System Engineering Effectiveness: A Complexity Point Paradigm for Software Intensive Systems in the Information Technology Sector

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Abstract: The ability to assess systems engineering effectiveness within organizations is receiving increasing emphasis. Most of the published research has been generic and domain independent. This article describes a technique to (1) estimate the cost and schedule of projects at an early concept phase, and (2) determine the effectiveness and efficiency of using systems engineering methods and practices on large integration projects in the information technology (IT) sector. A method based on the complexity point concept has been developed and is discussed. This technique has been validated on a number of IT integration projects. Resulting observations are presented in this article. Results do not provide conclusive evidence that systems engineering (on its own) enhanced productivity on specific projects. However, preliminary information indicates that application of formal systems engineering practices and methods, in conjunction with effective project management and test processes, can significantly improve development and integration productivity.

Determining the effectiveness of systems engineering (SE) practices and methods on programs and organizations is increasingly being addressed within the community. In a resource constrained development environment the question of return-on-investment with regard to SE is gaining more visibility. A number of research and industry-government groups have addressed this question over the last two decades in an effort to quantify in the value of implementing SE principles and practices.

Honour (2003) has discussed and depicted the intuitive value of SE, as shown in Exhibit 1. He states that as more time and resources are spent in the early design phases of a project (using SE), the time and cost savings in the later phases will be even larger.

The Rational Software Corporation (Davis and Leffingwell, 1996) described relative costs to repair a system requirement error with respect to the project stage in which errors were found. As shown in Exhibit 2, based on experiential data, Rational observed that the cost to fix the error is directly proportional to how early the error is discovered within the project life cycle. They also indicate that up to 40% of total project costs can be attributed to rework costs. Based on these observations, one could hypothesize that total project costs can be lowered by effectively defining project requirements early in the life cycle (and discovering project errors at that time).

The Standish Group (Standish, 1995) performed a study showing requirement-related errors as responsible for 34% to 44% of project failures. In the late 1980s, Werner Gruhl, of the NASA comptroller's office, presented findings that showed the effect of upfront work (including use of SE) on project quality (Gruhl, 1992). His findings were based on data from 32 projects and are shown in Exhibit 3, which reflects the ratio of dollars spent on project definition phases (NASA's phases A and B) against actual project cost overrun. The findings show that spending a greater percentage of project resources during project definition (up to 15%) can reduce total project costs.

In 2001, the International Council of Systems Engineering (INCOSE) initiated a project through the Systems Engineering Center of Excellence (SECOE) to quantify SE value. As part of this initiative, Mar and Honour (2002) and Honour (2003) indicated a positive correlation between effective SE and relative project success. They collected project data from different companies, organizations, and industries to try to determine the effectiveness of SE. Some of their findings are shown in Exhibits 4 and 5.

The INCOSE study relates aspects of development quality (cost and schedule overruns) to SE use. In this study, Mar and Honour address the notion of SE effort as a function of SE quality and percentage composition of SE cost in the context of

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