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Steve earned his Bachelors of Science degree in Physics at the University of Maryland and his Masters and Doctorate in Physics at the University of Colorado in Boulder. After graduating, he was hired by the NASA Jet Propulsion Laboratory (JPL) where he developed new and innovative microwave, millimeter-wave and submillimeter-wave remote sensing systems. In 2000, he joined Northrop Grumman Electronic Systems where he served in a variety of systems engineering and program management roles. In 2006 he moved to Fort Wayne, Indiana to accept the position as the IPFW Professor of Systems Engineering and Director of the Center of Excellence for Systems Engineering.

He is a member of the International Council on Systems Engineering, Project Management Institute, Institute of Electrical & Electronics Engineers, and the American Association for the Advancement of Science.
A Systems Approach to Engineering “Economics”

Introduction

A new course has been instituted at the graduate level that emphasizes a systems approach to teaching finance, economics, cost accounting and cost management. Topics were selected to increase the relevance of the course, thereby improving the alignment of this “engineering economics” course with industrial needs. The course’s pedagogical approach required eliminating some traditional engineering economic topics to make room for a number of new subject areas. The intent of restructured course was to create a framework that provides engineers with the tools needed to help them engineer for cost.

Industrial Practices

It is important for engineers to have a basic understanding of finance, economics, accounting and cost management because money influences and motivates behavior. In today’s competitive environment both development cost and product cost can be critical in determining the success of a new product. Increasingly, cost drives the choice of development practices, design decisions, technologies and product features.

The success of a new product is determined by its ability to satisfy customer needs in a cost-effective manner. Reducing product cost requires efficient development processes that generate cost-efficient designs. The recognition of industry’s need to streamline their approach to product development has led to the creation of capability maturity models that provide companies with a framework with which to document, benchmark and improve their core development processes. The Carnegie Mellon Software Enterprise Institute concisely articulates the premise behind this trend towards process-based management:

“The quality of a system or product is highly influenced by the quality of the process used to develop and maintain it.”

It was also important to review the ways in which engineers incorporate economics, accounting, finance and cost management in their jobs. Topics that needed to be taught as well as topics that should be discarded were identified. For example, most companies have accountants and business people that are responsible for corporate finances. These people handle issues such as taxes, capital financing, pricing and overhead rates. While these topics may be of academic interest, engineers rarely are involved in decisions related to these issues. On the other hand, engineers are routinely required to estimate cost, manage budgets, make design decisions, formulate subcontracting strategies, measure project progress, control cost and manage cash flow. These needs led to the redesign of the engineering “economics” course.

Offering this course at a senior or graduate level allows integration of the accounting, finance and economic topics with the student’s understanding of engineering and product development. Table 1 lists a variety of engineering assignments and some of the key knowledge areas
<table>
<thead>
<tr>
<th>Engineering Assignment</th>
<th>Knowledge Areas</th>
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</thead>
</table>
| Product Design                       | • Scope Assessment  
• Cost Estimation  
• Cost as an Independent Variable (CAIV)  
• Design to Cost (DTC)  
• Cost Reduction Strategies  
• Economic Decision Making  
• Risk Analysis and Management |
| Proposal Development                 | • Scope Assessment  
• Cost Estimation and BoE Preparation  
• Setting Cost Reserves  
• Risk Analysis  
• Budgeting (IMP/IMS)  
• Net Present Value  
• Resource Planning  
• Contracts and Financial Incentives |
| Work Package Management              | • Reading an Account Statement  
• Cost Management  
• Earned Value  
• Overhead Calculations  
• Cash Flow |
| Process Improvement And IRAD Planning | • Earned Value  
• Cost Estimation  
• Economic Decision Making  
• Cash Flow  
• Net Present Value |
| Technical Subcontract Management     | • Scope Assessment  
• Reading an Account Statement  
• Cost Control and Earned Value  
• Contracts and Financial Incentives  
• Risk Management  
• Net Present Value  
• Cash Flow |
| Manufacturing Support                | • Production Economics  
• Cost Reduction Strategies  
• Economic Decision Making  
• Risk Analysis and Management |
| Legal Requirements                   | • GAAP  
• Sarbanes Oxley Compliance  
• Nunn-McCurdy Breach |
| Corporate Financial Awareness        | • Financial Reporting  
• Cash Flow  
• Capital Budgeting  
• IRAD Budgeting  
• Contracts and Financial Incentives  
• Corporate Valuation |
Course Topics

The topics that have been selected for this new course address the ways in which cost and economics affect both product design and development processes. This course was designed for both senior undergraduates and graduate students. Another measure of relevance is the observation that the topics in this course are aligned with the thirty-two earned value management system (EVMS) guidelines outlined in the ANSI/EIA-748-A Standard for Earned Value Management Systems 2.

The course starts with concept of “project scope,” which is defined through the introduction of the work breakdown structure (WBS). The WBS then serves as the basis for the structure of the project cost accounting system, generation of cost estimates and project cost control. This treatment of scope leads into lectures on project accounting, budgeting and cost estimation. Key to these concepts is the notion that these processes span the entire project lifecycle. Sarbanes-Oxley compliance is then covered as a specialty topic to drive home the importance of ethical cost estimating, accounting and management. Methods for optimizing product design including CAIV, design-for-cost and trade studies are taught as system analysis techniques. A unit on risk management and earned value addresses the need for system control. The course then concludes with the concept of the time-value of money and economic considerations underlying project selection and investment strategies. Table 2 provides a typical, top-level listing of course topics.

Table 2. Typical Class Syllabus Listing

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project Scope and Work Breakdown Structures / Introduction to Cost Estimation</td>
</tr>
<tr>
<td>2</td>
<td>Cost Estimation: Methods and Basis of Estimate (BoE) Preparation</td>
</tr>
<tr>
<td>3</td>
<td>Accounting Systems and Sarbanes Oxley / Cost Allocation and Cost Pools</td>
</tr>
<tr>
<td>4</td>
<td>Structuring and Managing Overhead / Traditional and Activity Based Cost Accounting</td>
</tr>
<tr>
<td>5</td>
<td>Scheduling and Budgeting</td>
</tr>
<tr>
<td>6</td>
<td>Cost Risk and Risk Management</td>
</tr>
<tr>
<td>7</td>
<td>More Risk and Cost Reserves / Trade Studies and Economic Decision Making</td>
</tr>
<tr>
<td>8</td>
<td>Cost as an Independent Variable (CAIV) / MidTerm Exam</td>
</tr>
<tr>
<td>9</td>
<td>Design to Cost / Cost Reduction Strategies</td>
</tr>
<tr>
<td>10</td>
<td>EVMS and the EV Baseline</td>
</tr>
<tr>
<td>11</td>
<td>Monitoring Cost Performance / Overruns and Nunn-McCurdy</td>
</tr>
<tr>
<td>12</td>
<td>Production Economics</td>
</tr>
<tr>
<td>13</td>
<td>Cash Flow and Net Present Value</td>
</tr>
<tr>
<td>14</td>
<td>Subcontracting / IRAD and Capital Budgeting / Corporate Economics</td>
</tr>
<tr>
<td>15</td>
<td>Corporate Valuation and Financial Statements</td>
</tr>
<tr>
<td>16</td>
<td>Final Exam</td>
</tr>
</tbody>
</table>

Work Breakdown Structure

The course begins with the introduction of the Work Breakdown Structure (WBS), which defines project scope3,4. The Project Management Institute5 defines a WBS as a “deliverable-oriented hierarchical decomposition of the work to be executed by the project team to accomplish the project objectives and create the required deliverables. It organizes and defines the total scope of
the project.” The WBS identifies all the work that needs to be estimated, scheduled, budgeted and managed. It is the foundation for successful project planning, execution and control. The WBS provides the framework for assigning responsibility for work, estimating cost, structuring the chart of accounts, reporting status and authorizing work.

**Accounting**

Accounting systems facilitate planning, coordination, financial control and decision-making. Categories for segregating costs such as direct, indirect, overhead, G&A, sunk, opportunity, etc. are introduced to familiarize students with key concepts and standard vocabulary. The definition of cost pools and the factors that determine overhead rates are addressed giving students an understanding of how material, personnel and other costs are calculated. The Generally Accepted Accounting Principles (GAAP) is contrasted against the activity base costing (ABC) approach cost accounting. The purpose of this section is to provide insight into how money flows through a company, the value of tracking cost data and the importance of managing overhead costs in increasing profitability. This subject area also includes a section on how to read, interpret and use a project cost report.

The accounting section provides an opportunity to address present-day legal and ethical issues. This is especially important in the aftermath of Enron, WorldCom, and Tyco. This discussion is capped with a short overview of Sarbanes-Oxley compliance (SOX) and the legal requirements to accurately estimate and report cost.

**Cost Estimation**

The three types of cost estimation techniques are introduced (i.e., parametric, analogous and engineering estimation). The differing levels of effort, accuracies and tools required to generate estimates with each of these techniques provides guidance on when each of these technique is appropriate. Engineering estimation, which is inherently a “bottoms-up” approach, is keyed to the WBS. This section emphasizes that cost estimation is a process that spans the development lifecycle with requirements for increasing accuracy with increasing project maturity. Homework in this area furnishes students with an opportunity to learn how to generate a formal basis of estimate (BoE).

**Contracting**

The types of contracts used to contract or subcontract work help determine the level of risk and type of pricing strategies. The contractual arrangement and incentive structures used to purchase commodities or developmental items are key to ensuring that the project goals can be achieved at minimum cost. Since many engineers are involved in managing subcontracts, a foundation in the three classes of contracts (fixed price, cost-plus and level-of-effort) and their application will help students learn how to maximize the probability of getting the desired contracted service, result or product on-time and on-budget.

**Budgeting**
Budgeting is presented by flowing down the WBS into a set of tasks, which can then be scheduled. This topic introduces the concept of schedule networks and application of Gantt charts\textsuperscript{5,15}. Student schedules derived from a WBS can then be used to create a budget and cost profile.

**Risk**

The premise underlying risk management is best introduced using a quote from Former Secretary of Defense Donald Rumsfeld\textsuperscript{16}. In response to a question at a press conference he stated: “Reports that say that something hasn't happened are always interesting to me, because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns -- the ones we don't know we don't know.” Risk management techniques manage the “known unknowns.” Techniques for risk identification, assessment and methods are tailored to specific issue of cost risk\textsuperscript{5,17,18}. Risk response strategies are discussed including setting margins and mitigating, transferring and avoiding risks\textsuperscript{5,17,18}.

**Decision Making**

Good decisions are based on objective information, rely on well-defined customer preferences, are quantitative, transparent and documented\textsuperscript{19}. Quantitative project selection techniques are important in creating a growth-oriented project portfolio. The use of objective data and quantitative methods in decision making has been shown to maximize a company’s profitability. Additionally, decisions are routinely made in product engineering that affect the methods of development and determines product cost and quality. In development, design decisions based on quantitative, independent data improve product cost effectiveness.

**Value Engineering**

Methodologies for designing to cost (DTC) and treating cost as an independent variable (CAIV) have become standard techniques for achieving ambitious cost targets\textsuperscript{20,21}. Including these system level approaches in the curriculum provide students with tools for designing and developing cost-sensitive products.

**Earned Value**

The earned value measurement system (EVMS) integrates project scope, schedule and resources to provide an objective measure of completed work, work in progress and scheduled work\textsuperscript{22}. (Some of you may know EVMS as the DoD Cost Schedule Control Systems Criteria (C/SCSC)\textsuperscript{22}. ) EVMS is introduced as a technique to monitor and control cost during project execution. In the homework, students use their WBS to develop their own EV baseline. This exercise has helped to demystify program-level assessments of cost and schedule performance.

**Project Overruns**
A review of troubled government projects is included to highlight standard causes for cost overruns such as inadequate analysis of project scope, incomplete requirement definition, poor cost estimation and weak project management and control. This discussion naturally transitions into a presentation of the Nunn-McCurdy amendment that governs how Congress handles significant cost growth (i.e., breaches) on large DoD programs (> $2.2B)\(^2\). This issue is of special interest since many of the graduate students work for defense contractors.

*Production Economics*

A treatment of manufacturing economics provides students with an understanding of how capturing increased market share will drive down the product cost point. A break-even analysis is presented to illustrate how a company determines the minimum number of units that must be sold to ensure that product revenue will cover development and manufacturing costs\(^2\).

*Time Value of Money*

Time value of money encompasses concepts such as net present value (NPV) analysis of investments and calculation of equipment depreciation\(^2\). (An early articulation of the time value of money was made by Wimpy in the Popeye cartoon when he offered to: “gladly pay you Tuesday for a hamburger today.” Wimpy’s approach to buying a hamburger predates the credit card and provides an illustration of how time can be used to manage cash flow and reduce cost. Techniques for analyzing cash flow under various inflation assumptions are used to demonstrate the importance of time in determining profitability\(^2\).

*Corporate Finance*

The course ends with an overview of how to read a company’s annual report. Emphasis is placed on what is important as both a prospective employee and an investor. For students who are not employed, this exercise has turned out to be an invaluable lesson and has helped them glean information, which has impressed managers during job interviews.

*Conclusion*

In summary, a new course has been developed that provides engineers with a working knowledge of relevant finance, economics, accounting and cost management concepts and techniques. This course is designed to better prepare students with the tools to be successful in today’s competitive environment, where cost-efficiency is the key to profitability.

*Bibliography*

18. *Risk and Issue Management – Principles and Practice*, Dr. Iqbal Noor, P.E., CCE, PMP, Program Manager, PMOLink Inc.
23. United State Code, Title 10, Subtitle A, Part IV, Chapter144, §2433