A FRAMEWORK FOR A DEFENSE SYSTEMS EFFECTIVENESS MODELING AND ANALYSIS CAPABILITY

SYSTEMS EFFECTIVENESS MODELING FOR ACQUISITION

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Purpose

- The purpose of this paper is to present a response to two current Department of Defense (DOD) initiatives:
  - The first is the DOD National Defense Strategy of 2018 which encourages the adoption of new practices to improve system performance and affordability to meet current and future threats.
  - The second initiative is the DOD Digital Engineering Strategy which outlines five strategic goals in support of the first initiative.
  - The first strategic goal: “Formalize the development, integration, and use of models to inform enterprise and program decision making” is the specific subject of this paper.

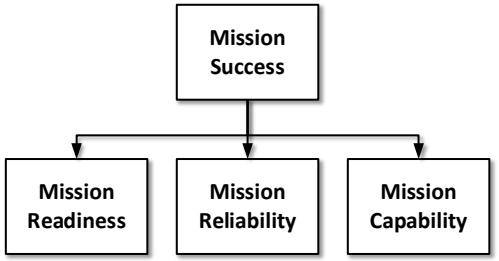
Goals

- To support the goals of the NDS, the Department of Defense's Under Secretary of Defense for Research and Engineering has initiated the Digital Engineering Strategy (DES) that has five goals.
- The goals are:
  - ***Formalize the development, integration, and use of models to inform enterprise and program decision making;***
  - Provide an enduring, authoritative source of truth;
  - Incorporate technological innovation to improve the engineering practice;
  - Establish a supporting infrastructure and environments to perform activities, collaborate, and communicate across stakeholders; and
  - Transform the culture and workforce to adopt and support digital engineering across the lifecycle.

Specific Contribution of this Paper

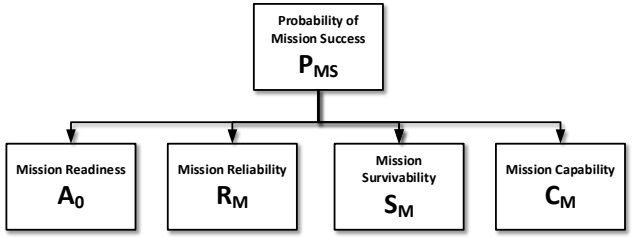
- The contribution of this paper is twofold.
  - First, it provides clarity of purpose for readiness, an oft used and abused term.
    - Why not readiness? A focus on readiness may lead to sub-optimum system solution because it ignores three other factors important to systems effectiveness and mission success.
    - Mission success is the applicable measure because it drives force projection and war-fighting capability.
  - Second, the paper presents a framework that addresses the role of readiness within the context of mission success. This framework applies to both systems and systems of systems acquisition, providing the stakeholders with quantified results.

Background

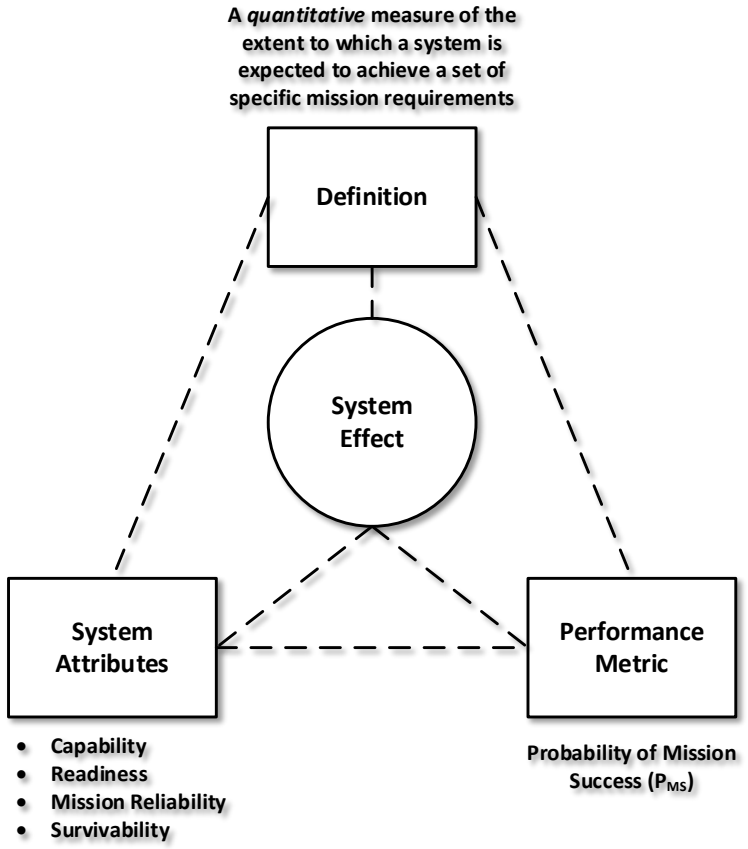


The WSEIAC Systems Effectiveness Hierarchy (Adapted from WSEIAC 1966)

$$P_{MS}=(P_{Ao})(P_{RM})(P_{SM})(P_{CM})$$



The Revised WSEIAC Systems Effectiveness Hierarchy

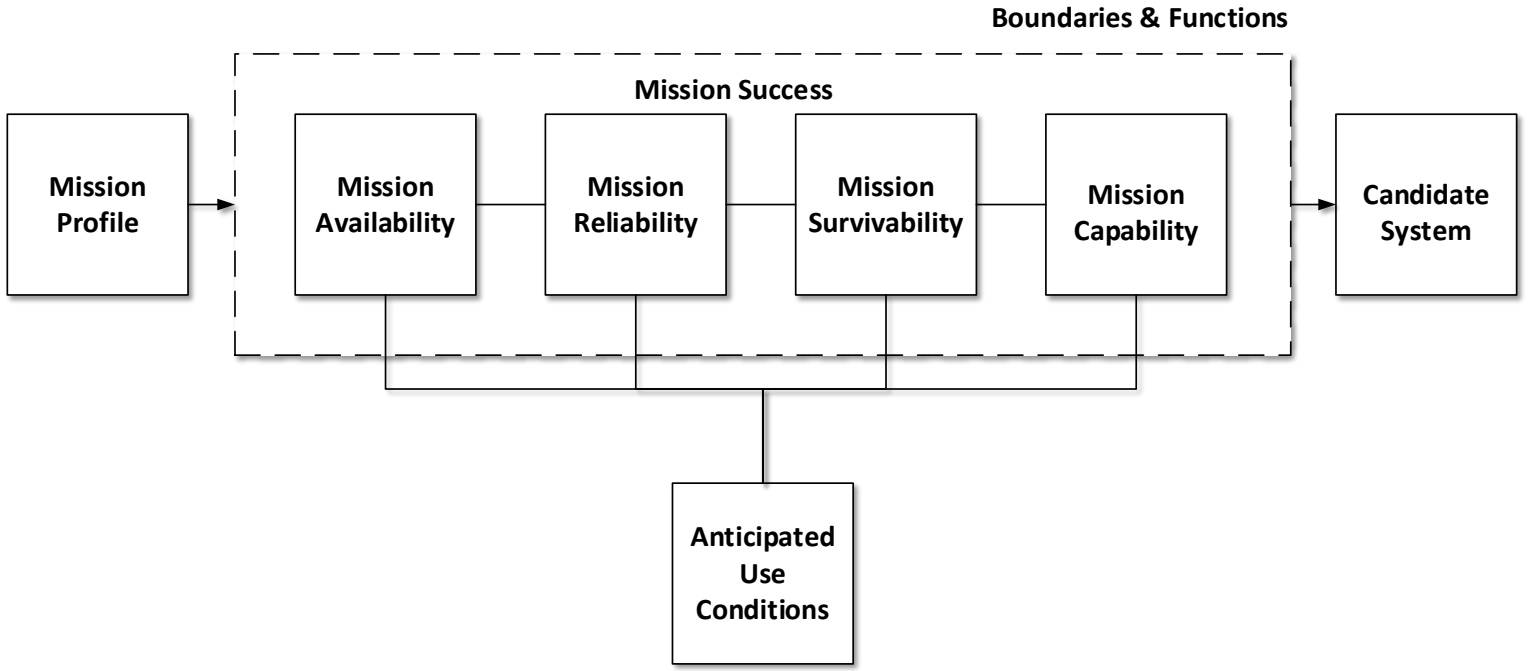


Systems Effectiveness Relationships

Basic Framework Requirements

- ***Quantitative***
- One of the first steps in an analysis is to describe the processes involved. Mathematics is precise and explanatory, facilitating analysis and explanation of more complex problems than possible using qualitative methods. The model for the probability of mission success must be based on proven methodology. The challenge is developing and maintaining a model for each mission which will be large and complex for complex systems.
- ***Probabilistic***
- Military operations are about achieving success and the estimation of event probabilities, typically described as measures of effectiveness (MOE) or measures of performance (MOP). Often parametric values are used incorrectly as measures. For example, detection of a threat is expressed as a probability of detection and is a function of several parameters including range. The outcome is the probability of detection as a function of range.
- ***Reliability-Based***
- Reliability theory is based on the premise of system success and failure ($P_{success} = 1 – P_{failure}$). Many of its concepts are foundational precepts to quantifying system effectiveness. Further, most of the system variables of interest are reliability related. Figure 3 identifies them as key system attributes.
- ***Hierarchy and Abstraction***
- Systems are hierarchical by nature with increasing detail at each level of expansion. The framework must support models that describe each level of expansion. This paper suggests a black box approach at each layer.

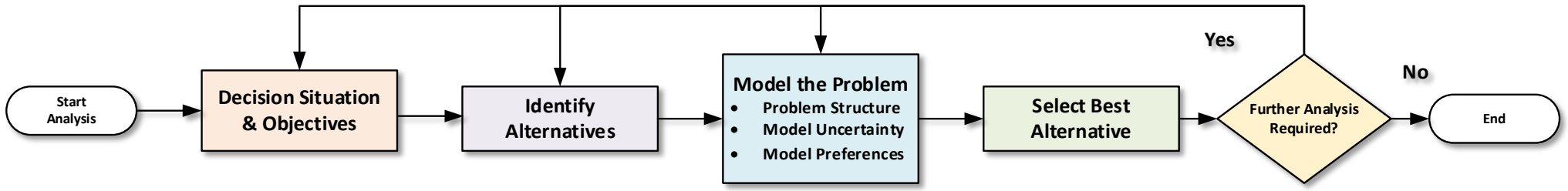
A Notional Effectiveness Model



A Systems Effectiveness Model
(Adapted from NAVWEPS 1964)

Supports the WESIAC Paradigm

Problem Formulation



Generic Decision Process

Maximize $P_{MS} = (P_{Ao})(P_{RM})(P_{SM})(P_{CM})$

Subject to the following constraints

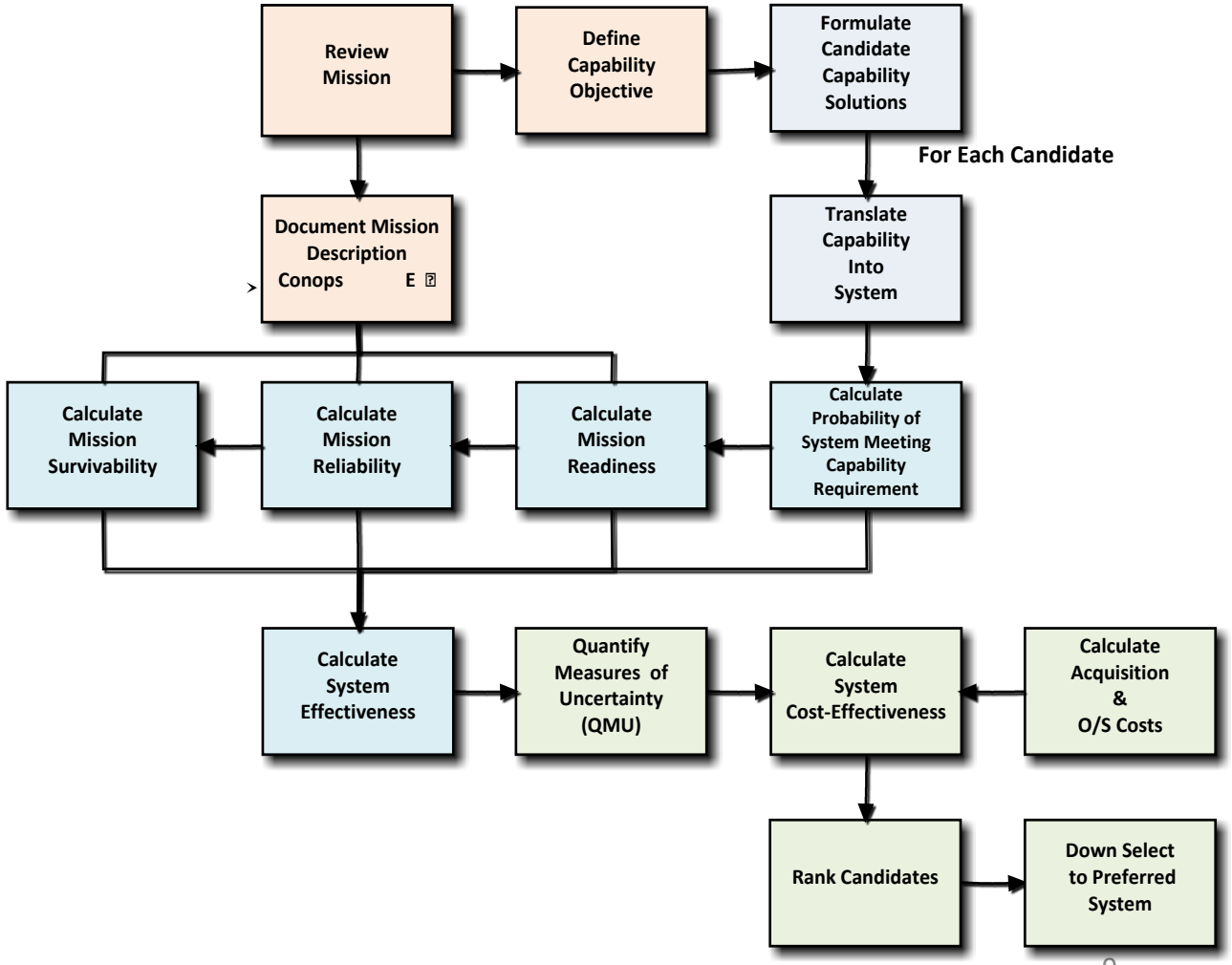
- Specified Mission
- Required Performance
- Budget

This is a basic optimization problem. It is decisive because the result is one system – the best one.

A Framework for a Defense Systems Effectiveness Modeling and Analysis Capability

Cost-effectiveness has been chosen as the criterion for the model because it is best used for ranking alternatives that are relatively similar especially when there is a single dominant objective whose attainment can be assessed directly or for which a good proxy value exists (Quade 1982).

It is axiomatic in the world of quantitative analysis that in general, the possibility of selecting between two alternatives based on cost and effectiveness data alone is not possible. It is a choice between specifying performance or cost. If the former, then cost is minimized, if the latter, then effectiveness is maximized.



Summary

- This paper presents the rationale for a framework for a “Defense Systems Effectiveness Modeling and Analysis Capability.”
- It describes why the key decision criterion is the probability of mission success and shows the approach to the derivation of the Framework.
- This Framework is inclusive of Capability, Readiness, Mission Reliability, and Survivability which is typically omitted in system effectiveness evaluations.

References

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