SUGGESTED CRITERIA FOR EVALUATING SYSTEMS ENGINEERING METHODOLOGIES

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ABSTRACT

Systems engineering is the application of mathematical and scientific principles to practical ends in the life-cycle of a system. A methodology for systems engineering is a carefully developed, relatively complex procedure or process for applying these mathematical and scientific principles. There are many systems engineering methodologies [or possibly many versions of a few methodologies] currently in use in government and industry. These methodologies are usually tailored to meet the needs of a particular organization. It has been observed, however, that many technical and non-technical problems arise when inadequate systems engineering methodologies are applied by organizations to their systems development projects. This paper discusses various criteria for evaluating systems engineering methodologies. Such criteria are developed to assist methodology-users in identifying and selecting methodologies that best fit the needs of the organization.

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Introduction

This paper is one of several results of a Dynamic Systems Engineering Methodology Research Study being conducted at Howard University under a grant from NASA. The study is sponsored by the Networks Division of the Mission Operations and Data Systems Directorate (MO&DSD) at Goddard Space Flight Center. The objective of the study is to examine systems engineering methodologies in light of changing environments and changing needs. The results of this investigation are to be used to identify and validate new methodologies with potential applications to NASA's systems life-cycle processes.

The study is divided into two phases. Phase One is a study of NASA's projects, its organization, resources, and environment to identify factors that affect the successful application of systems engineering methodologies. Phase Two involves evaluating existing methodologies, tools, and techniques with potential application to NASA's systems project.

The criteria for evaluating systems engineering methodologies were developed based on the findings in Phase One. These criteria are to be used as a guide and weighing scale for evaluating existing systems engineering methodologies in Phase Two of the project, and in making recommendations to NASA.

Purpose of a Systems Engineering Methodology

Systems engineering as described by Blanchard is a process employed in the evolution of system's development from the time when a need is identified through production and/or construction to the ultimate deployment of that system[1, p. 11]. The series of steps involved in this process is a systems engineering methodology. A methodology is primarily used to improve the effectiveness of the overall system. It provides a means to increase reliability, decrease downtime, maintain cost effectiveness, and avoid redundant and wasted efforts. Furthermore, it provides a means of checking, cross checking, and quality control.

A systems engineering methodology is almost vital for large-scale projects because the success of such projects depends upon a strong systems approach to integrate diverse elements into a harmonious whole[2, p. 2]. It is also vital to proper project management. The steps of a systems engineering methodology are generally presented in the context of a system life-cycle. A life-cycle is a logical evolutionary flow of what has to be done for the duration of the project.

Participants in the Systems Engineering Process

There are two basic participants involved in the systems engineering process—the problem originator and problem solver. The problem originator is the individual who has a problem that needs to be solved. Typically, the problem originator is referred to as the client, decision-maker, manager, sponsor, or problem owner[3]. The problem solver is responsible for providing the problem originator with a solution to his problem. This role is likely to be filled by a person called a consultant, analyst, or designer. The problem solver is also the methodology-user for (s)he is the one who uses the set of procedures, which may or may not be formally defined, to create an environment whereby a solution can be brought about[3]. Therefore, it is essential that the user identifies what tasks must be carried out to obtain the desired results. These tasks and the persons responsible for completing each task must be clearly defined in the organization's methodology.

Suggested Criteria for Evaluating Systems Engineering Methodologies

The criteria that were developed to evaluate a systems engineering methodology fall within five major categories: Structure, Flexibility, Accountability, Documentation, and Special Considerations of User (in this case NASA). Structure addresses the composition of the system life cycle process and its ability to accommodate simple to large-scale systems. Flexibility refers to the methodology's ability to adapt to change. The third area of interest is accountability. Accountability addresses the ability of the systems engineering methodology to ensure that proper procedures are being applied as intended and that appropriate procedures are being kept. Documentation refers to how well the methodology is written; the level of detail, clarity and ease with which it can be followed. Lastly, because all methodologies are tailored to meet an organization's particular needs, it is necessary to examine the factors that are of critical concern to that organization (in this case NASA). The criteria that were developed for each category are as follows:

1. Structure

   • Does the methodology address activities that are likely to involve engineering work such as design, construction, installation, and operation?

   • Is it structured to handle large-scale or complex systems (interacting components to achieve defined objectives)?

   • Is it structured to handle at least one component that is extensively hardware?

   • Is the methodology partitioned into clearly defined and logical phases, processes, activities, or tasks that can be used as a basis for resource allocation and events such as the start or completion of phases that can be used as milestones or decision points?

2. Flexibility

- Does the methodology accommodate systems of varying size, nature (such as utility/public sector, military, consumer products), and complexity?

- Does the methodology address ways of handling new information, feedback, or unforeseen circumstances (such as new requirements)?

- Does the methodology allow for acquisition through a variety of approaches (procurement, development, etc.)?

- Does the methodology allow maximum flexibility with time-allocation (scheduling) of resources?

- Does the methodology address ways of identifying and selecting the best human and material resources to assign or allocate to its various phases?

3. Accountability

- Does the methodology specify the documentation that is appropriate at different points during its application?

- Does the methodology provide for communication and information exchange to ensure that all participants are aware of significant project decisions and have the most up-to-date information on the project status and activities?

- Does the methodology specify an auditing or tracking procedure to ensure that it has been applied as intended?

- Does the methodology suggest a management structure to ensure that it is applied as intended?

- Does the methodology identify its intended users, class of systems, and scope of its intended applications?

- Does the methodology provide ways of addressing critical considerations such as national security, risk (environmental, evolving technologies), human safety, etc.?

4. Documentation

- Is the methodology written clearly, precisely, completely, and at a level of detail that is appropriate for its intended users? Is it a good road map?

5. Special Considerations of NASA

- Is the methodology fairly independent of organizational structure?

- Does the methodology allow for the retention of key personnel throughout the life-cycle?

- Does the methodology provide for the incorporation of requirements identified during the system analysis, design, or subsequent phases?

- Does the methodology provide tools and techniques for predicting or projecting future requirements, through the planning horizon?

- Does the methodology suggest strategies and techniques for designing and developing systems in the absence of specific requirements?

- Does the methodology provide tools and techniques (including graphics and prototyping) for communicating among individuals and various organizations or organizational units working on major systems projects?

- Does the methodology provide tools and techniques for redesigning and making major modifications to extend the useful life of a system in operation?

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Summary

As mentioned, these criteria will be used in Phase Two of the project to evaluate other agencies' and authors' systems engineering methodologies with potential applications to NASA. They will serve as a guide and weighing mechanism for justifying our recommendation to NASA/Goddard.

References

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3. Keys, Paul. "A Methodology for Methodology Choice." Department of Management Systems and Sciences, University of Hull, U.K. 1987 pp. 65-76.