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Earned readiness management for scheduling, monitoring and evaluating the development of complex product systems

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Abstract

How should the development of a complex product system (CPS) be managed in a manner that focuses on process milestones, which is responsive to changes in technology and requirements; based on maturity measures; and applied in an interactive manner, in addition to facilitating timely feedback? This is considered to be an important question in project management. Project management tools and techniques have been inadequate for monitoring technology development in a CPS. If the technologies are not properly matured by a specific period of time, the progress of the project can be in detriment. To address this important gap, the objective of this study is to develop a new maturity-focused methodology for scheduling, monitoring and evaluating the development of a system. We present Earned Readiness Management (ERM) for system scheduling, monitoring and evaluation which was developed and validated using a case study. Future research on ERM is also discussed in this paper.

Keywords: Control; Earned readiness management; Integration readiness level; IRL; Monitoring; Scheduling; System readiness level; SRL; Technology readiness level; TRL

1. Introduction

Proper planning and control through scheduling, monitoring and evaluation have been found to be among the necessary elements, which contribute to the success of new products and research and development projects (Dvir and Lechler, 2004; Pinto and Slevin, 1987). Likewise, product development is a significantly competitive advantage for firms (Browning and Ramasesh, 2005). Unfortunately, for complex product systems (CPS) (Hobday, 1998; Hobday et al., 2005) or high technology projects (Archibald, 2003), control cannot yet be effectively achieved because process metrics or performance measures for systems development have not been fully developed (Hertenstein and Platt, 2000; Suomala, 2004). CPS are characterized by customized, interconnected subsystems, high cost, produced in low volume, require a breadth and depth of knowledge and skills, involve multiple collaborators, and have continuous integration with client and supplier (Sauser, 2008). Herroelen (2005) would classify CPS as high variability and high dependency products which has witnessed a latency in research and practice for project scheduling. In the absence of performance measures, project results cannot be measured and compared against pre-specified benchmarks making it difficult to control outcomes (Choudhury and Sabherwal, 2003; Kirsch, 1996). In addition, currently available tools and techniques for planning and control are fragmented and not used consistently throughout the process (Patanakul et al., 2010; Pawar and Driva, 1999). This absence of process metrics along with high

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variability, dependency and lack of consistency make it difficult to realize the use of control mechanisms such that it can influence in a positive manner the performance of CPS development (Tiwana and Keil, 2009).

More than an unwillingness to bother with such measures, perhaps project or engineering managers do not use them consistently because they find them to be irrelevant or unable to address the need to control the development of CPS. In particular, these planning and control tools focus on measuring specific performance aspects of the system, such as task completion, cost and schedule, which may be important to some stakeholders but are unable to show if the system is maturing adequately over the development lifecycle. Concentrating on the measurement of these variables can mislead a project's focus in terms of which activities have been accomplished. Browning and Ramasesh (2005) showed this exist in product development models which have over emphasized the activities rather than the interactions or deliverables. In a review of process models for product development, Browning and Ramasesh (2005) state that most models focus on optimizing the relationship between elements, and do not consider the project or system-level view, which will sub-optimize the system. Humans tend to apply more attention to activities that are being measured and rewarded (Blackburn and Valerdi, 2009; Chiesa et al., 2008; Shuman et al., 1995). Therefore, it follows that when traditional project management tools are applied to measure cost and schedule variances, project managers will concentrate on meeting costs and schedule targets as they complete the prescribed work packages. Unfortunately, in the case of CPS, achieving favorable variances do not guarantee that the system is maturing as planned. Rather, what happens is that by focusing on the work packages and ensuring that they are achieved on time and within cost, the project manager is unable to view the system as a whole and assess its overall readiness. For example, when novel CPS development tasks are identified, there is no certainty that they will lead to the desired maturity[6] of the system as those tasks are completed. Those work packages are educated guesses based on expertise, data, and standards. As more information regarding the new technology becomes available, some tasks may have to be revised. However, by focusing on the project tasks and ensuring that they are achieved on time and within cost, the project manager may not realize this until much later. Maintaining a system-wide view is most important during the earlier phases of the development lifecycle when uncertainty is still high but corrective actions are still manageable (Tang and Otto, 2009). To encourage a system-wide perspective of the development process, the project manager must use system-wide process measures to control the development of systems through proper planning, scheduling and monitoring.

The importance of system scheduling, monitoring and evaluation and the absence of an accepted effective approach was a motivation to examine current practices through a review of the literature in product and systems management and engineering, and related fields followed by verifications through our research contracts and roundtable discussions with industry and government. We used our findings to develop a conceptual framework for CPS planning, scheduling, monitoring and evaluation which can help project and engineering managers to control the development process and contribute towards its success. We applied the model to a CPS (i.e. space system undergoing development) to show how it works and establish theoretical validity.

Our study makes a couple of novel contributions to research. First, it provides managerial context to the use of a system-focused development scale (i.e. System Readiness Level [SRL]), which has been previously proposed as a CPS measure of developmental maturity (Sauser et al., 2008a,b). Secondly, this research illustrates how a system development plan can be translated into a readiness-oriented scheduling, monitoring and evaluation approach which is simple and familiar to project and engineering managers. The approach is also interactive and absorbs changes in technologies, architecture and cost estimates.

2. Methodology

In order to understand how the development of a complex product system can be effectively controlled, we reviewed the literature, analyzed the concepts that previous researchers have suggested and talked to professionals involved in the field.

Our review of the literature focused on the fields of Systems Engineering Management which is currently the main arena where the development of complex products is discussed. We also included the fields of New Product Development (NPD) projects as well as the management of Research and Development (R&D). The search was done electronically using the key phrases *project control, scheduling, monitoring, evaluation, system maturity, system readiness*. We specifically looked for research output which focused on what factors were identified to be important to the success of the projects. More specifically, we wanted to know if Control (scheduling, monitoring and evaluation) was an important factor. It was. We then narrowed it down to the characteristics of the control mechanisms which would be effective as far as complex product systems are concerned. Those which were relevant are the ones cited in this paper. In cases where multiple papers have been published by the same author(s) on the same topic, we only used the most complete versions — not necessarily the earliest nor the latest versions. The goals were to establish the role which control mechanisms play as well as identify what characteristics such mechanisms should have in order to be effective.

In the event that practice in the field may be ahead of the literature, we discussed our initial findings with a small group of practitioners from the Department of Army, Northrop Grumman Corporation and Lockheed Martin Corporation. This group added their own thoughts to our efforts.

These early research activities allowed us to identify the characteristics of a management approach which can be effectively applied towards successful development of complex products. We, then, formulated a new approach which was discussed with an expanded group of practitioners and researchers. This group included participants from Analytic Services Inc., JB

[6] In this paper, "maturity" or "developmental maturity" is the characterization of the development status of a technology/integration/system that can be quantified to determine the corresponding readiness (Tan et al., 2011).