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A MULTI-PROJECT DECISION PROCESS SIMULATION OF DEFENSE CONTRACTOR BEHAVIOR (II)*

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ABSTRACT: This paper describes the design and initial validation of a computerized decision process model simulating the operating environment, behavior and performance of defense contractors. The conceptual foundations of this research are presented in Cohen, Lewin and Morey (1979). The model employs feedback adaption and search mechanisms to simulate the internal decision making structure of defense contractors at the project, corporate and DOD levels. The objective of this research is to develop a capability to model the impact of various contract incentive schemes on the performance of DOD contractors.

1. BACKGROUND

Preliminary findings of existing research seem to suggest that the goal hierarchy of defense contractors consists of survival, profit, growth, market share and prestige (Oppendahl 1977). Survival is perceived to depend on attaining the project performance objectives which affect future company image and the ability to obtain future business. Similarly contractors are strongly motivated to retain technical and supervisory staffs even in the face of declining business activity. Maintaining of such staffs is perceived to be critical to maintaining competitive positions for securing future business. Contractors pursue growth as a means to maintain internal capabilities and as a means to spread fixed costs over a larger base or as a strategy for achieving barriers to entry by a competitor. It also appears that in the short run contractor management will sacrifice short run profits on defense business in favor of securing new business, benefit from the spinoffs to the commercial business, improve opportunity for follow-on business, acquire personnel in scarce disciplines and gain competitive advantage by engaging in developmental efforts instrumental to gaining future business (IR&D).

A major premise of incentive contracts has been that defense contractors are primarily motivated to maximize profits. However, if as seems likely, contractors in managing their enterprises are motivated to satisfy a complex goal structure, then efforts at developing optimal incentive mechanisms will need to be cognizant of the defense contractor's diverse goal structure.

The contractor's behavioral responses and organizational actions utilized in their attempt to achieve their own goals comprise a basic element of the modelling approach. It is important to recognize that the contractor's internal actions have a direct impact on the DOD set of project goals. Furthermore, it is clear that in general the project goals and the contractor goals are not congruent, and that

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the ability of the DOD to accomplish improvements in DOD project goals depends on modifying the contractor's behavior in pursuing their own goals.

A major objective of this research effort is to develop a capability to model the potential impact of various incentive schemes on the performance of DOD contractors. It was therefore necessary to incorporate in the simulation model such basic elements as; i) DOD project goals, ii) DOD incentive mechanisms, iii) contractor goals and iv) contractor strategic and organizational response mechanisms.

In order to proceed from the current state of partial and intuitive research on contractor motivation it will be necessary to develop insights into the structure of internal resource allocation decision making of defense contractor firms. This approach has been advocated by Simon (1955, 1976, 1978 and 1978 b) and further developed by Cyert and March (1963). The application to the behavior of defense contractors is described in an earlier paper by Cohen, Lewin and Morey (1979). In summary, the basis of the simulation presented in this paper is to describe the procedural aspects of decision making within the firm so as to develop information processing descriptions of their economic behavior.

2. MODEL HIERARCHY

The decision process model (DPM) consists of eight loosely coupled sub-models which operate on three organizational levels; the project manager level, the corporate level and the DOD level. Each organizational level contains a separate set of goals, expectations and decision processes which are simulated by the appropriate sub-models. The synthesis of the resultant goals and expectations of the various organizational levels into an operational plan by the project manager is the foundation of the DPM (see Exhibit 1).

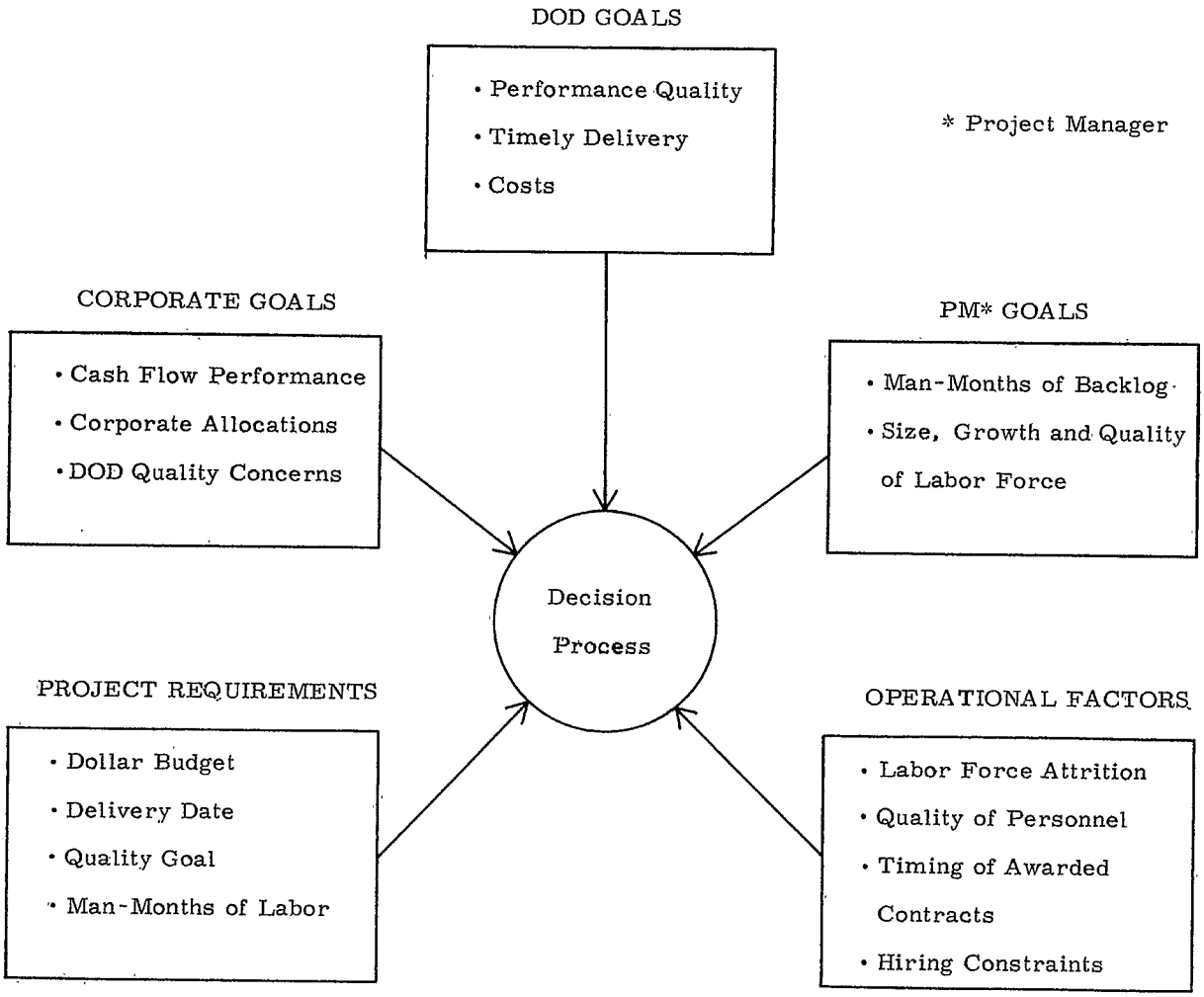

EXHIBIT 1
PROJECT MANAGER DECISION ENVIRONMENT

2.1 Organizational Structure and Interaction

Exhibit 2 shows the interdependency between the project manager, corporate and DOD organizational levels. The personal goals of the project manager are centered around the maintenance and growth of the Backlog Goal and the size, growth and quality of his staff (Volume Goal).

The DOD is assumed to be primarily concerned with the quality and timely delivery of work performed on individual projects. The DOD is able to monitor the project manager's monthly (but lagged) performance and discern when the quality is unsatisfactory. When necessary the DOD applies pressure directly on the project manager to affect his performance. If this action is ineffective, the DOD may apply pressure at the corporate level, presumably to be relayed to the project manager. Schedule pressure is applied by the DOD when a project has not been completed by the pre-arranged delivery date. In addition, the contractor is assumed to absorb any excess costs above the ceiling price of a contract award. In the current simulation DOD goals are assumed static and determined with the awarding of the contract.

In contrast to the DOD, the corporate level is not concerned with individual project performance (unless contacted directly by the DOD as mentioned above) but focuses on the overall system performance. Specifically, the corporate level concerns itself with the cash flow performance of the project manager's organization. When cash flow falls below planned levels, Corporate Pressure is applied on the project manager to increase DOD billings and/or decrease expenses. The corporate level goals, as well as the project manager's, are dynamic and adapt throughout the course of a simulation.

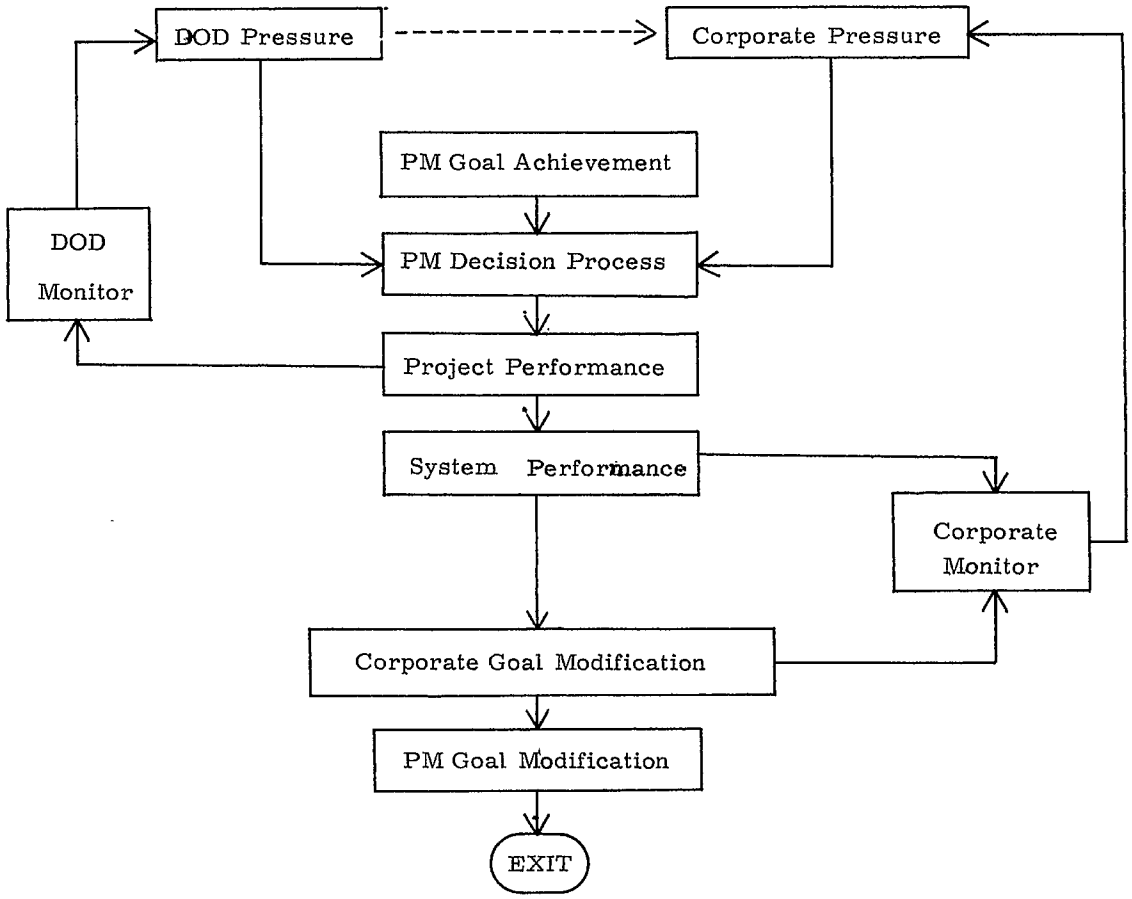

EXHIBIT 2
DOD, CORPORATE AND PROJECT MANAGER INTERACTIONS

2.2 Multiple Goals and Pressures

Exhibit 3 provides a listing and ranking of the pressures and goals facing the project manager as they are currently incorporated into the DPM logic flow. The paramount considerations of the project manager are Corporate Cash Flow Pressure and DOD pressures related to overdue or incomplete projects. The project manager is assumed to address these pressures before considering remaining problems. Other pressures and unsatisfied goals are not ignored but are given secondary consideration if they are in conflict with higher ranking priorities.

The next level of influence on project manager behavior concerns DOD quality pressure relayed from the corporate level-Corporate Quality Pressure. As mentioned above, the DOD approaches corporate with quality concerns only if previous Project Manager Quality Pressures has been ineffective. This may often be the case as the Backlog Goal (job security and growth) of the project manager takes precedence over Project Manager Quality Pressure. Finally, the Volume Goal has the lowest ranking in the project manager's decision making process.

Level 1: Corporate Cash flow Pressure
DOD Schedule Pressure
Deficient Quality Performance on Completed Project

Level 2: Corporate-level DOD Quality Pressure Relayed to PM

Level 3: Deficient Backlog Relative to PM Goal

Level 4: PM - level DOD Quality Pressure

Level 5: Deficient Volume Relative to PM Goal

Exhibit 3

Determinants of Project Manager Behavior

3. PROJECT DIFFERENTIATION

3.1 Major Projects and Spinoff Projects

The project manager's backlog consists of two types of projects; Major Projects and Spinoff Projects. The most obvious difference between Major and Spinoff projects concerns the magnitude of the project size. Major Projects are typically 10 to 20 times larger than Spinoff Projects - both in dollars budgeted and required man-months of work. In addition, the duration of a Major Project is usually 42 months while Spinoff projects will range from 3 to 18 months.

The project manager is able to affect the awarding of Spinoff projects through the volume and quality of submitted proposals while the decision to develop a Major Project proposal is made and financed at the corporate level. Allocations levied on the project manager's operation finance corporate level IR&D which in turn supports the solicitation of new Major Projects from the DOD. Once the contract is awarded it is assigned by corporate to a project manager.

At present the DOD monitors quality of work performed on the Major Project while Spinoff Projects are awarded on a best-effort basis only. Finally, the Major Project is not considered complete by the DOD until the minimum quality standard is achieved. Spinoff Projects are considered complete once the required man-months of work has been performed.

3.2 Project Attributes

All contracts of awarded projects specify a standard quality of man-months (SQMM's) of work to be performed, a dollar budget and a delivery date. In addition, Major Projects contain a quality goal

which is monitored and strictly enforced by the DOD. Note that low quality personnel, if used exclusively on a particular project, would eventually complete the SQMM requirement. However, consideration of the project's other attributes by the project manager - specifically budget and quality attributes - limit this type of behavior.

The relationship of the dollar size of a contract to the SQMM balance is a function of the existing quality composition of the workforce and the salary rates of high and low quality personnel. [Negotiated overhead rates and fee's are also included.] It is assumed that the salary differential between high and low quality workers is not justified by their marginal products. Specifically, the difference in productivity between high and low quality personnel is larger than the difference in wages. This suggests that if low quality workers were used exclusively on a given contract, the dollar budget would be exhausted sooner than the SQMM balance. The cost overrun which results from this type of behavior would generally discourage the project manager from using only low quality workers on a particular project.

In addition, Major Projects must attain a cumulative quality index which measures the quality of work performed. If the cumulative quality measure falls below the negotiated minimum specifications, then DOD Quality Pressure is applied at the project manager and/or corporate levels.

Finally, each Spinoff Project is assigned a delivery date when the project is initially awarded. The duration of a project is related to the size of the newly awarded contract which is determined in a quasi-random fashion dependent on past proposal development efforts.

4. LABOR FORCE DYNAMICS

The DPM assumes that there is a greater availability of low quality workers than high quality workers in the labor pool from which the project manager must hire new employees. Consequently, a limit exists on the number of high quality workers which may be hired in a given period. It is assumed that the project manager is always able to fill out labor requirements with low quality personnel. Because of the relative scarcity of high quality workers, often times the project manager will hire high quality workers even though a general hiring decision has not been made. Only low quality personnel will be fired by the project manager.

Differences are assumed to exist between the rates of attrition of high and low quality workers and that they are non-constant. Attrition rates will vary depending on employee perception of the current health of the project manager's organization. Specifically, high quality personnel are assumed to have higher attrition rates than their lower quality counterparts. Furthermore, in periods of prolonged reductions in force the attrition rate of high quality workers will increase. Labor force attrition is clearly beyond the direct control of the project manager but has important dynamic effects on the overall quality composition of his workforce (see Exhibit 1).

5. MODEL DECOMPOSITION

5.1 PM Manpower Assignment Sub-Model

The purpose of the PM Manpower Assignment Sub-Model is to assign each high and low quality worker to indirect proposal development activities or to a specific project. As discussed above, the project manager is assumed to make personnel allocation decisions based on the existence of various DOD and corporate pressures, the achievement of personal goals and the individual constraints posed by the backlog of incomplete projects.

5.2 Project Update Sub-Model

Based on the personnel allocation decision made by the project manager with respect to the quantity and quality of work performed on each project, several running measures must be updated for each project worked on. Specifically, the remaining dollars in the budget and the required SQMM balance must be decreased and the quality index of work performed adjusted accordingly. Finally, the time remaining before each project is due is calculated.

5.3 Personnel Sub-Model

The objective of the Personnel Sub-Model is to implement the decisions made by the project manager with respect to alterations in the size of the workforce. Labor force attrition is also reckoned with in this sub-model and is assumed to occur simultaneously with the project manager's hiring/firing decision - i.e., the project manager is unable to compensate for attrition in the current period.

The output of the Personnel Sub-Model is a description of the end-of-the-period labor force in terms of size and quality composition.

5.4 Backlog Determination Sub-Model

Based on the output of the previous sub-models, the Backlog Determination Sub-Model calculates the number of months of backlog (given current staffing levels) at the end of the period. This involves determining whether a project has been awarded and, if so, the dollar and SQMM size of the new project.

5.5 Cash Flow Determination Sub-Model

The Cash Flow Determination Sub-Model calculates the direct and indirect costs associated with the project manager's operation by project and the cumulative billings to the DOD allowed for the direct work performed on individual projects. Billings against a particular project are allowed only if the budget has not been depleted.

5.6 Corporate Goal Adjustment Sub-Model

The output of the Corporate Goal Adjustment Sub-Model is a determination of the level of appropriations in support of corporate administrative and IR&D expenses that is levied on the project manager's operation. Also a decision as to whether to apply cash flow pressure on the project manager is reached.

5.7 PM Goal Adjustment Sub-Model

The PM Goal Adjustment Sub-Model is responsible for modifying the project manager's personal Backlog and Volume goals based on the success of past and current performances and the existence of pressures from the corporate and DOD levels.

5.8 DOD Sub-Model

The DOD Sub-Model monitors progress made on each of the projects awarded to the defense contractor and determines whether schedule and/or quality pressure should be applied at the project manager or corporate levels.

6. SOLUTION SEQUENCE

All sub-models have several functional categories which collectively describe the work flow during the solution sequence. Each sub-model, except several routines in the Corporate Goal Adjustment Sub-Model (which are solved quarterly), are solved each time period of the simulation. A complete listing of the various sub-models and associated routines is provided in Appendix I.

As shown in Exhibit 4, the simulation begins with solution of the PM Manpower Assignment Sub-Model. This involves the project manager reviewing the operating environment (see Exhibit 1) taking note of various pressures and goal achievement. The labor force is then broken down between indirect and direct activities and assigned to specific tasks; either proposal writing or to an incomplete project. Decisions are also made concerning hiring or firing. After solution of the PM Manpower Assignment Sub-Model, each project in the project manager's backlog is updated through solution of the Project Update Sub-Model.

The Personnel Sub-Model is then solved which determines the size and quality composition of the labor force at the end of the period - taking into account the hiring and firing decisions of the project manager and labor force attrition. The Backlog Determination Sub-Model utilizes the output of the Personnel Sub-Model and calculates the actual months of backlog in the project manager's incomplete project inventory at the end of the period. This also requires determining if a new project has been awarded in the current period.

After solution of the Cash Flow Determination Sub-Model, the Corporate and Project Manager Goal Adjustment Sub-Models are solved. Finally, the DOD Sub-Model which monitors individual project performance, is solved.

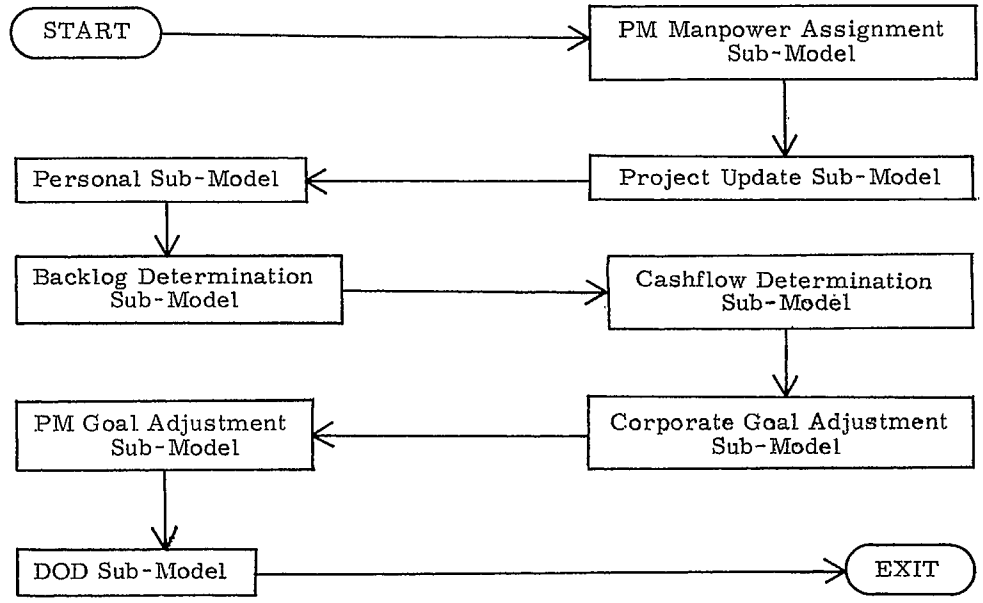

EXHIBIT 4
SUB-MODEL SOLUTION SEQUENCE

7. VALIDATION

Despite progress made in creating a sophisticated and realistic operating environment for the DPM, additional research is necessary before the model can be considered a viable tool in the designing of improved incentive schemes. The DPM's many behavioral parameters, underlying assumptions and structural composition must be tested and validated through use of several methodological approaches before policy recommendations may be formulated.

The initial step in the validation process is a general test of plausibility through examination of various scenarios generated by modification of model attributes. Several scenarios have been generated and seemed to provide reasonable and consistent results. The standard scenario incorporated all sub-models of the DPM and assumed a single major project was awarded at the beginning of the simulation. The second scenario de-activated the monthy monitoring component and pressure mechanisms of the DOD sub-model but still required that minimum specifications be achieved on the major project. Finally, a third scenario was generated which assumed the awarding of a second major project several months after completion of the first.

The next step in the validation process involves extensive statistical regression analysis of the behavioral parameters and initial conditions. A methodology similar to the approach developed by Cyert and March (1963) in A Behavioral Theory of the Firm is applicable for the DPM due to the number of variables involved and complexity of the model structure. A determination of model attributes to which key performance variables are most sensitive will be the objective of this statistical investigation. In conjunction with sensitivity analysis, field interviews and surveys of management in DOD contracting organizations will be undertaken to evaluate DPM consistency with the "real world."

Finally, after necessary modifications to the DPM are implemented as determined in the validation phase, the model will be used as a "testing-grounds" for the development and implementation of alternative incentive mechanisms. Thorough validation of the DPM is necessarily required, however, before policy recommendations can be made with any degree of confidence.

APPENDIX I

1. PM Manpower Assignment Sub-Model
   a. Goal Achievement and Pressure Check Routine
   b. Direct/Indirect Manpower Allocation Routine
   c. High/Low Quality Manpower Allocation Routine
   d. Project Specific Manpower Assignment Routine

2. Project Update Sub-Model
   a. Schedule Update Routine
   b. SQMM Balance Update Routine
   c. Dollar Balance Update Routine
   d. Quality of Performance Update Routine

3. Personnel Sub-Model
   a. Hiring/Firing Routine
   b. Labor Force Attrition Routine
   c. Quality of Labor Force Update Routine

4. Backlog Determination Sub-Model
   a. Capture Rate Determination Routine
   b. New Proposals Generation Routine
   c. New Contracts Awarded Routine
   d. New Project Determination and Award Routine
   e. New Project Attribute Assignment Routine
   f. Accululation of Existing Projects Routine
   g. Backlog Calculation Routine

5. Cash Flow Determination Sub-Model
   a. Direct Cost Determination Routine
   b. Indirect Cost Determination Routine
   c. DOD Billing Calculation Routine
   d. Cash Flow Calculation Routine

6. Corporate Goal Adjustment Sub-Model
   a. PM Corporate Allocation Routine
   b. Corporate Cash Flow Pressure Routine

7. PM Goal Adjustment Sub-Model
   a. Backlog Goal Modification Routine
   b. Volume Goal Modification Routine

8. DOD Sub-Model
   a. Schedule Pressure Routine
   b. PM Quality Pressure Routine
   c. Corporate Quality Pressure Routine

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