Abstract

System openness refers to the extent to which system components can be independently integrated, removed, managed, or replaced without adversely impacting the system. Openness (of a system and/or architecture), though intuitively understood, remains difficult to quantify in terms of its value for safety-, mission-, and infrastructure-critical systems. Examples of these critical systems include: aircraft, rail, industrial controls, power generation, and defense systems – all of these systems are characterized by large procurement costs, large life-cycle sustainment costs and very long support lives (e.g., it is not uncommon for these systems to be supported for 30 or more years).

Generally, it is taken for granted that the use of open systems decreases the total life-cycle cost of a system. Leveraging existing open technology, including commercial-off-the-shelf (COTS) components, avoids many costs associated with designing custom components, and reduces the time required for development and eventually refresh of a system. The use of open systems helps mitigate the effects of obsolescence, lengthens the system's support life, and allows for the incremental insertion of new technologies. Component design reuse also eliminates redundant components, thus reducing logistical costs.

However, building systems from open standards and commercially available components often relies on the use of generalized technology containing unnecessary additional functionality, which increases the system's complexity and adds new failure paths and additional qualification overhead. In other cases, it may be necessary to modify COTS components to meet performance requirements, thereby adding costs. In addition, the enterprise that manages the system often has no control over the supply-chain for COTS components, which adds supply disruption risk and introduces the risk compromised.

Previous efforts to establish the value of openness have relied on highly qualitative analyses, with the results often articulated as intangible "openness scores". Such approaches do not provide sufficient information to make a business case or understand the conditions under which life-cycle cost avoidance can be maximized (or whether there even is a cost avoidance).

This dissertation is focused on creating a general model for quantifying the relationship between system openness and life-cycle cost that can be used to optimize system openness strategies for critical systems, an outcome that could significantly reduce system sustainment costs. This work is composed of the following tasks: 1) Mining of public-source materials to solidify what is known and believed about the relationship between open-systems attributes and life-cycle costs. 2) Development of a multivariate model and associated simulation that quantifies the relationship between openness and life-cycle cost for systems composed of hardware and software. 3) A case study of the life-cycle cost difference between two implementations of the same system with differing levels of openness (the US Navy A-RCI sonar system on Los Angeles and Ohio class submarines is the case study system for this dissertation). 4) Generalization of the understanding of the relationship between system life-cycle cost and openness is achieved through a generic analytic model. This model efficiently estimates the relationship between relative life-cycle cost and system openness, considering relevant parameters. It enables the determination of optimum system openness without the need for running a detailed simulation.