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SYSTEM PERFORMANCE MODELS		

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EFFECTIVENESS **Q**UANTIFICATION **B**ULLETIN

SYSTEM PERFORMANCE MODELS



Engineering Department

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EFFECTIVENESS QUANTIFICATION BULLETIN NO. 1

SYSTEM

PERFORMANCE MODELS

Prepared by the
EIA G-47 Effectiveness Quantification Committee

Task Coordinator:
F. H. Kranz

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INTRODUCTION

System performance is the benefit that the user receives from the system; performance requirements are the needs that the system must satisfy and performance parameters are defined by the operational characteristics inherent in system design. System performance should be differentiated from contract performance. Contract performance is evaluated after the fact by a contractor performance evaluation group composed of legal, technical, and financial experts that reviews contracts and supplies the contractor performance data bank with inputs relative to meet contractual obligations (References 1 and 2). The confusion between these two often causes confusion as to who evaluated performance. Operations research personnel, systems analysts, systems engineers, design assurance engineers, management scientists, management information specialists, program control personnel, and even accountants consider themselves specialists in the field of performance evaluation.

Each of these functionaries must recognize the gaps existing in their technology relative to system performance. They must work together to bridge the gaps, appreciate the respective concern of the others, and obtain necessary data controlled by the customer.

The requirement for performance evaluation comes from the desire to maximize profit received from the development and sale of a system. The profit received as a result of a Government contract for the development of a hardware system is usually a function of the cost effectiveness (economic analysis) of the system being developed and the company's investment development. Economic analysis is accomplished by measuring the effectiveness (References 3 and 4), the cost and the development, and the production time of the system. System effectiveness is usually expressed in terms of parameters that fit the system and the mission that it will perform. Examples of such parameters are those selected by the Electronics Industries Association. These are availability, dependability, capability, utilization, and probability of employment. A significant and necessary feature of all system-effectiveness models is that they have capability or performance as a submodel.

Performance models are used throughout the life cycle of a program. In this prolonged period, the current model must maintain congruency with the system, sensitivity to the significant system parameters, relevance in the planned scenario, and adequacy for its intended use. As the program

progresses from feasibility studies to operation hardware, the confidence in the performance quantification should increase from a guess to a certainty.

To be of maximum use in the program, the performance model must not only be related to the mission and hardware, but should be related to the major program control tools including the work breakdown structure and PERT network. Thus, the performance model serves as the focal point for integration of cost, schedule, and performance for the program decisions.

Since the performance model serves in such a key spot in the decision process, investigation must be made as to the results of an error in performance estimation and as to the causes of such an error. Two tools of the reliability field may be used. Failure modes and effects analysis may be used to estimate the damage done by an incorrect performance estimate. Fault-tree analysis may be used to find the sources of error and their relative probability of occurrence. With these two tools, performance estimate errors may be investigated and avoided or reduced in impact.

PERFORMANCE MODEL REQUIREMENT

Government agencies have expressed the desire to reward a contractor for investing in the development of an effective system. This reward is obtained by making the profit depend on both the cost effectiveness of the system and the amount of investment made by the contractor. This relationship may be stated as

$$F = f_1 (E_c, I)$$

where F is the profit from an incentive fee contract, E_c is the system economic analysis or system cost effectiveness (Reference 5), and I is the contractor's investment in the program.

The system cost effectiveness may be expressed as

$$E_c = f_2 (E_s, C, T)$$

where E is the system effectiveness, C is the cost, and T is the time.

All of these variables are complex vectors. For example, cost is the total of research, engineering, development, test, procurement, operational support, training, and facility costs. Time may be expressed in terms of

development time, operational life, first operational date, first activation date, or force activation date. System effectiveness is a complex model and may be expressed as one of the following

$$E_s = f_3(A, D, C)$$

$$E_s = f_3(P, A, U)$$

$$E_s = f_3(W, A, D, C, U)$$

where A is the availability, D is the dependability or reliability, P~C is the performance or capability, W is the employment, and U is the utilization. Common to all models is the performance parameter.

NATURE OF PERFORMANCE

System performance can also be termed design performance, design characteristics, design adequacy, mission success, or mission objective accomplishment. A precise, acceptable, and consistent definition is not available. The system performance parameters are found in the incentivized characteristics portion and in the Part I specification. They usually read: cruise at Mach 1.5, range of 1600 miles at 80,000 feet, payload type, and delivery. On the other hand, a mission performance requirement might read: to intercept and destroy enemy aircraft with a 15-minute alarm. The difference between system performance and mission performance should be recognized. System performance parameters are the inherent characteristics of the system. They are derived from the design mission and span the spectrum of missions to be accomplished by the system. An understood and accepted system performance definition is difficult to develop. For the sake of mathematical clarity, a system performance model can be expressed in a matrix using the capability, the capacity, and the versatility of the system as follows

$$P = U (X_1, Y_1, Z_1, X_2, Y_2, Z_2 \dots X_i, Y_i, Z_i \dots X_n, Y_n, Z_n)$$

where U is the utilization function that expresses the part of the total design capability, capacity, and versatility that is used, X_i is the capability, Y_i is the capacity, Z_i is the design versatility, and i is the subsystem. Capability is the designed ability of a system. Maximum thrust and peak instantaneous electrical load are examples of system capability. Capacity implies the designed total life of the capability. Total usable battery life and all other measures of total consumables are capacity measures that influence system

performance. Versatility implies the growth capability of the system and the probability that the design will provide the required functions (the complement of design risk). The development of such a model requires the use of the basic laws of physics, particularly conservation of mass, conservation of energy, and conservation of momentum. The performance of the system, or the portion of the system of interest, must be reproduced abstractly and analytically by breaking the system into its elements or constituent parts. Thus, it must be a representation or "model" of the operating system. In this sense, a model is any abstract representation of an operating system consisting of (1) a definition of the elements or constituent parts of the system and (2) a set of rules or equations defining their operation or interaction within the system.

The actual model used will usually be a tool developed by a system analyst to demonstrate the performance of the system. This is the single most important model in system effectiveness evaluation. Performance is the parameter given first design consideration. The system must inherently be capable of performing the functions required during the mission. The various engineering disciplines (such as, structures, dynamics, control theory, propulsion, electrical power, communications, aerodynamics, environmental analysis, and navigation) are required to translate design features into performance parameters. Reference 3 states, "There is no general method by which elements of the capability vector can be estimated." This implies only that the model must fit the system and mission. A generalized model represents the concepts to be used in developing the explicit mathematic model to be exercised.

SENSITIVITY

A large proportion of the system cost is assignable to the test program and to the verification of the tests that validate the operational capability, capacity, and reliability of the system. The requirement and importance of testing is discussed later in this paper. A less obvious requirement is for the performance model or simulator. Like the test equipment, a major problem is showing that the model has adequate congruence with the developed system. That is, that the results of applying the model must be usable to make decisions relative to the system. This may be stated another way. The outputs of the model should change with inputs in the same way as the system. This is accomplished by determining how the system performance value changes with changes in input parameters from the test program.

The advent of computer technology has tremendously expanded the system analyst's capability because it is a powerful tool for the operation of complex models. Once developed, a model may be exercised at length with variations in inputs, parameters, or operating rules to extract the sensitivity of outputs to these variations. The value of each of the primary performance

parameters must meet specification requirements. Since all inputs affecting the system cannot be modeled within the capability of man and computers, only significant parameters can be considered. To accomplish this, two types of parameters are defined.

1. Common: These performance parameters are normally expected to be accomplished satisfactorily with routine engineering, quality control, and manufacturing. The model should be fairly insensitive to these parameters.
2. Significant: These are the performance parameters that are critical to mission success and represent recognized technical risk or potential growth for the system. The model should be quite sensitive to these parameters.

The model developed must be sensitive to significant performance parameters. Care should be taken to assure that the model is not so inclusive of parameters as to be cumbersome to exercise or difficult to change. Change is frequently necessary. The most common cause for change in the performance model is change in the scenario, threat, or mission. These result in change of performance parameters or their significance. Severe problems in system development can result from believing the model to be totally congruent to the mission and system and not subject to change. The model must evolve with both the mission and system to maintain near congruence.

CONFIDENCE

The model that inspires the most confidence in the decision maker is the system functioning in its operational environment. The most desirable way to evaluate performance is to observe and record the functioning of the system as an entity. Lacking the ability to observe operations, models and simulators are devised to estimate performance based upon incomplete data. Performance is estimated from incomplete data such as physical laws, handbook data, qualified parts lists; and finally, from analysis of component, subsystem, and system test results. Since testing is expensive, there is always the question of just how much testing is required to establish a consistent degree of confidence in meeting the specification requirements of performance goals. An example of part of the set of equally significant performance requirements for a fighter/attack aircraft would include:

- a. Maximum speed at sea level
- b. Maximum (burst) speed at altitude
- c. Acceleration

- d. Excess maneuver energy
- e. Combat ceiling
- f. Combat radius
- g. Military payload

Here, a set of performance parameters were selected rather than a single-performance quantification. Such quantification, particularly undimensionalized, does not provide the program decision maker confidence in its credibility. Sets of dimensionalized performance parameters present areas for decision and support the credibility of the values. Each of these performance factors may have been calculated, by analysis of all available data, to be at least up to the specified performance. However, the data inputs have different degrees of hardness; consequently, the confidence in the performance varies from parameter to parameter. This is shown in Figure 1, which indicates where the performance should be checked by the program. The priorities of allocation of performance test effort should be d, e, c, b, a, g, and f.

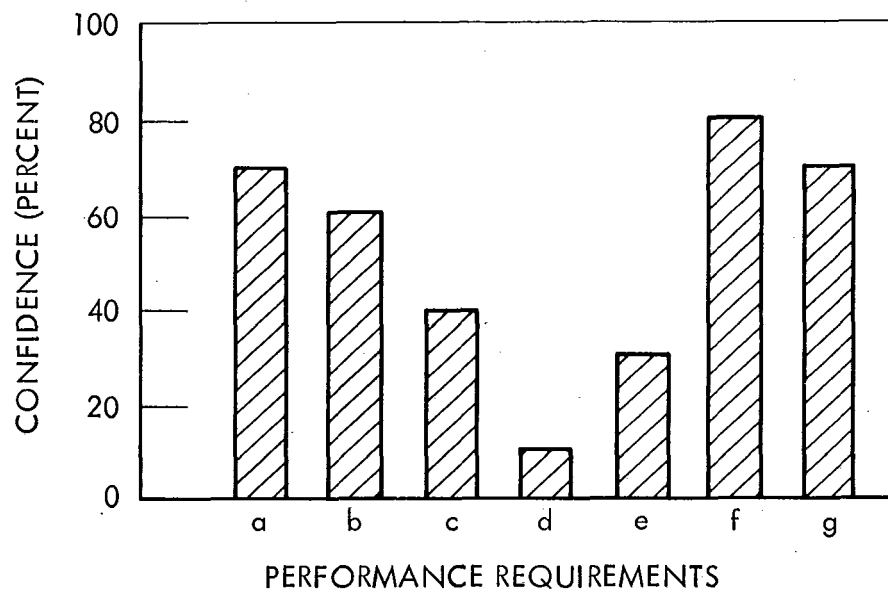


Figure 1. Analysis Degree of Confidence in Performance Parameters