

The Design of a Certificate Course for Chief Engineers

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Abstract

The companies that participate in the Joint Arizona Consortium for Manufacturing and Engineering Education for Tomorrow (JACME²T) have expressed concern about the preparation process for future Chief Engineers and other technical leaders. There are two principal factors: the current generation is approaching retirement and the challenges of future technology demand an even greater combination of breadth and depth of understanding.

A series of short courses has been prepared to address some of the skills required by potential chief engineers. The courses can be taken individually or they can be combined into a non-academic certificate.

To formulate the certificate requirements, we followed the methodology used by the participating companies to design complex products. A detailed evaluation of the chief engineer job specification and skills led to an analysis of best practice and courses already available to JACME²T and the companies. The translation into specific course modules was undertaken by the authors and with additional contributions from academic and industry experts. The full certificate will be delivered in 2004 and it has potential to be extended as a component of a distance MS degree within the Arizona universities.

Introduction – the challenge

High-technology companies face a quiet crisis of technical leadership. Their products are systems characterized by the technical complexity, global support requirements and massive connectivity of processes. While these demands increase, the supply of experienced technologists who could take on the chief engineer role is diminishing fast. Figure 1 shows a demographic from one company that is typical of the aerospace industry.

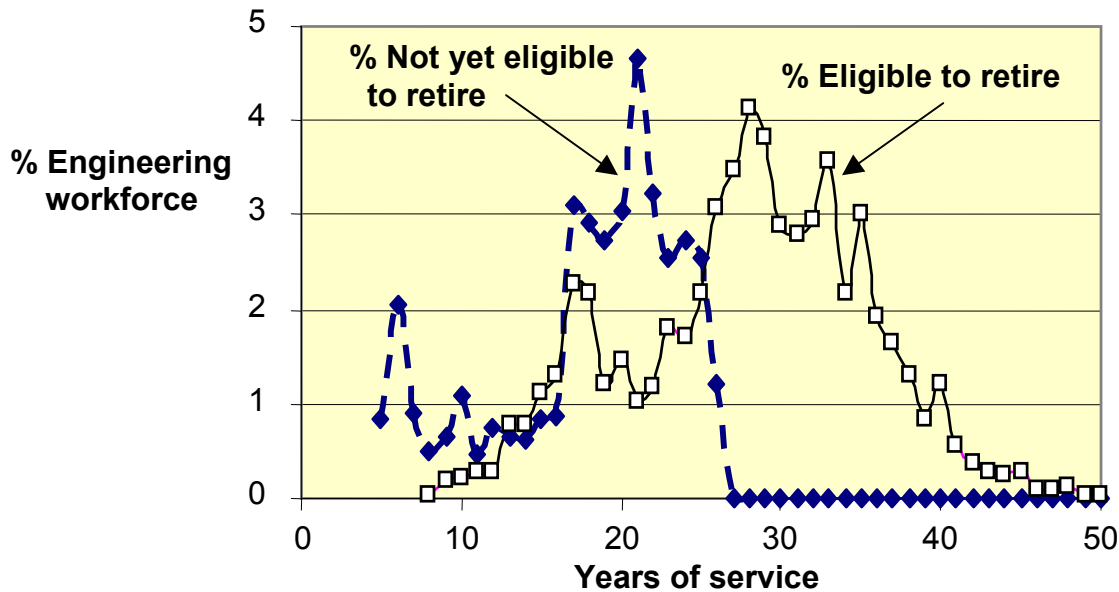


Figure 1: Proportion of engineering workforce able to retire (in one company).

The data can be summarized more starkly by saying that 60% of the technical workforce is presently eligible for retirement. Even more dramatic – almost 90% of these key personnel have 15 or more years of service so the replacement problem is not likely to ease in the future. The chief engineer sits at the top of this intellectual food chain and is thus the most endangered species.

A member of the JACME²T Policy Board raised the brain drain issue at a board meeting. It was quickly apparent that all member companies faced similar technical leadership questions. The problem was most immediate for the aerospace companies but the cluster of electronics companies in the Consortium is heading the same way. An action came out of the meeting to look at what could be done to capture the knowledge and train the next generation of Chief Engineers.

JACME²T provides training for its member companies by sharing internal resources and also by commissioning academic presenters to develop and deliver new course material. Topics are usually focused into 1 or 2-day courses which may then be combined as certificates. A certificate typically requires about 100 hours of class time. In the past 3 years, JACME²T has delivered more than 250 Project Management and 70 Software Engineering certificates. The challenge from the Board was to develop a Chief Engineer Certificate as the first step in the path to a long-term solution.

Solution methodology

New JACME²T programs are defined and commissioned by Learning and Competency Teams (LCTs) with both academic and industry members. The Design LCT was asked to look at what could be done and took on the Chief Engineer Certificate realization.

Over the past 5 years, the Design LCT has examined the evolving practices and needs of the constituent companies. Most use some form of phased-gate review approach to drive their design process. After a review of the member company practices, the Design LCT adopted a generic 9-step process:

1.	Identify customer needs	Do we want the business?
2.	Define the design task	
3.	Quantify system specs	
4.	Define major sub-systems	Make the business case
5.	Launch preliminary design work	
6.	Detailed design work	
7.	First product realization (prototype)	Go for it !
8.	Series production	
9.	Field support and feedback	Did we win?

There is a distinctly different combination of design skills involved at each stage and at each phase gate is an opportunity for review and consolidation. There are, however, no hard boundaries and the dashed lines show 4 other key break-points in any project. Each company can relate its own practice to these 9 steps so it is a good generic template for the design process.

Not surprisingly, the Design LCT treated the Chief Engineer Certificate as a product and worked through the 9 steps to define and deliver the program. One of the primary roles of a chief engineer is to oversee the progress and balance of these 9 steps so there is some ironical justification in using the same process to design the Chief Engineer Certificate.

Program definition

The starting point was to define the role of chief engineer. Every company has its own job specification but all shared similar attributes:

- Broad experience of the whole product realization process.
- Sufficient depth of understanding to follow, review and challenge the subject experts in all facets of the program.
- Represent best practice clearly and concisely.
- Understand the quantitative interactions between engineering, markets and costs.
- Communicate complex interactions in effective terms to all stakeholders.

There is frequently also a management role but that varies a lot from company to company. We have therefore concentrated on aspects of technical communication and interaction. To further explore the job and its implications, groups of chief engineers in the member companies were interviewed. As well as identifying ways in which they could directly contribute to the planned certificate, this process also highlighted a number of current issues:

- Change at all levels is continuous and endemic.

- The effects of the recession over the past 3 years has been much more far-reaching than the economic data suggests.
- The expected period of product support is now much greater than the life of manufacturing processes.
- Design is moving towards a consulting role (as in civil engineering) and is diminishing as a critical business competency.
- Computer-based design tools combined with highly capable production processes allow fast and almost continuous product improvements.
- There is job security in technical expertise – under some conditions.
- Think the unthinkable. If it is cheaper, it will happen.
- Costs sit at everyone’s elbow – but is cost the only relevant metric?

These outcomes have many implications. Whatever model we may have for future product development, it is severely challenged by the operational conditions that prevail now. There was once a steady progression from engineering to management functions. Now businesses are operated more as financial entities with engineering and manufacturing as procured services – from anywhere in the world. The Chief Engineer sits in the middle trying to reconcile technical excellence with a good bottom line.

In most high-technology programs, the most demanding – and frustrating – design challenges arise at the beginning. The first 4 steps listed above constitute the “fuzzy front end”. All assumptions can be questioned and few specifications are immutable. This is very much the domain of the Chief Engineer. Everything is about balance and trade-offs. Experience brings deep understanding of best practice but it can never degenerate into conservative incrementalism.

The scope of the Chief Engineer functions is represented by figure 2. Each of the segments may have an optimized solution but their reconciliation demands great foresight and patience as well as lots of down-to-earth expertise. The components in figure 2 can be defined in many other ways. However, we needed a starting point that would provide adequate scope to demonstrate interactions and serve as a platform to show how specific skills would contribute to the whole task.

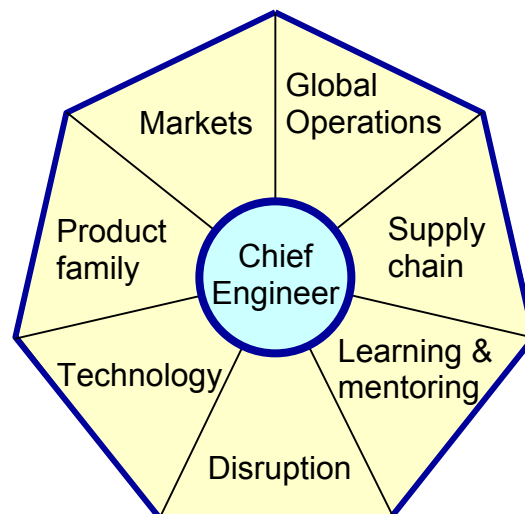


Figure 2.
Scope of Chief Engineer functions.

Major components

To determine the topics that should be included in the certificate, the team undertook an analysis of existing company training materials that were being used for training their senior level project and systems engineers. This was done by setting up a matrix of companies and courses then looking for common needs. It was found that in the cases where specific material was required, it was usually of a proprietary nature and would be taught in-house.

An abbreviated version of a very large spreadsheet is shown in Table 1:

Topic	Company			
	A	B	C	D
Decision Making	X	X		
Critical Thinking	X	X		
Six Sigma Tools	X	X		X
Risk Management	X	X		X
Trade Studies	X	X		
Systems Design	X	X		
Dynamic System Modeling	X			
Requirements Analysis	X	X	X	
Design Process	X	X	X	
Requirements Management	X			
Design Change Management			X	
Design Process & Tools		X	X	

Table 1. Relevant courses from contributing companies

It focuses on outcomes skills. During the analysis, 2 classes of activity were excluded:

1. Topics that were already covered adequately in all the participating companies.
2. Topics that had proprietary or company-specific implications, eg for safety or regulatory conditions.

The outcome was a list of skills that had general applicability and would serve as a good foundation to demonstrate the skills that potential chief engineers would be expected to develop.

The next step was to combine these skills into a series of course modules to form a conventional activity-skills matrix. Course modules of 8 – 16 hours each provided a good blend of subject focus with delivery flexibility. The topics selected for the certificate were:

- *Overview of Chief Engineer role*
- Requirements analysis

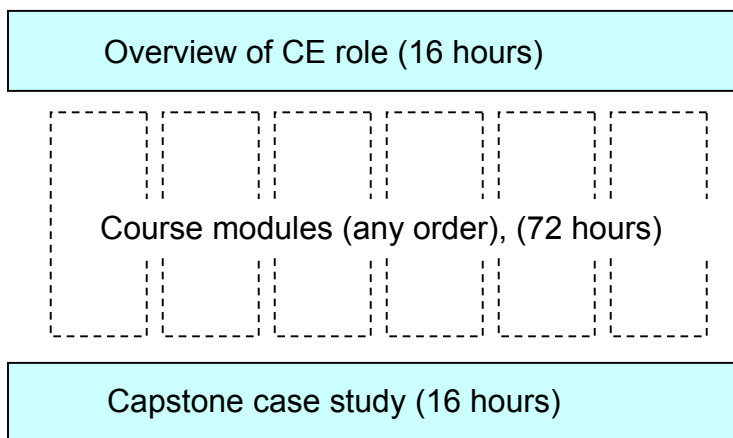
- Quality function deployment
- *Proposal response*
- System requirements – flow-down & validation
- *Make the business case*
- Risk management
- Root cause analysis
- Design for reliability
- Legal issues
- *Capstone case study*

The italicized titles have been created to meet the needs of the new certificate. However, it is likely that the strategic viewpoint that is so much a feature of chief engineer activities will lead to substantial modifications to existing courses.

The case study is still the subject of some discussion with the company chief engineers. At one extreme, a real design activity is too proprietary and driven by its own timetable to fit into a training program. At the other extreme, conventional (eg. business school) case studies do not have sufficient latitude to show technical decision-making. The best option is an in-depth analysis of a product to examine the interplay between design goals and assessment criteria.

Execution and evolution

Modularity allows a great deal of flexibility to meet individual and company needs. A ‘sandwich’ structure was therefore adopted:



The overview provides a stand-alone introduction that should appeal to many who are thinking of a chief engineer career but are not yet ready to take the whole certificate. Similarly, the individual course modules that form the bulk of the certificate can be taken in any order or simply as single modules within a different training program. The first complete delivery of the whole certificate has been scheduled throughout 2004.

The approach taken to create this certificate has demonstrated the robustness of the 9-step design methodology. We also knew that it takes time for a committee from several companies to deliver a working program. In this case, the design phase has lasted almost 2 years. However, a few issues have emerged as we translated principles into practice:

- The changes in industry operations over the past decade have been profound.
- Reconciling continuous technical change with aggressive pricing and long-term market support is a new ball-game.
- Job descriptions for chief engineers are evolving and there is no good template.
- Our certificate is a prototype that will undoubtedly undergo many changes as it meets the demanding expectations of the customers.

Although some of the planned course content appears in current MS courses, they are spread across many departments. As part of the JACMET policy to extend the training experience with the engineering workforce back into academia, features of the certificate are being considered for a new type of post-graduate qualification.

Biographical information:

John Robertson has been Professor of Microelectronics at ASU's new East campus since 2001. He was previously a Program Director with Motorola and serves on the JACME²T Design LCT and the Technical Advisory Board.

Paul Hruska is Engineering Director at Honeywell Engines. He chairs the JACME²T Design LCT.

Bill Charlton is an Engineering Department Manager at the Boeing Apache helicopter plant in Mesa. He is a member of the JACME²T Design LCT.

Dave Lowery has been Managing Director of JACME²T since 2001. He was previously an Executive with Honewell.

Ron Thomas is a Senior Principal Engineer at Raytheon Missile Systems in Tucson. As well as being a member of the JACME²T Design LCT, he is a member of the TAB and chairs the Continuous Improvement LCT.