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QUANTIFICATION OF ESSENTIALITY AND UTILIZATION TERMS		

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

QUANTIFICATION of

ESSENTIALITY and

UTILIZATION TERMS



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EFFECTIVENESS QUANTIFICATION BULLETIN NO. 4

QUANTIFICATION OF ESSENTIALITY
AND UTILIZATION TERMS

Prepared by
EIA Committee G-47 on Effectiveness Quantifications

November 1972

ELECTRONIC INDUSTRIES ASSOCIATION
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ABSTRACT

This report on quantification of Essentiality (W) and Utilization (U) terms extends the scope of the basic expression for system effectiveness ($E_s = ADC$) to include the additional "W" and "U" parameters needed for the quantification of multi-functioned and multi-missioned systems. Methods and procedures for applying these terms to system effectiveness quantification are discussed and simple examples to demonstrate the principles of usage are included. The need to look at the system being quantified in terms of its level in the mission/function hierarchical tree is explained. The relationships between system elements (hardware, software, and personnel) and performance functions are discussed and illustrated with examples. Two methods for applying the "W" and "U" weight factors, LOGIC AND (weak link model) and LOGIC OR (degraded operational modes model) are described and examples are shown for these cases.

FOREWORD

The techniques for quantifying system effectiveness for systems having a single function or having multiple functions which are all required at all times during a mission has been well described in the current literature. In particular, the Weapon System Effectiveness Industry Advisory Committee (WSEIAC) Reports present the basic methodology using the ADC triple product, Availability (A) - Dependability (D) - Capability (C), which is the heart of system effectiveness quantification. In order to accommodate those situations in which (a) different missions require different functions and (b) the lengths of time during which the individual functions are required varies, some extension of the ADC method is needed.

At the EIA Systems Effectiveness Workshop in Chicago, Illinois on 18 - 20 September 1968, the Es = WCADU quintuple was proposed in which an index of Utilization (U) term and a probability of System Activation (W) term were added to the basic ADC expression.

During G-47 meetings following the workshop, the committee felt that activation probability could be included in the utilization term. This led to the initiation of Task G-47-70-01, "Quantification of Utilization Term". During the performance of Task 70-01, it became evident that an additional term for the essentiality or worth of missions and functions was also needed. Task G-47-70-01 was closed and a new task G-47-71-01, "Quantification of Essentiality and Utilization Terms" was opened. This document is the final report for this task.

The task coordinator for this task was Mr. H. A. Eimstad of Philco-Ford, Western Development Laboratories.

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SECTION 1

INTRODUCTION

1.1 PURPOSE

The purpose of this report is to do the following:

- a. Extend the scope of the basic expression ($E_s = ADC$) for system effectiveness to include parameters needed in the quantification of multi-functioned and multi-missioned systems by means of terms for Essentiality (W) and Utilization (U).
- b. Define the essentiality and utilization terms.
- c. Reiterate the need to look at several hierarchical levels when quantifying system effectiveness.
- d. Provide some discussion on the use of weight factors in quantification.
- e. Show the relationship between functions and system elements (hardware, software, personnel, etc.).
- f. Present several examples of quantification of multi-functioned and multi-missioned systems.

1.2 SCOPE

This report proposes a methodology for applying weighting factors to system effectiveness quantification expressions of mathematical models for multi-function situations. Since the circumstances for applying "W" and "U" terms are almost unlimited, no attempt is made to show all possible applications of these terms. Rather, the basic principles are discussed and illustrated by simple examples in order to keep the focus on the principles for quantifying "W" and "U". The methods that are used at lower levels of the mission-function hierarchical tree are equally valid at higher levels. Consequently, the extension of these basic methods to more complicated situations was deliberately excluded from the content of this report.

1.3 BACKGROUND

The quantification of system effectiveness is a reasonably straightforward matter for systems having only one function or having several functions and requiring that all functions be performed for mission success. In these two cases, the WSEIAC techniques can be applied and effectiveness determined. However, as soon as one begins to consider certain functions as being more important than others and also allow for variations in the amount of mission time that the different functions require, then a more sophisticated model than the WSEIAC ADC matrix product is needed. The use of two additional terms, one for Essentiality (W) and one for Utilization (U), make it possible to quantify system effectiveness for:

- a. Almost any purpose (trend analysis, choosing between systems, incentive awards, etc.).
- b. Type of system.
- c. Hierarchical level.
- d. Phase of system life cycle.

The "W" and "U" terms find use primarily when the user is required to apply weighting factors to missions and functions. The weighting factors can be applied for worth of the individual functions or missions (essentiality), for the relative amount of time that a function is performed within a mission (utilization) or for a combination of both worth and time usage.

Whenever the multi-missioned or multi-functioned system is modeled for system effectiveness, a primary procedure that must be observed is that of relating the functions and missions of the system at each of the hierarchical levels that bear upon the analysis being performed. A general rule that was advocated at the EIA Systems Effectiveness Workshop in Chicago was to always examine two hierarchical levels above the one being modeled. This rule of thumb, when followed, should enable the user to broaden his perspective sufficiently to properly relate the functions and missions of a given system.

The "W" and "U" terms like the Capability (C) term are normally applied to functions which are performed by groups of system elements (hardware, software, personnel, etc.). Some of these system elements may be utilized in more than one function. This contrasts with the Availability (A) and Dependability (D) terms. The elements of these latter terms are the reliability and maintainability parameters which are applied directly to system elements. Reliability in terms of failure rate is applied to the component or piece part level, software, and personnel while maintainability or mean repair (or restore) time is calculated for the Lowest Replaceable Hardware Unit (LRU) level. In preparing a mathematical model for effectiveness, two additional tasks that must be accomplished at the outset are as follows:

- a. The analysis of performance requirements in order to identify those functions for which expressions for capability, essentiality, and utilization can be developed.
- b. The analysis of the system elements as represented by the Work Breakdown Structure (WBS) in order to identify those equipment/personnel units comprising each function of the system. The analysis must identify those system elements that are common to more than one function and those that are peculiar to just one function.

The principles, considerations, and tasks enumerated above have a direct bearing on the quantification of essentiality and utilization and will be elaborated upon later in this report.

SECTION 2

REFERENCES

No attempt will be made to identify all of the reference documents that pertain to system effectiveness quantification. Rather, a listing of references that do have direct bearing upon the W and U terms are discussed in this section of the report. Some pertinent references are as follows:

- a. Weapon System Effectiveness Industry Advisory Committee (WSEIAC) Final Report of Task Group II (AFSC-TR-65-2, Volumes I, II, and III), Prediction - Measurement. This document presents the concepts of system effectiveness measurement and prediction. Eight formalized tasks necessary to evaluate effectiveness are reviewed. Four major examples of quantification are presented.
- b. Proceedings of the EIA Systems Effectiveness Workshop, Chicago, Illinois, 18-20 September 1968. The entire proceedings are addressed to system effectiveness quantification; however, the Interim Progress Report for Task G-47-68-04 by J. O. Lawson of Texas Instruments is particularly pertinent to this report. The referenced task was to investigate the relationship between system performance measurements and the work breakdown structure (WBS). This was done in considerable detail using an Anti-Submarine Warfare example.
- c. MIL-STD-721B, Definitions of Effectiveness Terms for Reliability, Maintainability, Human Factors, and Safety.
- d. Final Report on Task G-47-68-02, Identification of a Projected Outline for Effectiveness Factor Breakdown Structure. This report was prepared by John G. Rau and is included in the 3 November 1969 minutes of the EIA Engineering Department, Effectiveness Quantification (G-47) Committee Meeting. This task delineated system performance (capability) measures.

SECTION 3

DEFINITIONS

Most of the current definitions that relate to system effectiveness can be found in MIL-STD-721. A review of these definitions is presently being made by the G-47 Committee. However, the terms for essentiality and utilization do need defining. A brief literature search has revealed several definitions for utilization each of which have merit. In order to standardize terminology, definitions for utilization, and essentiality are proposed in this section. Further, for convenience, the definitions of the other system effectiveness terms are also included. These definitions are as follows:

- a. System Effectiveness (Es) (MIL-STD-721B). A measure of the degree to which an item can be expected to achieve a set of specific mission requirements, and which may be expressed as a function of availability, dependability, and capability.
- b. Availability (A) (MIL-STD-721B). A measure of the degree to which an item is in the operable and committable state at the start of the mission, when the mission is called for at an unknown (random) point in time.
- c. Dependability (D) (MIL-STD-721B). A measure of the item operating condition at one or more points during the mission, including the effects of Reliability, Maintainability, and Survivability, given the item condition (s) at the start of the mission. It may be stated as the probability that an item will (a) enter or occupy any one of its required operational modes during a specified mission, (b) perform the functions associated with those operational modes.
- d. Capability (C) (MIL-STD-721B). A measure of the ability of an item to achieve mission objectives given the conditions during the mission.

- e. Utilization (U) (Proposed). The probability that a system function will be used during a specific mission under stated conditions. It is normally expressed as:

$$U(i,j) = \frac{T(i,j)}{T(j)}$$

where:

$U(i,j)$ = Utilization of i^{th} function during the j^{th} mission.

$T(i,j)$ = Demand time of the i^{th} function during the j^{th} mission.

$T(j)$ = Demand time of the j^{th} mission

- f. Essentiality (W) (Proposed). The relative worth of a function or mission when performed in a multi-function/mission situation under stated conditions. For the required functions for a given mission, essentiality is expressed as:

$$W(i,j) = \frac{F(i,j)}{\sum_{i=1}^n F(i,j)}$$

where:

$W(i,j)$ = Essentiality of the i^{th} function during the j^{th} mission.

$F(i,j)$ = Weight factor of the i^{th} function during the j^{th} mission.

$\sum_{i=1}^n F(i,j)$ = Sum of all required function weight factors for the j^{th} mission.

For alternate (degraded mode) functions for a given mission, essentiality is expressed as:

$$W(i,j,k) = \frac{F(i,j,k)}{F(i,j,M)}$$

where:

$F(i,j,k)$ = Weight factor of the k^{th} operating mode of the i^{th} function of the j^{th} mission.

$F(i,j,M)$ = Weight factor of the primary (M^{th}) operating mode of the i^{th} function of the j^{th} mission.

Note - The definitions of essentiality and utilization are expressed in terms of system functions for specific missions, but the definitions are equally applicable at all hierarchical levels of missions and functions as shown in Section 5.

SECTION 4

SUMMARY

This final report on EIA Task G-47-71-01, Quantification of Essentiality and Utilization Terms, extends the scope of the basic expression (Es = ADC) for system effectiveness to include the additional W and U parameters needed for the quantification of multi-functioned and multi-missioned systems. The body of the report contains the following four sections:

- a. General. This section contains discussions of the underlying topics and procedures that must be considered in quantifying essentiality and utilization. The subordinate paragraphs are as follows:
 1. Usage. The use of W and U terms in system analysis are discussed. The topics are: function and mission assessment, optimization of improvements, use during different life cycle phases, and use for incentive awards.
 2. Hierarchical Levels. The changes in the manner of quantification depending upon the level at which the system is being analyzed are presented. A naval vessel (a destroyer) is used as an example of the effect of the point of view (hierarchical level) upon quantification of "W" and "U".
 3. Function and Hardware Relationships. The relationship between system elements (hardware, software, and personnel) and performance functions are treated. Two examples are provided for better understanding of this relationship.
 4. Weight Factors. Two methods for applying weight factors are discussed. The first is the LOGIC AND method which is used where several functions are each required. The second method is the LOGIC OR technique which is used where primary and alternate, standby or degraded modes of performing a function are possible.