Our present workload here at the Center involves development of training devices for missile systems, aircraft, tanks, and weapon systems. Last year the Army Group budget was in excess of $11,000,000. Looking into the future, you can anticipate training device requirements for our new generation of weapon systems, such as Main Battle Tank 1970, Advanced Aerial Fire Support System, and new Air Defense and Antitank Missile Systems.

The Army Group, recognizing the wealth of experience and R&D facilities provided by the Navy and our close working relationship with the Navy and industry, are confident that we can continue to satisfy the needs of the Army in the Training Device area as we have in the past.

PREDICTION OF COST AND LEAD TIME

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The task of looking into the future and predicting or forecasting always has some element of risk or unknown. Reducing the risk element to a manageable tolerance requires a positive and concerted effort on the part of the estimator. The crystal ball cannot be given credence in the estimating process. How then do you take the element of risk out of estimating?

Today I would like to develop the techniques which are employed in preparing budget cost and lead time estimates within NTDC and how these techniques can also be applied to contractor cost estimating.

The development of sound techniques is more important today because of the advanced type of incentive contracting and the high risk associated with poor estimating. The older type cost contracts condoned poor estimating both with respect to cost and time. Figures of 350 percent overrun in cost and 150 percent overrun in time are reported as DOD averages. The key to sound estimating requires two basic conditions: first, that there be a complete and thorough understanding of all elements of the project. And second, that the project consist of development within the current state of the art, i.e., that significant advancement in the state of the art or invention is not a significant element of the project.

Before it is possible for anyone to estimate the cost or lead time on a project, it is essential that he have a thorough understanding of the requirement or the intended use of the equipment. It is only placing one's self in the shoes of the user that the various elements of the project can be realistically evaluated and balanced. The tactical environment that is to be simulated should be recognized as highly complex, and not susceptible to a completly rigorous mathematical analysis. But one must know its complexities and anomalies in order to consider the training equipment design features required in a particular training device. The tactical environment consists of three basic elements: own ship (aircraft, surface ship, submarine or tank), the media (ocean, air, beach or terrain) and the threat or target (fixed, moving). In a tactical trainer the entire simulation problem can be stated in mathematical terms (Math Model). If the development of the math model is to be valid, it must be based on a rigorous statement of the physical phenomenon of the tactical environment. The meaningful simplification of this rigorous model is an important element of the science of simulation for training. But the simplification must be based on knowledge of the various parameters and their relative contribution to the training problem to be valid.

Let us examine the three basic elements of the tactical environment; own ship, the media and the target, in greater detail

The role of "own ship" in the training problem must be established. If the training task is ship control, the requirement for the simulation of the vehicle dynamics and steady state performance must be precise as in the case of flight trainers or submarine ship control trainers. This would include the effect of all systems relating to ship control such as electrical, hydraulic, pneumatic, control surface, etc., and the associated emergency and casualty control systems. If the training goes beyond vehicle control, the tactical systems of the vehicle also play an important role. Such systems as sensors, threat analysis and evaluation and fire control systems must then be included. In the sensor area we are speaking only of the sensor's characteristics with respect to the detection and processing of data, not the source of the data and its processing by the media. Finally there are the weapons which a vehicle may employ with their respective characteristics. Ship control systems, tactical systems and weapons are the elements which make up the own ship portion of the tactical environment.

The second and most difficult element of the environment to assess is that of the media. It is the media which causes many difficulties and anomalies in the case of the operational equipment. If the media were well-behaved, the operational tactical task would be much easier as would be the training problem. The media has two basic effects on the simulation problem. The motion of the media effects the track of vehicles and weapons. This motion influences the navigation problem and must be considered to varying degrees in various types of trainers. In some cases, the influence of media motion on vehicle attitude must also be considered, e.g., fire control systems.

The other effects of the media result from its physical properties and include such parameters as pressure, temperature, density, moisture content, dispersion, reflection, refraction, absorption, etc... A typical example would be the effect the media has on sound energy as it moves through water. The extent to which each of the properties of the media influence a particular tactical problem must be analyzed in terms of the training requirements. This task is extremely complex and is often neglected or ignored in determining system requirement. Paradoxically, this is the area which causes the most difficulty in trying to achieve user acceptance.

The final element which makes up the tactical environment is the threat or target. The role assigned to the target can, by design, vary quite considerably. The target can be assigned a very passive instructor controlled role. At the other end of the spectrum the training requirement may establish the need for a fully manned target with complete tactical capability as in the case of submarine vs. submarine tactics. Besides the role which the target is designated to play, there is another important effect of the target, namely the specific characteristics which have an effect on own ship sensor detection behavior. Such parameters as the radar reflectivity and target size for a radar target or the radiated noise spectral density as a function of operating conditions of a submarine are typical examples of these characteristics.

With a good understanding of the training problem and the tactical environment, we can move into the next phase of the estimating process, namely, the pre-project definition phase.

The first and most significant element of this phase is the development of a preliminary system concept or design that will meet the training requirement. This preliminary design is concerned with the major component of the system and the functional inter-relationship between elements in terms of variables and their rates and ranges. The trainee station or mock-up areas, instructor's station, evaluation and scoring system and computer system requirements would be analyzed and a proposed solution would be documented.

The most important part of the pre-project definition phase is the identification of those elements of the system or subsystems which are beyond the current state of the art and cannot be considered as development tasks. If one or more of such subsystems exist and these subsystems are critical to the success of the device, then the risk elements are identified and assessed and separate research action would be initiated to advance the state of the art in these areas. The willingness or the insight required to perform this task is difficult because of the basic optimism of the engineer and the urgent user requirement to solve serious training problems. The lack of a strong position to separate research from development has led to numerous unsuccessful projects in the past. The "invention approach" to design problems is a highly risky business and has usually resulted in failure.

As an adjunct to establishing the preliminary system design, an assessment is made of availability of data on the operational equipments or systems which are included in the project. This particular area has been and probably always will be, a problem in the training device field. A good understanding of the problem and a positive and aggressive attack reduces it to a manageable and estimable proportion in all but a few isolated cases.

Another element of the pre-project definition phase is the establishment of the site preparation requirement. Effort in this area can be easily overlooked. Such things as space, power, air-conditioning, fire protection, and maintenance and parts storage areas must be considered. In this determination, a demarkation line dividing government and contractor responsibility is established since it influences the contract portion of project cost.

The one remaining technical factor which should be considered is that of related experience. All of the effort in analyzing the task and establishing a preliminary system design is evaluated against the backdrop of previous experience to see if the estimates are logical and reasonable. In utilizing the experience data sufficient caution must be exercised to insure that credence is given to applicable previous experience, rather than question it as being poorly designed and/or managed and therefore not realistically priced. In addition, economic growth factors are included to cover the anticipated time frame of the project execution. Last year's labor rates are not valid three years from now.

The one remaining element of the pre-project definition phase is that of developing a schedule. There are two basic elements; the pre-award and the contract phase. The pre-award phase is controlled by availability of the Military Characteristics data and the technical data on the operational system. To a lesser degree, the detailed steps of the formal contracting procedures, together with their approval times establish the pre-award schedule. It frequently appears that this latter phase of the pre-award activity is the controlling element. At that point in time it usually is. But the important point to remember is that a substantial effort must take place before a Request for Proposal (RFP) is issued. The development of the post-award schedule is determined by analyzing the project and relating it to similar systems previously developed. Here again the greatest pitfall encountered in achieving good scheduling is to discount the unpleasant experiences in previous development and say, "It will not happen on this project." With the pressure of user needs coupled with a later than desired project initiation, the inevitable usually happens, e.g., squeeze it out of the development schedule.

In general, the preliminary schedules are developed making use of normal activity time. If the required dates cannot be met with the preliminary plan, then a more extensive analysis of each critical activity is necessary to insure that no artificial constraints exist and that the most optimum planning is utilized. These actions do not imply squeezing theestimate of known activities to achieve schedule dates.

With the preliminary system design completed and cost and lead time estimates developed, activity continues at a modest level with the Center's Directorates. The activity increases significantly when a project is authorized and a specific "ready-for-training" date is established.

The starting point for the project definition phase is an approved Military Characteristic which sets forth the user training requirement. This document forms the basis for the specific system design requirements. The preliminary system design is updated as required. This system design forms the basis for the preparation of the engineering specification that will be used in the procurement.

The system design requirement and the specification are the tools necessary for the next stage of the estimating process. It is essential that this estimate be made to determine whether the initial estimate used for budgeting is still valid. If changes in requirements or other assumptions have taken place, further examination and analysis of the task is necessary. The process is similar to the earlier stages of the cycle. This estimate is made by analyzing each of the subtasks and assessing the material and manpower requirement that would be needed for the development. This breakdown is, in essence, the Work Breakdown structure of the PERT/COST System. The estimates for the equipment subsystems are usually straightforward based on a specification which quantitatively defines the system requirement. The elements of the estimate which are not usually quite as straightforward are the system engineering and the test and evaluation subsystems, no hardware but usually plenty of manpower. A good knowledge of these two elements is the key to good estimating, a lack of this knowledge can be chaos. Naiveness and optimism are constantly stalking the estimating process and usually manifest themselves in these areas by rationalizing that the errors of past experience will not be repeated, e.g., system analysis and check-out problems.

Technical documentation of an engineering project covering Engineering Design Report, Test Report, Reliability Plans and Drawings is good engineering practice. Normally the estimating of technical documentation effort is straightforward if the basic task is well identified. With a good grasp of the project engineering requirement the effort for technical documentation should bear a fixed relationship to the development and testing effort.

Similar comments can be made concerning the logistic support areas. Good support documentation and technical services are a normal part of the project and should be given the proper emphasis. The normal logistic support effort usually bears a relatively fixed relationship to the project magnitude and complexity. However, each individual case must be analyzed to insure that the exceptions are provided for.

The procurement schedule can be developed when the preliminary steps of defining the system and the various subsystems have been completed. In addition, the plan for the design, fabrication, assembly and checkout must be established; then the task of identifying activities or events takes on significance. I am sure you are all well acquainted with PERT and recognized its benefits as a management tool. For those of you who might have some reluctance about its usefulness, it might be worthwhile to point out that those who criticize PERT or refuse to use it are the ones who are usually in trouble from a schedule standpoint.

The ability to lay out a comprehensive project plan is a necessary part of determining how long the job can take and what subsystems or activities are critical. The subsystems with the greatest risk can be identified by using the pessimistic time estimate and computing the completion date based on these estimates to achieve a 99% confidence level.

The PERT network can be measured against the basic phases of a development project, namely, design, fabrication, and testing. Experience has indicated that the ratios should be approximately 1/3, 1/3, and 1/3. The last phase will probably raise the most questions but will be the easiest to validate. To insure that we are all using the same definition, the last phase includes all effort after the basic manufacturing process has been completed. This test phase covers checkout, test, redesign and rework of unacceptable subsystems as well as the site installation phase of major devices.

The initial plan or network which is developed may not be realistic in terms of previous related experience. Reanalysis and revision to the plan is necessary to optimize the schedule. This does not imply that the network is warped to meet schedules. It does mean that much of the development plan can be optimized by analysis of the PERT network.

The project has been defined and a funding and time estimate has been established. These preliminary but important steps are part of the project approval process. When the project has been approved and funds authorized, the project enters the next major phase, that of contracting for the articles and services.

In specifying technical proposal requirement, it is logical to obtain cost and schedule information for evaluation purposes on a rational and meaningful basis. The work package breakdown structure has these characteristics. It is therefore usual to find the hardware breakdown submission requirement is in that format. The format basically consists of a subsystem vs. manpower requirement matrix. Its completion by offeror should be straightforward. However, the interpretations that are placed on this requirement attests to the ingenuity of industry to evolve numerous logical ways of satisfying a particular requirement. The variety of submittals complicate the proposal analysis task and can lead to delays in the completion of the evaluation.

The task of estimating is not a simple one. There are many around who have excellent hindsight, 20-20 or better, who will tell you what you should have done. The second guesser will always be with us. However, the estimator is a decision maker. As a decision maker he should have available to him all of the data and information he can possibly amass to aid in that process. He should assess the risks and reflect these factors in his estimates. The process must be a continuing one, estimates must be re-reviewed as additional data revises the basis for the estimate.

It is not unusual that a discussion of estimating would evolve into a discussion of how well we know the thing we are estimating. It is not the labor rates that give the trouble, it is the hours or material items required to develop a specific system. Then let us summarize the keys to good estimating:

a. Know the requirement

b. Separate research from development

c. Develop a comprehensive plan

d. Insure adequate effort for system checkout and test.

With good background, knowledge and planning, actual project cost should be consistent with the estimate. It can be done.