Chapter 12
System-of-Systems Cost Estimation:
Analysis of Lead System Integrator Engineering Activities

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ABSTRACT

As organizations strive to expand system capabilities through the development of system-of-systems (SoS) architectures, they want to know "how much effort" and "how long" to implement the SoS. In order to answer these questions, it is important to first understand the types of activities performed in SoS architecture development and integration and how these vary across different SoS implementations. This article provides results of research conducted to determine types of SoS lead system integrator (LSI) activities and how these differ from the more traditional system engineering activities described in Electronic Industries Alliance (EIA) 632 ("Processes for Engineering a System"). This research further analyzed effort and schedule issues on "very large" SoS programs to more clearly identify and profile the types of activities performed by the typical LSI and to determine organizational characteristics that significantly impact overall success and productivity of the LSI effort. The results of this effort have been captured in a reduced-parameter version of the constructive SoS integration cost model (COSOSIMO) that estimates LSI SoS engineering (SoSE) effort.

INTRODUCTION

As organizations strive to expand system capabilities through the development of system-of-systems (SoS) architectures, they want to know "how much effort" and "how long" to implement the SoS. Efforts are currently underway at the University of Southern California (USC) Center for Systems and Software Engineering (CSSE) to develop a cost model to estimate the effort associated with SoS lead system integrator (LSI) activities. The research described in this article is in support of

the development of this cost model, the constructive SoS integration cost model (COSOSIMO). Research conducted to date in this area has focused more on technical characteristics of the SoS. However, feedback from USC CSSE industry affiliates indicates that the extreme complexity typically associated with SoS architectures and political issues between participating organizations have a major impact on the LSI effort. This is also supported by surveys of system acquisition managers (Blanchette, 2005) and studies of failed programs (Pressman & Wildavsky, 1973). The focus of this current research is to further investigate effort and schedule issues on "very large" SoS programs and to determine key activities in the development of SoSs and organizational characteristics that significantly impact overall success and productivity of the program.

This article first describes the context for the COSOSIMO cost model, then presents a conceptual view of the cost model that has been developed using expert judgment, describes the methodology being used to develop the model, and summarizes conclusions reached to date.

COSOSIMO CONTEXT

We are seeing a growing trend in industry and the government agencies to "quickly" incorporate new technologies and expand the capabilities of legacy systems by integrating them with other legacy systems, commercial-off-the-shelf (COTS) products, and new systems into a system of systems, generally with the intent to share information from related systems and to create new, emergent capabilities that are not possible with the existing stove-piped systems. With this development approach, we see new activities being performed to define the new architecture, identify sources to either supply or develop the required components, and then to integrate and test these high level components. Along with this "system-of-systems" development approach, we have seen a new role in the development process evolve to perform these activities: that of the LSI. A recent Air Force study (United States Air Force Scientific Advisory Board, 2005) clearly states that the SoS Engineering (SoSE) effort and focus related to LSI activities is considerably different from the more traditional system development projects. According to this report, key areas where LSI activities are more complex or different than traditional systems engineering are the system architecting, especially in the areas of system interoperability and system "ilities;" acquisition and management; and anticipation of needs.

Key to developing a cost model such as COSOSIMO is understanding what a "system-of-systems" is. Early literature research (Jamshidi, 2005) showed that the term "system-of-systems" can mean many things across different organizations. For the purposes of the COSOSIMO cost model development, the research team has focused on the SoS definitions provided in Maier (1999) and Sage and Cuppan (2001): an evolutionary net-centric architecture that allows geographically distributed component systems to exchange information and perform tasks within the framework that they are not capable of performing on their own outside of the framework. This is often referred to as "emergent behaviors." Key issues in developing an SoS are the security of information shared between the various component systems, how to get the right information to the right destinations efficiently without overwhelming users with unnecessary or obsolete information, and how to maintain dynamic networks so that component system "nodes" can enter and leave the SoS.

Today, there are fairly mature tools to support the estimation of the effort and schedule associated with the lower-level SoS component systems (Boehm, Valerdi, Lane, & Brown 2005). However, none of these models supports the estimation of LSI SoSE activities. COSOSIMO, shown in Figure 1, is a parametric model currently under develop-