AN INNOVATIVE GRADUATE PROGRAM IN SYSTEMS ENGINEERING

Mihir K. Das, Ph.D.
California State University, Long Beach
and
Forrest S. Keeler
Rockwell International, Seal Beach, California

Abstract

The College of Engineering of the California State University, Long Beach (CSULB), in partnership with Rockwell International, has created an innovative graduate program in Systems Engineering (SE). The main objective of this SE program is to offer to selected graduate engineers already employed in industry a Master's Degree curriculum which can significantly enhance their understanding of disciplines directly related to their own assignments, increase their worth, and enhance their performance in the U. S. industry marketplace using up-to-date SE related disciplines and skills.

Introduction

A key issue of high industrial and national importance is the identification and translation of sophisticated, state-of-the-art system techniques from independent research and isolated complex military programs to university research, to the university curriculum, and to graduate level students for eventual valuable dissemination and application to multiple other programs in the student's work environment. Systems Engineering is such a discipline. It has been in existence for a considerable time and it has grown out of a host of methodologies that have emerged over time to support Systems Design Engineering as a key element of complex design teams.

This paper reports on our recently developed Graduate program in SE focused toward development of complex systems. Each such complex system requires a clear Systems Engineering Master Plan, a set of SE Methodologies, appropriate tools, a rigorous requirements flow-down technique, and a comprehensive Project Management Plan to enable system design and project management for effective and efficient human interaction. In today's technology, the total Systems Engineering Life Cycle from womb-to-tomb may take as many as 40 years or more (e.g., the B-52 and C-13 **O** aircraft), and each stage in the System Life Cycle and its system ramifications must be clearly understood by the engineer.

The Fundamental SE Concepts

The subject of Systems Engineering has been discussed by many researchers and authors [1 - 12]. According to Rhode, et al. [1], SE can be viewed in many different ways: a discipline involving engineering and management science; a design process technology; a methodology for defining or designing "anything"; an organizational concept and a "culture" transcending all project oriented actions and activities; and more conventionally, a

structured orderly process for the design and engineering of a complex system. In the context of defining, building and using complex systems, it is vital to comprehend the difference between *functional* and *physical* requirements the system must satisfy. The present Graduate program is built around the SE methodologies and tools to answer such questions. It emphasizes the need of designers of complex systems to decompose large system design requirements into smaller subsystem requirements, and eventually to component requirements, to design and build the components (be they hardware or software or both), to integrate the components into subsystems, and then to "integrate-test-deliver-install" the resulting complete system as a network of subsystems. A great deal of material related to customer's requirements is available in the following standards: MIL-STD -499, 1S0 9001, the U.S. Air Force Integrated Management System, and EIA IS 632. The curriculum of the SE program takes into account the appropriate applications and integration of these standards and the people dimension of Total Quality Management (TQM) principles and the fundamental concepts of Concurrent Engineering.

The Systems Engineering process, with its key terms, has been well defined in Department of Defense literature and EIA IS 632 as shown in FIGURE 1. It states the following: *The system engineering process is applied iteratively throughout the system life cycle to translate stated problems into design requirements, providing an integrated system solution consisting ofpeople, products and processes with the capability to satisfy customer needs [12].*

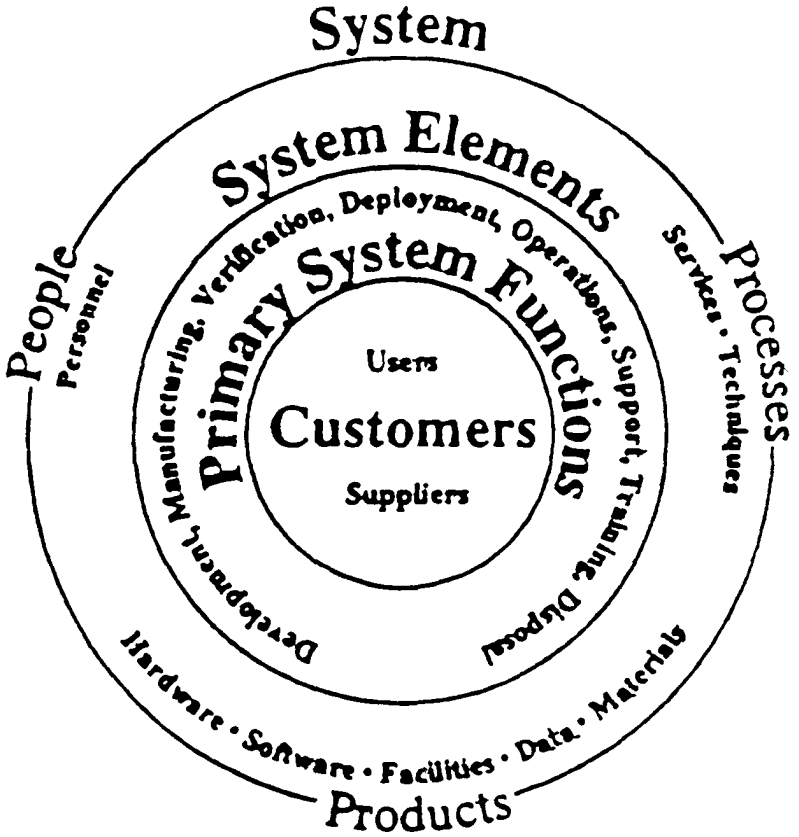

FIGURE 1: KEY TERMS IN SYSTEMS ENGINEERING [12]

The Main Goal

The main goal of the inter-disciplinary "Master of Science in Engineering - Systems Engineering Emphasis" program is to increase the Systems Engineering understanding of practicing engineers and at the same time, offer them the expertise, tools, typical problem exposure and knowledge for planning and executing complex programs. The program is motivated by the need for technical leaders in the system integration environment who have depth in their own disciplines and who are eager to develop new breadth and depth in SE in anticipation of future complex program assignments.

The Curriculum Structure

The curriculum structure of the program is graphically presented in FIGURE 2. The program starts with a set of "core" courses. CSULB College of Engineering has developed these core courses and related course material at the graduate level focused toward offering a Master of Science in Engineering (MSE) with specific emphasis on Systems Engineering. The core course set emphasizes the important elements of Systems Engineering including the SE process, SE related procedures/tools, the Concurrent Engineering concept (i.e., considering the voices of Engineering, Logistics, and Manufacturing up-front for every program), and the "functions-purposes-approaches" of Integrated Product Development (IPD) and Integrated Product Teams (IPTs) as applied to real industry programs.

As shown in FIGURE 2, planned innovative approaches include examination of various SE related industry lessons learned, participation in comprehensive training regarding integrated SE Principles, Logistics Overview, Advanced Manufacturing Technology & Processes, and Engineering Management& Policy courses as the heart of a "core" SE course set.

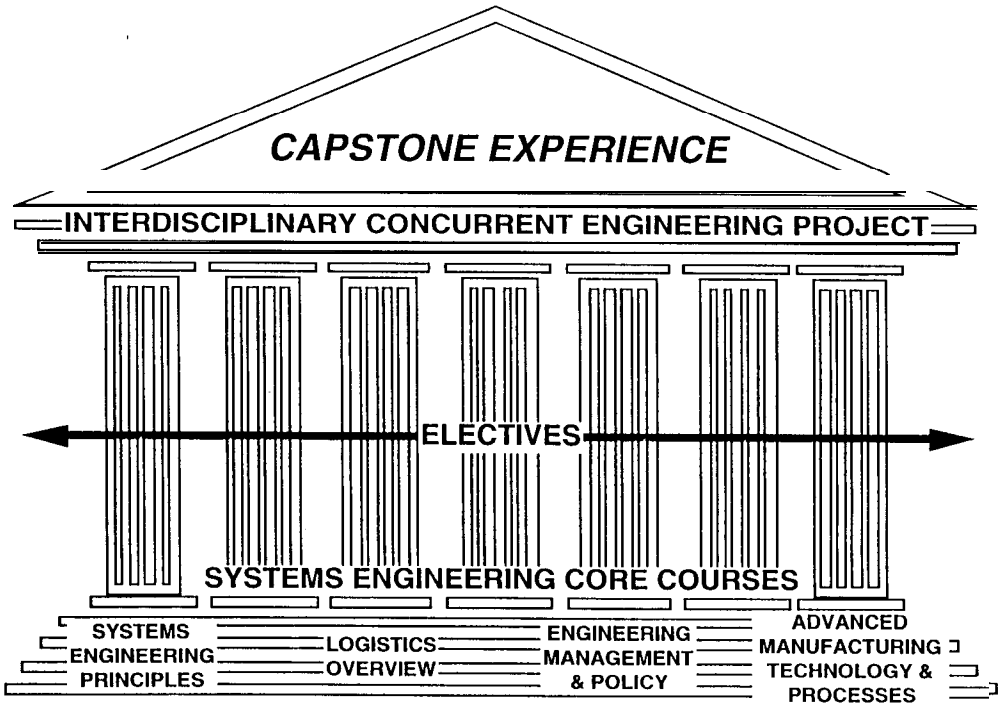

FIGURE 2: THE STRUCTURE OF THE PROGRAM

The program requires a minimum of 30 semester units, successful completion of which leads to a Master of Science in Engineering. To satisfy the requirements of Systems Engineering Emphasis, 12 units must be taken covering the four courses shown at the foundation of FIGURE 2. An additional 6 units of Advanced Engineering Mathematics are also required to satisfy the M. S. standard. The remaining 12 units are to be taken as follows: 6 units of elective courses from the graduate Engineering or Science curriculum, and 6 units of an Interdisciplinary Concurrent Engineering Project. The courses are offered in the evenings so that fill-time working students can participate in the program.

The Unique Features of the Program

An added feature in the CSULB/Rockwell International planning is development and incorporation of a realistic "Interdisciplinary Concurrent Engineering Project" into the program in lieu of a Master's Degree thesis. The goal is to provide the Engineering student "hands-on" Capstone experience with a real research program into various aspects of the SE process, SE procedures, SE tools, and SE products as part of the MSE-SE program.

The MSE-SE program "core" course set (12 semester units) and Interdisciplinary Concurrent Engineering project (6 semester units) combined with graduate level Engineering "electives" of each student's own choosing (12 semester units) will result in significant preparation at the graduate level for enhanced student participation and performance in the 21st Century U. S. industrial marketplace.

Conclusions

The details of a Graduate program in Systems Engineering at the Master's level are discussed. It has been jointly developed by the California State University, Long Beach and Rockwell International to meet the growing needs of industry. The program is flexible enough to accommodate students with specific experience in a wide variety of Engineering disciplines and involvement in complex programs. It will provide new expertise in understanding, working, and managing multi-disciplined SE processes. It will result in a significant enhancement to the student's training, in-place industry experience and value in the marketplace .

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Biographical Information

DR. MIHIR K. DAS

Dr. Mihir K. Das is the Associate Dean for Instruction and Professor of Mechanical Engineering at the California State University, Long Beach (CSULB). He directs the Graduate programs at CSULB, including the *Ph.D. in Engineering Mathematics* offered jointly with The Claremont Graduate School. He holds a Ph.D. in Mechanical Engineering from the Birmingham University, England. A regular contributor to the ASEE Annual Conference, Dr. Das has published extensively with over 80 papers to his credit. His current interests are *New Academic Programs, Teaching & Learning Innovations,* and *Total Quality Management (TQM).*

FORREST S. KEELER

Mr. Forrest S. Keeler is a senior member of the Technical Team at Rockwell International in Seal Beach, California. He has 40 years of industry experience, 33 of which is at Rockwell. His expertise includes the following: Software/hardware system design and development, Avionics systems, Command & Control systems, Ground instrumentation systems, Cryptographic systems, Major weapon system development, and Systems Engineering process technique development.