.K/AMP.K                                      PE-21
L      AP.K=AP.J+(DT)(1/TAP)(PF.JK-AP.J)                         PE-22
C      TAP=3                                                     PE-23
N      AP=10                                                     PE-24
L      AMP.K=AMP.J+(DT)(1/TAMP)(MPF.JK-AMP.J)                    PE-25
C      TAMP=3                                                    PE-26
N      AMP=10                                                    PE-27
A      PEIMPC.K=TABHL(TPEIPC,IMPCRO.K,0,2,.25)                   PE-28
T      TPEIPC=2/1/.5/.25/.1/-.25/-.5/-.75/-1                     PE-29
L      IMPCRO.K=IMPCRO.J+(DT)(1/TIPCRO)(IMPCR.J-IMPCRO.J)        PE-30
C      TIPCRO=3                                                  PE-31
N      IMPCRO=IMPCR                                              PE-32
A      PERDFA.K=TABHL(TPERFA,RDFRO.K,0,2,.25)                    PE-33
T      TPERFA=4/4/3.9/3.7/3.2/2/.5/-.5/-1                        PE-34
A      PEPFA.K=TABHL(TPEPFA,PFRO.K,0,2,.25)                      PE-35
T      TPEPFA=4/4/3.9/3.7/3.2/2/.5/-.5/-1                        PE-36
L      RDFRO.K=RDFRO.J+(DT)(1/TRDFRO)(RDFR.J-RDFRO.J)            PE-37
C      TRDFRO=2                                                  PE-38
N      RDFRO=RDFR                                                PE-39
L      PFRO.K=PFRO.J+(DT)(1/TPFRO)(PFR.J-PFRO.J)                 PE-40
C      TPFRO=2                                                   PE-41
N      PFRO=PFR                                                  PE-42
A      PEEDCH.K=TABHL(TPEECH,EDCHRO.K,0,2,.25)                   PE-43
T      TPEECH=-1/-.5/-.1/.3/1/1.5/1.8/2/2                        PE-44
L      EDCHRO.K=EDCHRO.J+(DT)(1/TECHRO)(EDCHR.J-EDCHRO.J)        PE-45
C      TECHRO=3                                                  PE-46
N      EDCHRO=EDCHR                                              PE-47
A      PECW.K=PERDB.K+PEB.K+PEMB.K+PEIMPC.K+PERDFA.K+
X1     PEPFA.K+PEEDCH.K                                          PE-48
L      PE.K=PE.J+(DT)(1/TPES)(PECW.J-PE.J)                       PE-49
C      TPES=3                                                    PE-50
N      PE=5                                                      PE-51
A      PEPR.K=(PE.K+6*PEB.K)/12                                  PE-52
NOTE
NOTE     EXOGENOUS INPUT FACTORS
NOTE
A      RDEXOG.K=1+RDNOIS.K+RDSINE.K                              EX-1
A      PEXOG.K=1+PNOIS.K+PSINE.K                                 EX-2
A      RDNOIS.K=SAMPLE(RNORNS.K,RDINT,RDISAM)                    EX-3
C      RDINT=12                                                  EX-4
C      RDISAM=0                                                  EX-5
A      PNOIS.K=SAMPLE(PNORNS.K,PINT,PISAM)                       EX-6
C      PINT=12                                                   EX-7
C      PISAM=0                                                   EX-8
A      RNORNS.K=1.0*NORMRN(RDMEAN,RDSTDV)                        EX-9
C      RDMEAN=0                                                  EX-10
C      RDSTDV=0                                                  EX-11
A      PNORNS.K=1.0*NORMRN(PMEAN,PSTDV)                          EX-12
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C       PMEAN=0                                                  EX-13
C       PSTDV=6                                                  EX-14
A       RDSINE.K=(RSNAMP)*SIN((3.1417)(TIME.K)/RDPER)            EX-15
C       RSNAMP=0                                                 EX-16
C       RDPER=12                                                 EX-17
A       PSINE.K=(PSNAMP)*SIN((3.1417)(TIME.K)/PPER)              EX-18
C       PSNAMP=0                                                 EX-19
C       PPER=12                                                  EX-20
A       CAEXOG.K=.02*SIN(.283*TIME.K/36)                         EX-21
NOTE
NOTE        SUPPLEMENTARY INFORMATION
NOTE
NOTE
NOTE        PRINT AND PLOT SPECIFICATIONS

PRINT 1)CONPD,CONOR,FUTREV,MODIMP,TAFINC
PRINT 2)EDLC,PLC,FIPR,EPC,BDLD
PRINT 3)PS,PDDO,UNITSF,PREIM
PRINT 4)PFPC,RFEDAC,IMPCM
PLOT EDLC=L/PS=P
PLOT MODSTA=I/TAFINC=A
PLOT CONOR=F/MYOR=G
NOTE
NOTE       BASIC SYSTEM--ORIGINAL PARAMETERS
NOTE
SPEC DT=0.25/LENGTH=120/PRTPER=6/PLTPER=2
RUN
```

APPENDIX F

MYP MODEL VARIABLE LIST

MARKET SECTOR
VARIABLE LIST

Variable Name	Variable Description	Units of Measure
AFFLN	Air Force FoLlow-oN	units
CONOR	CONtingent production Order Rate	units/month
CONPD	CONtingent Potential Demand	units/month
CONPDM	CONtingent Production potential Demand	units/month
CONREV	expected future CONtingent order REVenue	dollars
FEDCD	Final Engineering Design Completion Delay	months
FEDCDN	Final Engineering Design Completion Delay Normal	months
FEDCDO	Final Engineering Design Completion Delay Observed	months
FEDDRO	Final Engineering Design completion Delay Ratio Observed	dimensionless
FEDEM	Final Engineering Design completion Delay Effect on Market	dimensionless
FLWCO	FoLloW-on COefficient	dimensionless
FLWFAC	contractor FoLloW-on confidence FACtor	dimensionless
FLWORD	units expected in FoLloW-on ORDer	units
FMYREV	expected Follow-on Multi-Year contract REVenue	dollars
FUTREV	expected FUTure program REVenue	dollars
MYDUR	Multi-Year contract DURation	months
MYFAC	Multi-Year FACtor	dimensionless
MYOR	Multi-Year Order Rate	units/mo
MYREM	Multi-Year contract time REMaining	months
MYREV	expected Multi-Year contract REVenue	dollars
PDDEM	Production Delivery Delay Effect on the Market	dimensionless
PDDN	Production Delivery Delay Normal	months
PDDO	Production Delivery Delay Observed	months
PDDRO	Production Delivery Delay Ratio Observed	dimensionless
PDGPR	Production Demand Generated by PRofessional effort	units/worker-month
PEXOG	Production EXOGenous input	dimensionless
PRC	PRofessional Capability	workers
PRDGPR	Potential R&D demand Generated by PRofessional effort	designs/worker-month
PREIM	PRofessional Effort Influencing the Market	workers
PROLIF	PROgram LIFe	months

MARKET SECTOR
VARIABLE LIST CONT'D

Variable Name	Variable Description	Units of Measure
PROREM	PROgram time REMaining	months
RDEXOG	R&D EXOGenous input	dimensionless
RDOR	R&D Order Rate	designs/month
RDPD	R&D Potential Demand	designs/month
REVPR	contingent REVenue PRobability	dimensionless
SCONOR	Smoothed CONtingent production Order Rate	units/month
SORTIM	Smoothing ORder TIMe	months
TFECDO	Time for Final Engineering design Completion Delay Observation	months
TFEDEM	Table for FEDEM	dimensionless
TIME	TIME	months
TMYOR	Table for MYOR	dimensionless
TPDDEM	Table for PDDEM	dimensionless
TPDDO	Time for Production Delivery Delay Observation	months
TPREM	Time for PRofessional Effort to influence the Market	months
TREVPR	Table for REVPR	dimensionless
UNIPR	UNIt PRice	dollars

FINANCIAL SECTOR
VARIABLE LIST

Variable Name	Variable Description	Units of Measure
AFINC	Air Force INCentive payment	dollars/month
ANDLC	ANnual Direct Labor Cost clipped	dollars
ANDLCI	ANnual Direct Labor Cost Initial	dollars
AROR	Average Rate Of Return	percent
BWR	Burdened Wage Rate	dollars/hour-worker
CAEXOG	CApital cost EXOGenous input	percent
CAPCST	CAPital CoST	percent
CAPI	CAPital cost Initial	percent
CFSF	Cash Flow Short Fall	dollars
CORMAX	CORporate MAXimum investment rate	dollars/month
DETRET	DEbt RETirement rate	dollars/month
ECCPE	Estimated Cost to Complete Production Effort	million dollars
ECCRDE	Estimated Cost to Complete R&D Effort	million dollars
EDLC	Effective Direct Labor Capacity	workers
ETPE	Estimate of Total Production Effort	units/month
ETRDE	Estimate of Total R&D Effort	engineering designs/month
FDPR	Fractional Decrease of Production Funds	1/month
FDRDF	Fractional Decrease of R&D Funds	1/month
FIPF	Fractional Increase of Production Funds	1/month
FIPR	Fractional Increase in PRoductivity	dimensionless
FIRDF	Fractional Increase of R&D Funds	1/month
FUTREV	Estimated FUTure REVenue	dollars
INC	INCentive from cost share ratio	dimensionless
IPR	Increase in PRoductivity	dimensionless/month
MCPE	Months to Complete Production Effort	months
MCRDE	Months to Complete R&D Effort	months
MODCC	Contract MODernization Cancellation Ceiling	dollars
MODDEC	MODernization DECision	dollars
MODDEL	MODernization DELay	months
MODDIF	MODernization DIFference	dollars
MODES	MOdernization DESired	dollars
MODEXP	MODernization EXPenditure rate	dollars/month
MODIMP	MODernization being IMPlemented	dollars
MODINP	MODernization IN Place	dollars

FINANCIAL SECTOR
VARIABLE LIST CONT'D

Variable Name	Variable Description	Units of Measure
MODLEV	MODernization LEVerage	dollars
MODOP	MODernization OPportunity	dollars
MODPL	MODernization in PipeLine	dollars
MODPRO	MODernization rate PROposed	dollars/month
MODR	MODernization Rate	dollars/week
MODRAT	MODernization to revenue RATio	dimensionless
MODREQ	MODernization investment REQuested	dollars
MODRSK	corporate willingness to incur MODernization RiSK	dimensionless
MODSTA	MODernization STAtus	dollars
MYINC	Multi-Year contract cost sharing INCentive	dimensionless
OPMOD	OPtimal MODernization investment level	dollars
OPMOR	OPtimal MOdernization Ratio	dimensionless
PE	Pressure for Expansion	pressure units
PFA	Production Funds Availability	million dollars
PFAR	Production Funds Acquisition Rate	million dollars/ month
PFDR	Production Funds Departure Rate	million dollars/ month
PFI	Production Funds Initial	million dollars
PFR	Production Funds Availability Ratio	dimensionless
PFRC	Production Funds availability Ratio Clipped	dimensionless
PFRM	Production Funds availability Ratio Minimum	dimensionless
PROACQ	PROductivity being ACQuired	dimensionless
RDFA	R&D Funds Availability	million dollars
RDFAR	R&D Funds Acquisition Rate	million dollars/ month
RDFDR	R&D Funds Departure Rate	million dollars/ month
RDFI	R&D Funds Initial	million dollars
RDFR	R&D Funds availability Ratio	dimensionless
RDFRM	R&D Funds availability Ratio Minimum	dimensionless
RETTIM	RETirement TIMe period	months
ROR	Rate Of Return	percent
RPED	Revenue Per Engineering Design	million dollars/ engineering design

FINANCIAL SECTOR
VARIABLE LIST CONT'D

Variable Name	Variable Description	Units of Measure
RPPU	Revenue Per Production Unit	million dollars/ unit
TAFINC	Total Air Force INCentive payment	dollars
TFDPF	Table for FDPF	dimensionless
TFDRDF	Table for FDRDF	dimensionless
TFIPF	Table for FIPF	dimensionless
TFIRDF	Table for FIRDF	dimensionless
TINC	Table for INC	dimensionless
TMODCC	Table for MODCC	dimensionless
TOPMOR	Table for OPMOR	dimensionless
TROR	Table for ROR	dimensionless

DESIGN (ENGINEERING) SECTOR
VARIABLE LIST

Variable Name	Variable Description	Units of Measure
AFEDCR	Average Final Engineering Design Completion Rate	engineering designs/month
ARDOR	Average R&D Order Rate	engineering designs/month
BURDO	Backlog of Unfilled R&D Orders	engineering designs
BURDOC	Backlog of Unfilled R&D Orders Clipped	engineering designs
DDEC	Delay for absorbing Design (Engineering) Capacity	months
DEC	Design (Engineering) Capacity	design engineers
DECAR	Design (Engineering) Capacity Acquisition Rate	design engineers/ month
DECBA	Design (Engineering) Capacity Being Absorbed	design engineers
DECBE	Design (Engineering) Capacity Becoming Effective	design engineers month
DECDR	Design (Engineering) Capacity Departure Rate	design engineers/ month
DECI	Design (Engineering) Capacity Initial	design engineers
DEPROD	Design (Engineering) PRODuctivity	engineering designs/ design engineer-month
DIEDC	Delay for Initial Engineering Design Completions	months
DPFEDN	Delay in Processing Final Engineering Designs Normal	months
ECCRDE	Estimated Cost to Complete R&D Effort	million dollars
EDCH	Engineering Design CHanges	engineering designs/month
EDCHR	Engineering Design CHanges Ratio	dimensionless
EDCHRO	Engineering Design CHanges Ratio Observed	dimensionless
EDEC	Effective Design (Engineering) Capacity	design engineers
ETRDE	Estimate of Total R&D Effort	engineering designs/month
FA	Factor Allowance ratio	engineering designs/ design engineer-month
FDDEC	Fractional Decrease of Design (Engineering) Capacity	1/month

DESIGN (ENGINEERING) SECTOR
VARIABLE LIST CONT'D

Variable Name	Variable Description	Units of Measure
FEDC	Final Engineering Design Completions rate	engineering designs/month
FEDCD	Final Engineering Design Completion Delay	months
FEDCDO	Final Engineering Design Completion Delay Observed	months
FEDCHN	Fraction of Engineering Design CHanges Normal	dimensionless
FIDEC	Fractional Increase of Design (Engineering) Capacity	1/month
FREDCH	Fraction of Engineering Design CHanges	dimensionless
IEDC	Initial Engineering Design Completions	engineering designs/month
IEDS	Initial Engineering Design Starts	engineering designs/month
MDEPRO	Multiplier on Design (Engineering) PROductivity	dimensionless
MPS	Material Production Starts	units/month
MRDBL	Months of R&D BackLog	months
MRDBLD	Months of R&D BackLog Desired	months
NDEPRO	Normal Design (Engineering) PROductivity	engineering designs/ design engineer-month
NEDCH	Normal Engineering Design CHanges	engineering designs/month
PE	Pressure for Expansion	pressure units
PFEDC	Processed Final Engineering Design Completions	engineering designs/month
PS	Production Starts	units/month
RDFR	R&D Funds availability Ratio	dimensionless
RDOR	R&D Order Rate	engineering designs/month

PRODUCTION SECTOR
VARIABLE LIST

Variable Name	Variable Description	Units of Measure
AP	Average Production	units/month
APOR	Average Production Order Rate	units/month
APSR	Average Production Shipping Rate	units/month
BDLR	Burdened Direct Labor Rate	dollars/month
BUO	Backlog of Unfilled Orders	units
BUOC	Backlog of Unfilled Orders Clipped	units
BWR	Burdened Wage Rate	dollars/hour-worker
CONOR	CONtingent Order Rate	units/month
DADL	Delay for Acquisition of Direct Labor	months
DAPC	Delay in Acquiring Plant Capacity	months
DLAR	Direct Labor Acquisition Rate	workers/month
DLBA	Direct Labor Being Absorbed	workers
DLBE	Direct Labor Becoming Effective	workers/month
DLC	Direct Labor Capacity	workers
DLDR	Direct Labor Departure Rate	workers/month
DLO	Direct Labor Overtime	hours/worker-week
DLU	Direct Labor Utilization	hours/worker-week
DLUD	Direct Labor Utilization Difference	hours/worker-week
DMIMPC	Desired Multiplier for Inventory of Material/Parts/Components	months
DP	Delay for Production	months
EDLC	Effective Direct Labor Capacity	workers
EDLCI	Effective Direct Labor Capacity Intermediate	workers
EPC	Effective Production Capacity	units/month
EPLC	Effective PLant Capacity	units/month
ETPE	Estimate of Total Production Effort	months
F1	Factor 1 for production starts	dimensionless
F2	Factor 2 for production starts	dimensionless
F3	Factor 3 for production starts	dimensionless
FAPOR	Fraction of Average Production Order Rate required	dimensionless
FDDL	Fractional Decrease in Direct Labor from pressure-for-expansion	dimensionless
FDDLU	Fractional Decrease in Direct Labor due to Utilization	dimensionless
FDPC	Fractional Decrease in Plant Capacity	dimensionless
FIDL	Fractional Increase in Direct Labor from pressure-for-expansion	dimensionless

PRODUCTION SECTOR
VARIABLE LIST CONT'D

Variable Name	Variable Description	Units of Measure
FIDLU	Fractional Increase in Direct Labor due to Utilization	dimensionless
FII	Fractional Increase of Inventory	dimensionless
FIPC	Fractional Increase in Plant Capacity	dimensionless
FIPR	Fractional Increase in PRoductivity	productivity units
IAR	Inventory Acquisition Rate	units
IMPC	Inventory of Material/Parts/ Components	units
IMPCA	Inventory of Material/Parts/ Components Available	months
IMPCAM	Inventory of Material/Parts/ Components Available Minimum	months
IMPCM	Inventory of Material/Parts/ Components Multiplier	months
IMPCR	Inventory of Material/Parts/ Components Ratio	dimensionless
INDEDL	INput pressure DElay Direct Labor	months
INDELP	INput pressure DELay for Production	months
MBLD	Months of BackLog Desired	months
MDD	Material Delivery Delay	months
MDDEM	Material Delivery Delay Effect on the Market	dimensionless
MDDN	Material Delivery Delay Normal	months
MDDO	Material Delivery Delay Observed	months
MDDRO	Material Delivery Delay Ratio Observed	dimensionless
MDL	Multiplier for Direct Labor	week-worker/ hour
MDLH	Maximum Direct Labor Hours	hours/week-worker
MPRO	Multiplier on PROductivity	dimensionless
MSR	Material Shipping Rate	units/month
MYOR	Multi-Year Order Rate	units/month
NIMPC	Normal Inventory of Material/ Parts/Components	units
NPROD	Normal PRODuctivity	dimensionless
PCAR	Plant Capacity Acquisition Rate	units/month-month
PCBA	Plant Capacity Being Absorbed	units/month
PCBE	Plant Capacity Becoming Effective	units/month-month
PCDR	Plant Capacity Departure Rate	units/month-month

PRODUCTION SECTOR
VARIABLE LIST CONT'D

Variable Name	Variable Description	Units of Measure
PD	Production starts Desired	units/month
PDD	Production Delivery Delay	months
PEDL	Pressure-for-Expansion acting upon Direct Labor	pressure units
PEPC	Pressure-for-Expansion affecting Plant Capacity	pressure units
PEPR	Pressure-for-Expansion acting upon PRoduction	pressure units
PF	Production Finishes	units/month
PFRC	Production Funds availability Ratio Clipped	dimensionless
PLC	PLant Capacity	units/month
PLCT	PLant Capacity Total	units/month
PMOR	Potential Material Order Rate	units/month
PP	Production starts Possible	units/month
PROD	PRODuctivity arising from pressure-for-expansion	dimensionless
PRODOR	PRODuction Order Rate	units/month
PS	Production Starts	units/month
PSR	Production Shipping Rate	units/month
RFEDAC	Ratio of Final Engineering Design completions Available Clipped	dimensionless
SDLTIM	Smoothing of Direct Labor over TIMe	months
SDLU	Smoothed Direct Labor Utilization	hours/worker-week
TAPOR	Time to Average Production Order Rate	months
TAPSR	Time to Average Production Shipping Rate	months
TFDDL	Table for FDDL	dimensionless
TFDDLU	Table for FDDLU	dimensionless
TFDPC	Table for FDPC	dimensionless
TFIDL	Table for FIDL	dimensionless
TFIDLU	Table for FIDLU	dimensionless
TFII	Table for FII	dimensionless
TFIPC	Table for FIPC	dimensionless
TMDDEM	Table for MDDEM	dimensionless
TMDDO	Time for Material Delivery Delay Observation	months
TMDL	Table for MDL	dimensionless
TMPRO	Table for MPRO	dimensionless
UNITSF	UNITS Finished	units

MATERIAL SECTOR
VARIABLE LIST

Variable Name	Variable Description	Units of Measure
AMP	Average Material Production rate	units/month
AMSR	Average Material Shipping Rate	units/month
BUPO	Backlog of Unfilled Purchase Orders	units
BUPOC	Backlog of Unfilled Purchase Orders Clipped	units
DAMPC	Delay for Absorbing Material Production Capacity	months
DMP	Delay for Material Production	months
DPFMN	Delay for Processing Finished Material Normal	months
EMPC	Effective Material Production Capacity	units
FDMPC	Fractional Decrease of Material Production Capacity	1/months
FIMPC	Fractional Increase of Material Production Capacity	1/months
IMPC	Inventory of Material/Parts/ Components	units
INDELM	INput pressure DELay for Material	months
MDD	Material Delivery Delay	months
MDDO	Material Delivery Delay Observed	months
MMBL	Months of Material BackLog	months
MMBLD	Months of Material BackLog Desired	months
MOR	Material Order Rate	units/month
MPC	Material Production Capacity	units
MPCAR	Material Production Capacity Acquisition Rate	units/month
MPCBA	Material Production Capacity Being Absorbed	units
MPCBE	Material Production Capacity Becoming Effective	units/month
MPCDR	Material Production Capacity Departure Rate	units/month
MPCI	Material Production Capacity Initial	units
MPF	Material Production Finishes	units/month
MPS	Material Production Starts	units/month
MSR	Material Shipping Rate	units/month
PE	Pressure for Expansion	pressure units
PEMPC	Pressure for Expansion delayed for Material Production Capacity	pressure units
PRED	PRofessional Effort Desired	men

MATERIAL SECTOR
VARIABLE LIST CONT'D

Variable Name	Variable Description	Units of Measure
RFEDAC	Ratio of Final Engineering Design completions Available Clipped	dimensionless
TAMSR	Time to Average Material Shipping Rate	months
TFDMPC	Table for Fractional Decrease of Material Production Capacity	1/months
TFIMPC	Table for Fractional Increase of Material Production Capacity	1/months
WDF	Work Distribution Factor	months

PROFESSIONAL SECTOR
VARIABLE LIST

Variable Name	Variable Description	Units of Measure
DAPE	Delay for Absorbing Professional Effort	months
DEC	Design (Engineering) Capacity	design engineers
DRDEC	Desired Ratio of professional effort to Design (Engineering) Capacity	men/design-engineer
DRMPC	Desired Ratio of professional effort to Material Production Capacity	men/unit
DRPRC	Desired Ratio of PRofessional effort to production Capacity	men/unit
EPC	Effective Production Capacity	units/month
EPRE	Effective PRofessional Effort	men
FDPR	Fractional Decrease of PRofessional effort	1/months
FIAP	Fractional Increase of professional effort from Availability of Professional effort	1/months
FIPE	Fractional Increase of Professional Effort from pressure for expansion	1/months
FIPR	Fractional Increase of PRofessional effort	1/months
FPRA	Fraction PRofessional effort being Absorbed	dimensionless
FPRD	Fractional PRofessional Deviation	dimensionless
MPC	Material Production Capacity	units
PE	Pressure for Expansion	pressure units
PEBA	Professional Effort Being Absorbed	men
PEBE	Professional Effort Becoming Effective	men/month
PEEI	Professional Effort Effective Initial	men
PRAR	Professional Acquisition Rate	men/month
PRC	PRofessional Capability	men
PRDA	PRofessional Departures from Absorption	men/month
PRDE	PRofessional Departures from effective Effort	men/month
PRE	PRofessional Effort	men
PREA	PRofessional Effort Available	men
PRED	PRofessional Effort Desired	men
PREIM	PRofessional Effort Influencing the Market	men

PROFESSIONAL SECTOR
VARIABLE LIST CONT'D

Variable Name	Variable Description	Units of Measure
PRER	PRofessional Effort Recruiting	men
RCE	ReCruiting Effectiveness	man-months/ man
TAPR	Time to Adjust PRofessional effort	months
TDAPE	Table for Delay for Absorbing Professional Effort	months
TFDPR	Table for Fractional Decrease of PRofessional effort	1/months
TFIPE	Table for Fractional Increase of Professional Effort from pressure for expansion	1/months
TPREF	Table for PRofessional EFficiency	dimensionless

PRESSURE-FOR-EXPANSION SECTOR
VARIABLE LIST

Variable Name	Variable Description	Units of Measure
AFEDCR	Average Final Engineering Design Completion Rate	engineering designs/month
AMP	Average Material Production rate	units/month
AP	Average Production rate	units/month
BLR	BackLog Ratio	dimensionless
BLRO	BackLog Ratio Observed	dimensionless
BUO	Backlog of Unfilled Orders	units
BUOC	Backlog of Unfilled Orders Clipped	units
BUPO	Backlog of Unfilled Purchase Orders	units
BUPOC	Backlog of Unfilled Purchase Orders Clipped	units
BURDO	Backlog of Unfilled R&D Orders	engineering designs
BURDOC	Backlog of Unfilled R&D Orders Clipped	engineering designs
EDCHR	Engineering Design CHanges Ratio	dimensionless
EDCHRO	Engineering Design CHanges Ratio Observed	dimensionless
FDDEC	Fractional Decrease of Design (Engineering) Capacity	1/months
FDEMC	Fractional Decrease of Material Production Capacity	1/months
FDPC	Fractional Decrease of Production Capacity	1/months
FDPF	Fractional Decrease of Production Funds	1/months
FDPR	Fractional Decrease of PRofessional effort	1/months
FDRDF	Fractional Decrease of R&D Funds	1/months
FIDEC	Fractional Increase of Design (Engineering) Capacity	1/months
FIMPC	Fractional Increase of Material Production Capacity	1/months
FIPC	Fractional Increase of Production Capacity	1/months
FIPE	Fractional Increase of Professional Effort from pressure for expansion	1/months
FIPF	Fractional Increase of Production Funds	1/months
FIRDF	Fractional Increase of R&D Funds	1/months
IMPCR	Inventory of Material/Parts/ Components Ratio	dimensionless
IMPCRO	Inventory of Material/Parts/ Components Ratio Observed	dimensionless
MBL	Months of BackLog	months

PRESSURE-FOR-EXPANSION SECTOR
VARIABLE LIST CONT'D

Variable Name	Variable Description	Units of Measure
MBLD	Months of BackLog Desired	months
MBLR	Material BackLog Ratio	dimensionless
MBLRO	Material BackLog Ratio Observed	dimensionless
MDEPRO	Multiplier on Design (Engineering) PROductivity	dimensionless
MMBL	Months of Material BackLog	months
MMBLD	Months of Material BackLog Desired	months
MPF	Material Production Finishes	units/month
MPRO	Multiplier on PROductivity	dimensionless
MRDBL	Months of R&D BackLog	months
MRDBLD	Months of R&D BackLog Desired	months
PE	Pressure for Expansion	pressure units
PEB	Pressure for Expansion from Backlog	pressure units
PECW	Pressure for Expansion Currently Warranted	pressure units
PEEDCH	Pressure for Expansion from Engineering Design CHanges	pressure units
PEIMPC	Pressure for Expansion from Inventory of Material/Parts/Components	pressure units
PEMB	Pressure for Expansion from Material Backlog	pressure units
PEPFA	Pressure for Expansion from Production Funds Availability	pressure units
PEPR	Pressure for Expansion affecting PRoduction	pressure units
PERDB	Pressure for Expansion from R&D Backlog	pressure units
PERDFA	Pressure for Expansion from R&D Funds Availability	pressure units
PF	Production Finishes	units/month
PFR	Production Funds availability Ratio	dimensionless
PFRO	Production Funds availability Ratio Observed	dimensionless
RDBLR	R&D BackLog Ratio	dimensionless
RDBLRO	R&D BackLog Ratio Observed	dimensionless
RDFR	R&D Funds availability Ratio	dimensionless
RDFRO	R&D Funds availability Ratio Observed	dimensionless
TAP	Time to Average Production rate	months
TAMP	Time to Average Material Production rate	months
TBLRO	Time for BackLog Ratio Observation	months
TECHRO	Time for Engineering design CHanges Ratio Observation	months

PRESSURE-FOR-EXPANSION SECTOR
VARIABLE LIST CONT'D

Variable Name	Variable Description	Units of Measure
TIPCRO	Time for Inventory of material/ Parts/Components Ratio Observation	months
TMBLRO	Time for Material BackLog Ratio Observation	months
TPEB	Table for Pressure for Expansion from Backlog	pressure units
TPEECH	Table for Pressure for Expansion from Engineering design CHanges	pressure units
TPEIPC	Table for Pressure for Expansion from Inventory of material/Parts/ Components	pressure units
TPEMB	Table for Pressure for Expansion from Material Backlog	pressure units
TPEPFA	Table for Pressure for Expansion from Production Funds Availability	pressure units
TPERDB	Table for Pressure for Expansion from R&D Backlog	pressure units
TPERFA	Table for Pressure for Expansion from R&D Funds Availability	pressure units
TPES	Time for Pressure to Effectively Stimulate action	months
TPFRO	Time for Production Funds Ratio Observation	months
TRBLRO	Time for R&D BackLog Ratio Observation	months
TRDFRO	Time for R&D Funds Ratio Observation	months

EXOGENOUS INPUT FACTORS
VARIABLE LIST

Variable Name	Variable Description	Units of Measure
CAEXOG	CApital cost EXOGenous input	percent
PEXOG	Production EXOGenous input	dimensionless
PINT	Production sampling INTernal	months
PISAM	Production Initial value of SAMple	dimensionless
PMEAN	Production noise MEAN	dimensionless
PNOIS	Production NOISe	dimensionless
PNORNS	Production NORmal NoiSe	dimensionless
PPER	Production sine PERiod	months
PSINE	Production SINE wave function	dimensionless
PSNAMP	Production SiNe wave AMPlitude	dimensionless
PSTDV	Production noise STandard DeViation	dimensionless
RDEXOG	R&D EXOGenous input	dimensionless
RDINT	R&D sampling INTerval	months
RDISAM	R&D Initial value of SAMple	dimensionless
RDMEAN	R&D noise MEAN	dimensionless
RDNOIS	R&D NOISe	dimensionless
RDPER	R&D sine PERiod	months
RDSINE	R&D SINE wave function	dimensionless
RDSTDV	R&D noise STandard DeViation	dimensionless
RNORNS	R&D NORmal NoiSe	dimensionless
RSNAMP	R&D SiNe wave AMPlitude	dimensionless
TIME	TIME	months

APPENDIX G

CONTRACTOR INTERVIEW GUIDE

SECTION I

Interviewee's Name

Interviewee's Job Title

Number of Years Employed By:

Overall Corporation

Government Aerospace Division

Other Government Aerospace Contractors

All Other Government Contractors

Commercial Contractors

Government Organizations

Most Familiar with Finance, Market, or Production

Date of Interview

DIRECTIONS

Please respond as accurately as possible to the following items using the key below:

Answer	Description
1	If you Strongly Disagree
2	If you Disagree
3	If you are Uncertain
4	If you Agree
5	If you Strongly Agree

SECTION II

Production

1. The MYP model assumes that a direct labor work force of 2000 people is needed to produce 20 aircraft per month in a single shift operation with an average 43 hour work week.

Is this realistic?

1 2 3 4 5

Comments

2. The MYP model uses a maximum work week of 50 hours per worker per week. Is this accurate?

Yes

No, a better figure is

Comments

3. The MYP model uses an average direct labor wage rate of $15 per hour. Is this accurate?

Yes

No, a better figure is

Comments

4. The MYP model assumes that it takes six months to hire and train new production workers. Is this realistic?

Yes

No, a better figure is

Comments

Market

5. In a MYP environment, the market for your product can adequately be described by identifying three market groups: a government provided MYP contract, a possible follow-on MYP contract, and an outside market that responds to your firm's capability and performance.

1 2 3 4 5

Comments

6. The MYP model calculates future revenue from the ongoing MYP contract by multiplying unit price, order rate, contract life remaining, and a probability estimate. This adequately describes my firm's MYP revenue estimate.

1 2 3 4 5

Comments

7. The MYP model uses a MYP probability estimate of .95. Is this number accurate? If the answer is no, please give a more reasonable estimate.

Yes

No, a better estimate is

Comments

8. The MYP model calculates projected revenue from the potential follow-on MYP contract by multiplying unit price, estimated production units, and a probability estimate. This adequately describes my firm's follow-on MYP revenue estimates.

1 2 3 4 5

Comments

9. The MYP model uses a follow-on MYP probability estimate of .5. Is this figure accurate? If the answer is no, please give a more reasonable figure.

Yes

No, a better figure is

Comments

10. The MYP model calculates potential revenue from the outside (non-USAF) market by multiplying unit price, average order rate of the last year, estimated program life remaining, and a probability estimate. This adequately describes my firm's outside market revenue estimate.

1 2 3 4 5

Comments

11. The MYP model uses Figure 1 to derive the outside market probability estimate. In the graph, the probability estimate decreases with longer program life remaining. Is this an accurate representation? If the answer is no, please explain your objections.

Yes

No

Comments

Finance

12. Figure 2 shows the modernization investment decision process used in the MYP model. Does this adequately describe the modernization investment process of your firm?

1 2 3 4 5

Comments

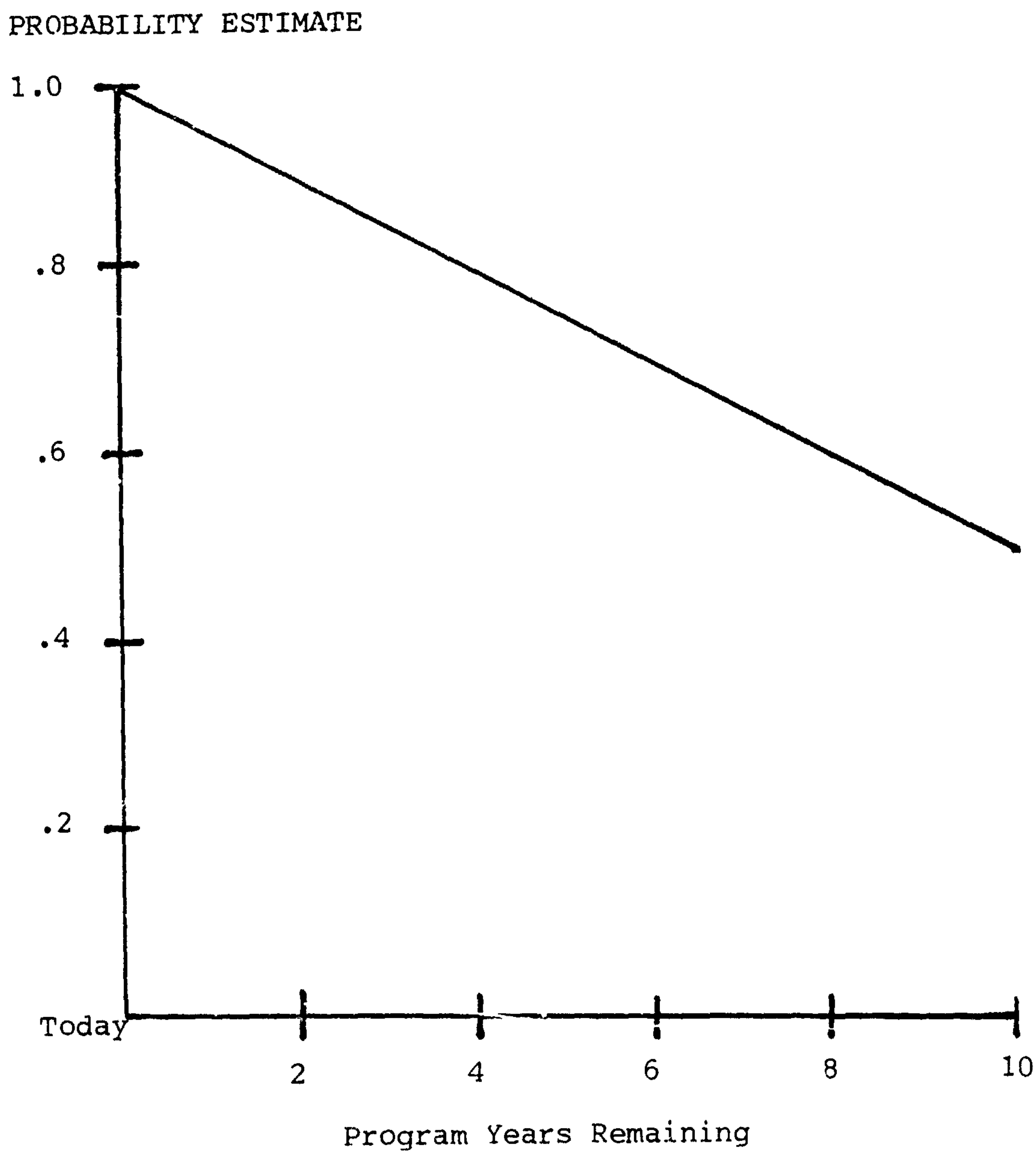
PROBABILITY ESTIMATE
1.0
.8
.6
.4
.2
Today
2
4
6
8
10
Program Years Remaining

Figure 1

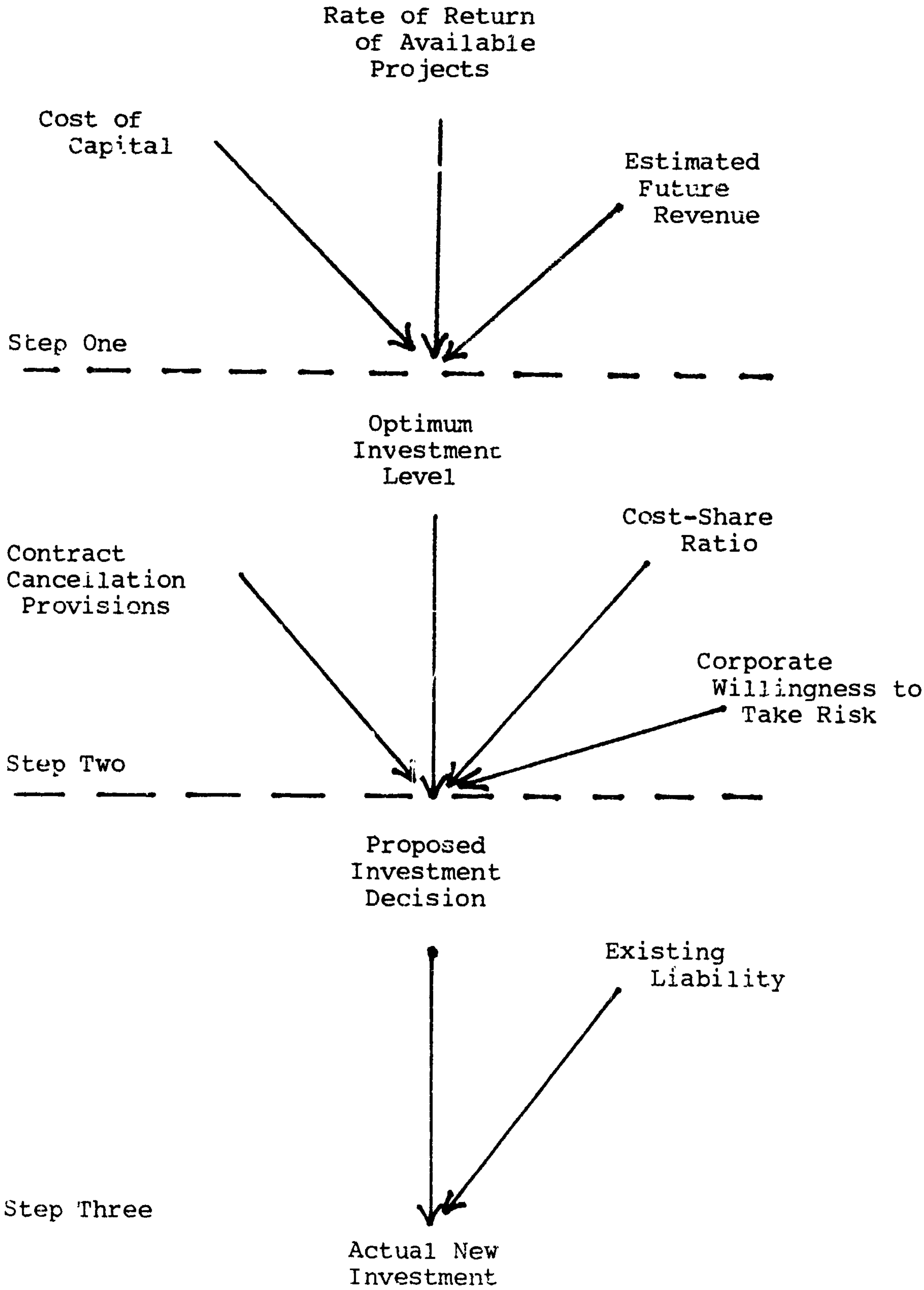
Rate of Return
of Available
Projects
Cost of
Capital
Estimated
Future
Revenue
Step One
Optimum
Investment
Level
Cost-Share
Ratio
Contract
Cancellation
Provisions
Corporate
Willingness to
Take Risk
Step Two
Proposed
Investment
Decision
Existing
Liability
Step Three
Actual New
Investment

Figure 2

13. The MYP model uses the graph shown on Figure 3 to accomplish Step One. The vertical axis represents the annual rate of return (cash flow divided by investment capital) of available modernization projects. The horizontal axis represents the investment costs of available modernization projects. Does the shape of this curve adequately describe your modernization investment opportunities? If not, please draw a more descriptive curve on Figure 3.

Yes

No

Comments

14. If your firm estimated future revenue for a product to be $5 billion and capital was cost-free, what dollar value of modernization investment would result in maximum savings over the life of the project?

15. What is the annual rate of return of the most desirable modernization investment?

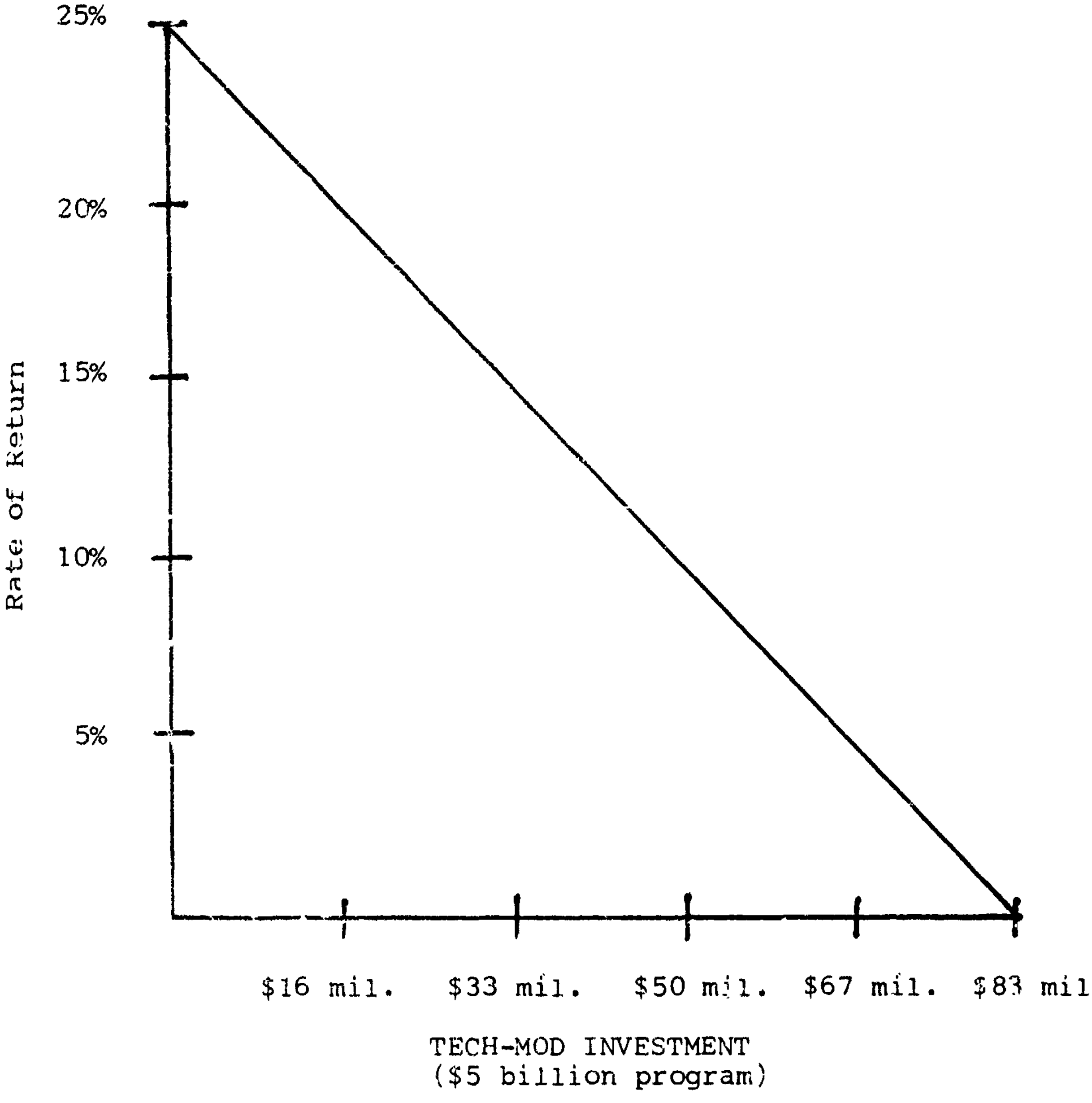
25%
20%
15%
10%
5%
Rate of Return
$16 mil.
$33 mil.
$50 mil.
$67 mil.
$83 mil
TECH-MOD INVESTMENT
($5 billion program)

Figure 3

16. The effect of contract cost-sharing ratio is equated to a coefficient by the graph shown of Figure 4. Is this concept accurate?

1 2 3 4 5

Comments

17. Corporate willingness to take risk in investment is represented as a coefficient used to multiply the difference between the optimum investment level and the contract cancellation ceiling. The present MYP model uses a value of .1. Is this figure accurate?

Yes

No

Comments

18. The MYP model's first version assumes that all the benefits of modernization are realized in reduced direct labor requirements. In percentages, what is a more accurate breakdown of modernization benefits?

Direct labor

Variable overhead

Fixed overhead

Comments

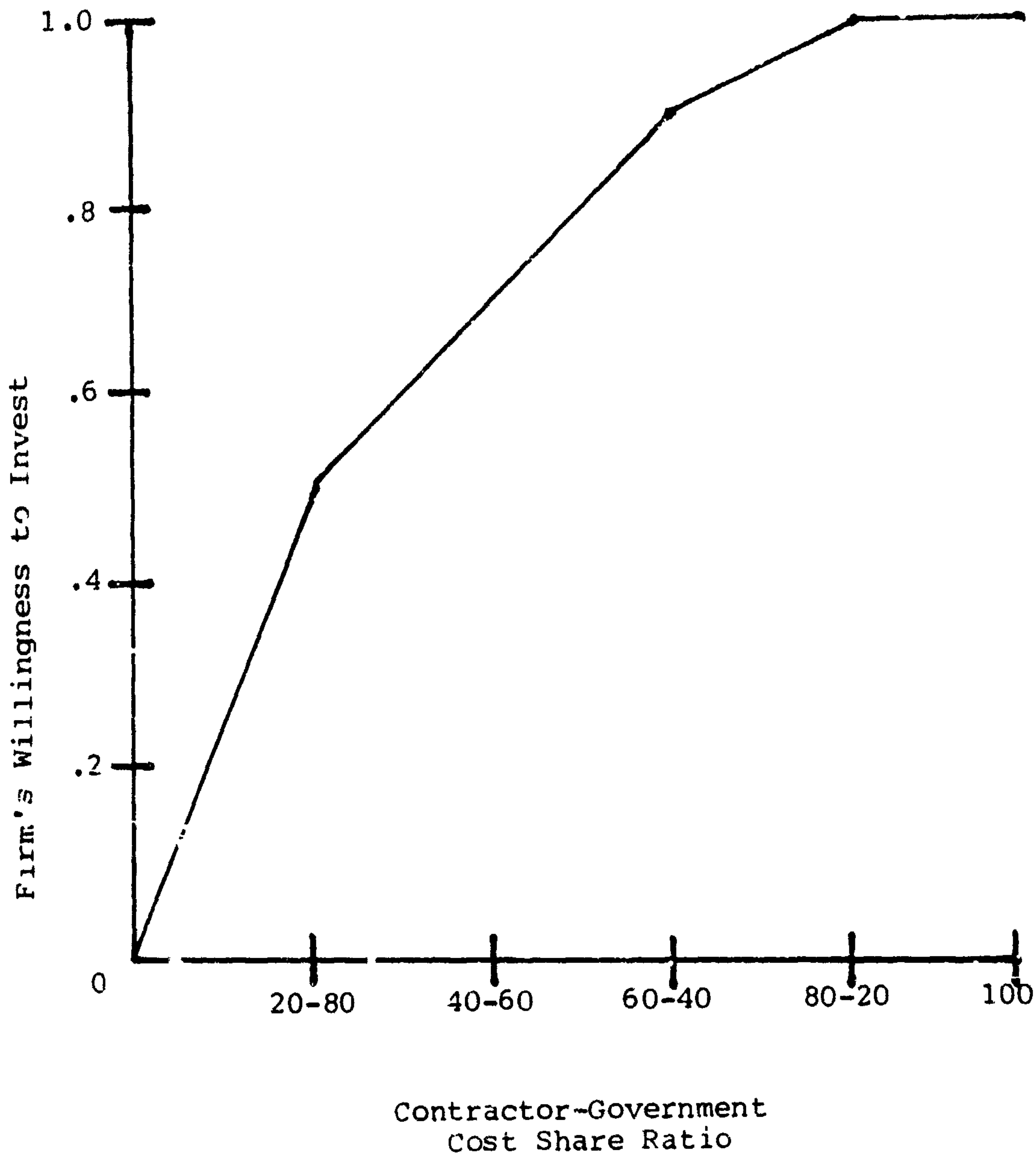
1.0
.8
.6
.4
.2
0
Firm's Willingness to Invest
20-80
40-60
60-40
80-20
100
Contractor-Government
Cost Share Ratio

Figure 4

19. The MYP model uses an average modernization implementation time of 18 months. Is this figure accurate?

Yes

No, a better figure is

Comments

20. The MYP model assumes that your firm will invest in tech modernization at least to the level of the cancellation ceiling if all the projects show a positive net return. Is this accurate?

1 2 3 4 5

Comments

SECTION III

The computer generated graphs reflect the results of an MYP model simulation run over a ten year time span. MYP contracts of 10 aircraft per month are awarded at the 24 and 84 month points. Remember that the MYP model assumes all modernization projects serve to reduce direct labor requirements.

21. Is the liability for modernization curve accurate?

1 2 3 4 5

Comments

22. How well does the labor force curve reflect your firm's likely labor force behavior?

1 2 3 4 5

Comments

23. Does the total production order curve accurately represent expected market behavior?

1 2 3 4 5

Comments

SECTION IV

24. What investment models does your firm use in advance material buy decisions?

25. Given your firm's model, what is the expected cost savings of advance buy investments?

26. What is the average production period supported by a "typical" material order using MYP?

27. What type production schedule do you expect your suppliers to use: accelerated or a schedule designed to just support your requirements so as to reduce inventory costs?

28. The MYP model uses a material order to final assembly lead time of 20 months. Do you realistically think this will be reduced by MYP. If so, how much?

29. Can advance buys increase your firm's ability to surge production if you maintain your present shipset inventory policy?

30. What if you decide to reduce your shipsets on hand?

APPENDIX H

SURVEY DEMOGRAPHICS

	Number of Responses
1. AREA OF RESPONSIBILITY	
Manufacturing/Operations Management	4
Financial Management	8
Contracts	23
Engineering/Research and Development	1
Personnel/Management	8
Program/Management	2
Marketing	11
Other (write-ins)	
Director of Multi-year Proposals	1
Business Planning	1
Law	1
Logistics	1
Purchasing	1
Material Cost Control	1
Manufacturing Material Management	1
Procurement and Subcontracting	2
Spare Provisioning and Management	1
Material Cost Analysis	1
Total*	68

* total includes multiple responses

	Number of Responses
2. POSITION WITHIN FIRM	
Executive Management	22
Middle Management	35
Foreman/Line Supervisor	2
Contract Administration (write-ins)	2
Total	61

	Number of Responses
3. YEARS IN PRESENT POSITION	
Less than 1 year	4
1 to 3 years	17
3 to 5 years	10
5 to 7 years	8
7 to 10 years	4
10 to 15 years	11
15 to 25 years	6
over 25 years	1
Total	61

	Number of Responses
4. YEARS WITH FIRM	
Less than 1 year	2
1 to 3 years	4
3 to 5 years	0
5 to 7 years	2
7 to 10 years	0
10 to 15 years	9
15 to 25 years	25
over 25 years	15
Total	61
5. YEARS IN DEFENSE INDUSTRY	
Less than 1 year	0
1 to 3 years	1
3 to 5 years	0
5 to 7 years	2
7 to 10 years	1
10 to 15 years	8
15 to 25 years	24
over 25 years	25
Total	61
6. ACTIVITIES WHICH CONSUME MOST OF TIME	
Planning	16
Supervising	19
Dealing with Government Representatives	2
Production/Manufacturing	2
Budgeting	1
Other (write-ins)	
Coordinating with vendors and internal managers	1
Contract proposals, negotiations, and definitions	1
Contract administration	2
Status Analysis	1
Contract Analysis/review	2
Performance measurement	1
Accounting	1
Administration	1
Risk and business analysis	1
Total*	51

* Total does not include missing or multiple responses.

		Number of Responses
7. WORKED MYP CONTRACT WITHIN PAST 5 YEARS		
Yes		33
No		28
	Total	61

APPENDIX I

RESULTS OF THE ANALYSIS OF THE ENTIRE SAMPLE

Question	t Value	2-tail Prob	Mean	$\bar{d}$ Value	Number of cases	Null Hypothesis
Modernization of Plant Facilities						
14			2.246		61	-
33	6.88	.000	3.855/2.108	1.836	55	R
Stabilize Work Force						
13			5.738		61	-
Lower Production Costs						
8			5.607		61	-
10			2.508		61	-
11			4.918		61	-
18	-7.763		-6.517		60	R
19	-5.550		-4.300		60	R
20	-6.302		-7.583		60	R
21	-11.648		-9.333		60	R
Advanced Material Buys						
30	-11.56	.000	19.125/51.339	-32.214	56	R
31	-8.78	.000	18.482/46.964	-28.482	56	R

Question	t Value	2-tail Prob	Mean	$\bar{d}$ Value	Number of cases	Null Hypothesis
Improved Surge Capability						
17			4.721		61	-
24	7.38	.000	17.353/11.750	5.373	51	R
27	5.69	.000	5.537/4.352	1.185	54	R
28	4.18	.000	3.804/3.339	.464	56	R
29	5.22	.000	3.386/2.789	.597	57	R
32	-10.12	.000	4.189/8.330	-4.142	53	R
Increased Competition						
15			3.951		61	-
16			4.900		60	-
22	-.46	.649	57.708/58 150	-1.042	48	A
23	-5.03	.000	53.800/63.800	-10.000	50	R
25	1.33	.188	4.000/3.736	.264	53	A
26	1.11	.273	2.286/2.107	.179	56	A
Increased Standardization						
9			2.448		58	-

Question	t Value	2-tail Prob	Mean	$\bar{d}$ Value	Number of cases	Null Hypothesis
Improved Productivity						
12			5.525		61	-
Special Case: No Progress Payments for MYP Advanced Material Buys						
34	-10.96	.000	18.396/51.604	-33.208	53	
35	-8.15	.000	18.679/47.642	-28.962	53	
Improved Surge Capability						
36	-3.12	.003	6.431/8.382	-1.951	51	

APPENDIX J

RESULTS OF THE ANALYSIS BY MYP EXPERIENCE

Question	t-Value	Total Prob.	Number of Cases
8	.81	.419	33/28
9	-2.12	.039	31/27
10	-1.06	.293	33/28
11	1.26	.214	33/28
12	1.82	.073	33/28
13	.97	.334	33/28
14	.18	.856	33/28
15	2.60	.012	33/28
16	1.04	.304	32/28
17	.83	.409	33/28
18	-.97	.335	32/28
19	.33	.746	32/28
20	-2.06	.044	32/28
21	-1.53	.131	32/28
22A	1.13	.266	25/23
22B	1.15	.255	25/23
23A	.18	.858	26/24
23B	-.15	.878	26/24
24A	-1.13	.266	27/24
24B	-.14	.887	27/25
25A	.33	.740	29/24
25B	.66	.512	29/24
26A	1.93	.059	31/25
26B	1.47	.146	31/25
27A	1.57	.122	28/26
27B	2.48	.016	28/26
28A	-.56	.577	30/26
28B	-1.43	.158	30/26
29A	-1.61	.113	30/27
29B	-1.64	.106	30/27
30A	-.60	.553	31/25
30B	-.34	.738	31/25
31A	.90	.370	31/25
31B	2.07	.043	31/25
32A	.50	.617	28/25
32B	.23	.816	28/25
33A	-.81	.419	29/26
33B	-.86	.396	29/26
34	.85	.398	29/24
35	.96	.343	29/24
36	.02	.983	27/24

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