Impact of Industrial Partnership Experience on Engineering Education: Case Study with Boeing Company

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Abstract

The objective of the Boeing - A. D. Welliver Faculty Summer Fellowship is to impact on the content of engineering education in the U.S. Universities and Colleges in ways that will better prepare future engineering graduates for the practice of engineering in a world-class industrial environment. To accomplish this noble objective, every year since 1995, the Boeing Company competitively selects ten Faculty Fellows across the nation’s Universities to visit Boeing operations in Seattle, Philadelphia, Huntsville and Wichita. Thus, the ten Faculty Fellows are exposed to the key elements of industrial competitiveness and the practice of engineering by enabling them to "look over the shoulders" of working engineers at several levels of the technical and management career paths. The program allows Faculty Fellows leave Boeing with an appreciation for their customers’ needs and to form a network of contacts with engineers and scientists within Boeing Company for the purpose of research and development. I had the opportunity to work and do joint research with sixty engineers and five managers at Boeing during the fellowship program.

Introduction

The eight-week program began with one-week workshop centered about the theme: “Industrial Competitiveness and the Practice of Engineering.” The workshop succinctly describes the environment in which engineering of the future will be practiced and it includes the following main elements:

• The meaning of being customer driven.
• Environment, attitude and beliefs that lead to world class competitiveness (WCC).
• Economics and economic interactions in the practice of engineering and research.
• The importance of focusing on processes and process improvement.
• Cycle time, cost, variation, and customer satisfaction as key measures for business success.
• Role of "people skills" in engineering in a team environment.
• Technical versus management career paths.
• The process of system integration.

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The integrated relationship between manufacturing engineering and design engineering.

Factory processes and culture.

The first week workshop was followed by a sequence of six week custom-tailored "shadowing assignments" in which each Faculty Fellow "looked over the shoulders" of practicing engineering professionals in the field of the Faculty Fellow's specialty. The shadowing assignments were across different levels of technical and management career paths.

The Fellowship Program concluded with a second one-week workshop which captured and crystallized the understanding of the practice of engineering and research; and reflected upon the essential attributes of engineering graduates that would best position them for a rewarding, exciting, and productive careers. Each Faculty Fellow was given the opportunity to present a personal plan to initiate activities aimed at improving engineering education, and to discuss what Boeing, the National Science Foundation (NSF), and other private companies and government agencies could do to further catalyze positive change in engineering education. The program was exciting, educational, and very successful. It is my hope that through this publication, other companies would be made aware of such a noble program initiated by the Boeing Company, and is willing to participate in it.

**Custom Tailored Shadowing Assignments**

The planned shadowing assignments for each Faculty Fellow was different and unique to their teaching and research interests; and mine fell under two categories because of my interest and technical specialty in manufacturing processes and materials. Three weeks of the shadowing assignments were spent with the Boeing Defense & Space Group Operations Technology under the directorship of Mrs. Kathryn Whiting. The other three weeks were spent with Boeing Commercial Group Operations Technology under the supervision of Mr. Tom Tobey, Director.

**Assignment with Boeing Defense and Space Group Operations Technology**

The shadowing assignments and research covered a variety of areas including the following technologies and operations: electronics (manufacture of printed wiring boards); manufacturing techniques for composite components for airplane wings, including resin transfer molding (RTM) process; chemical processing and finishing processes such as alodining and anodizing; rapid prototyping technology; induction heating and ceramic die making for superplastic materials such as titanium; and friction stir welding and electron beam welding processes. There were a lot of fruitful discussions between me, the engineers and first line managers and their directors. The team group meetings were especially helpful because we were able to learn from each other. At these meetings, I had the opportunity to offer technical input on their manufacturing processes and some research areas. Detailed discussion on this topic has been provided in the Final Report to Boeing, under the section entitled "Research Areas of Interest to the Boeing Company" [Owusu, 1995]. This shadowing assignment took place at the Kent facility of Boeing Company (near Seattle). I had the opportunity to work with thirty engineers and technicians directly involved with solving factory floor problems.

**Shadowing Assignment with Boeing Commercial Group Operations Technology**

The shadowing assignments included the following technologies and research operations: Airplane Door Assembly (with "lean manufacturing" concept); Bluestreak and Assembly; Wire Shop and Assembly; Fuselage Assembly Process (old process and new Fuselage Assembly Improvement Team/Program - FAIT); Composite Manufacturing Technology; and Tubing Operations at Everett plant. All the other operations, except tubing, are located at the Renton Facility (near Seattle). The facilities at Auburn and Frederickson exposed me to the following operations and technologies: sheet metal forming, welded duct operation, non-destructive inspection
and metrology, super-plastic hot metal forming, and composite manufacturing. I worked with forty-two engineers and technicians with varied technical background and disciplines.

**Lesson Learned During Faculty Fellowship Program**

Lessons learned during the eight week Faculty Fellowship Program were invaluable. It is not possible to put a “price tag” on it. I learned about Boeing Company (university customer), new ideas, joint research opportunities, techniques about manufacturing and new technologies which, are directly applicable to university classroom, research and laboratory situations. Only highlights of lessons learned during the summer fellowship at Boeing Company have been summarized in this publication.

**Workshop on Industrial Competitiveness and Engineering Practice**

The workshop organized by the Executive Management Team for the Faculty Fellows clearly demonstrated that Boeing Company is a world class company and that the upper management is totally committed to the vision of world class competitiveness (WCC). We were exposed to the global goals and vision of the Boeing Company.

Since 1916, Boeing Company has made machines that fly - - carrying people and their goods the world over, defending the peace, and helping in the exploration of space. In the process, Boeing has become one of the nation's largest companies, and the world leader in designing and building commercial jet airplanes and military airplanes.

The Boeing Company is organized into three major business segments: commercial airplanes, defense and space, and computer services. In 1993, the company revenues exceeded $25 billion: making Boeing the number one U.S. aerospace firm and among the nation's largest industrial corporations. Worldwide, Boeing and its subsidiaries employ about 120,000 people, with most of the major operations located in the Seattle-Puget Sound area in the State of Washington.

**Desired Attributes of Engineering Graduates**

The list presented here as the expectations of Boeing from new engineering graduates (or as Boeing puts it: Desired Attributes of an Engineering Graduate) was compiled through discussions with management, engineers, and factory floor workers during the six week shadowing assignments. This list is quite comprehensive and detailed. This research was conducted to determine the attributes that universities should attempt to impart to their students as they go through the engineering education system, in order to meet the needs of their customers (i.e. entities that employ new engineers). The ten most important desired attributes found during the investigation include the following:

1. **Communication Skill**
   - Engineers must be able to communicate well both in written and oral form.
   - Ability to prepare and deliver technical presentations.
   - Must be able to communicate or promote their ideas to the management and their peers.

2. **Technical Knowledge**
   - Strong knowledge base in materials, materials selection, and chemistry of materials.
   - The interactive behavior of materials in different environments.
• Manufacturing processes and finishing processes.

• Strong background in probability and statistics, statistical process control, continuous quality improvement, and design of experiment.

• Knowledge of risk analysis

3. Ability to Define Problems Clearly and Come up with Solutions

• System design - analysis and synthesis.

• Techniques of solving practical engineering problems.

• Usage of computer as a tool, but not as a means to an end of solving all engineering problems.

• Avoid being biased in engineering conclusions to problem solutions.

• Understanding the interpretation of qualitative and soft data (incomplete and imprecise data).


• Must be knowledgeable on environmental issues, undesirable chemicals and processes.

• Must understand how decisions on materials selection, processes, and manufacturing system selection affect the environment (concept of product life cycle).

• Knowledge about design, costing, and scheduling based on deliverables.

5. Team Work (Concurrent Engineering) in a System

• Concept of re-engineering through teamwork.

• Being able to work in a system by understanding the philosophy and processes of a company as a system.

• Know about the concept: plan, design, implement, and control.

• Knowledge about organizational development, cost evaluation of design and research.

• Understanding of business reality--profitability and cost reduction are the bottom lines.

• Enthusiasm in team work environment.

• Learn to build "team leadership skills" in an integrated production team (IPT) environment.

• Focus on the customer need.

6. Critical and Creative Thinking

• Capability to picture in the mind (in a three dimensional form) how to assemble complex components together into a whole unit (product).
7. **Practical Knowledge (not the same as experience)**

- Reasonable "shop tolerance" capabilities.
- Cost associated with tight tolerances.
- Trouble shooting skills.
- Awareness of difference between real world and modeled or laboratory world.

8. **Concept of continuing education while working**

9. **Engineers must be willing to go to Manufacturing/factory Floor to work with Shop Floor people to help solve problems.**

10. **Understand the Concept of Cross Functional Training/Learning (in order to satisfy customer needs).**

**Knowledge Gained in Manufacturing Engineering Practice at Boeing Company**

General knowledge was gained by observing the operations of a world class competitive company like Boeing. Over the past fifteen-(15) years, dramatic changes have taken place throughout the leading business organization in the world, including Boeing. The revolutionary changes have taken the form of strategic initiatives and supporting business practices. This has given rise to the term “world-class competitiveness” (WCC) in business. The term **“world-class”** is defined as being one of the best in the world in terms of both overall success and in the performance of key practices that lead to overall success. When referring to organizations like Boeing, the term “world-class” is generally used as a comparison against all other organizations, not just those in one's own industry. Regardless of the size and type of a company, the following characteristic business practices are common to world-class companies, like Boeing:

- Clear understanding of what business they are in.
- Customer driven.
- Quality first, quality built in processes.
- Value and develop a committed and competent workforce.
- Safe and effective workforce.
- Coordinated and cooperative cross-functional operations.
- Reliable process focused on value added, waste elimination, and simplification.
- Manufacturing as total system.
- Management leadership.
- Continuous quality improvement (CQI).

Throughout the eight week summer fellowship, it was observed through research that everybody at Boeing from the Chief Executives to the factory floor workers, was working hard towards a common goal of achieving and
maintaining world-class competitiveness in order to remain number one in the aerospace industry. To achieve this goal, Boeing Company trains and empowers employees to control quality at the source. Employees take responsibility for the quality of their work. Indeed, Boeing Company understands and practices the underlying assumptions that guide world-class management and people practices: that people are a source of competitive advantage and that the success of the company is linked to the well being of its people.

**Environmentally Conscious Manufacturing Observed at Boeing Company**

My most recent research interest involves “environmentally conscious design and manufacturing and bioconversion of waste materials into useful products.” Therefore, a research was conducted to determine how Boeing was complying with the concept of *environmentally conscious design and manufacturing*.

Cleaning electronic hardware to remove impurities or contaminants resulting from handling and assembly operations has long been a standard practice. Aesthetic (visual), electrical test, and performance requirement often govern the level of cleaning required. There is, however, accumulating scientific evidence that chlorofluorocarbons (CFCs) are damaging to the Ozone ($O_3$) layer in the stratosphere [Monastersky, 1987]. The stratosphere is, of course, the ozone-rich layer of the earth’s atmosphere beginning roughly six to ten miles above the earth’s surface and extending about a height of thirty miles.

In recent years, the ozone problem has been broached under the auspices of the United Nations. In 1987, the so-called Montreal Protocol was proposed by the United Nations Environmental Program (UNEP) to regulate CFCs and halons [Anonymous, 1987]. The halon molecules contain bromine in addition to chlorine and fluorine. The bromine radical is even more destructive towards ozone than chlorine by a factor of 10 [Hymes, 1991]. Similar U.S. Environmental Protection Agency (EPA) regulations are also in places governing emission and disposal of these chemicals. The EPA 33/50 Program (Industrial Toxic Project) aims, through voluntary pollution prevention activities, to reduce releases of a target 17 chemicals, nationwide, by 50% by 1995. The list of EPA 17 target chemicals include:

<table>
<thead>
<tr>
<th>Lead</th>
<th>Benzene</th>
<th>Carbon Tetrachloride</th>
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<tr>
<td>Chloroform</td>
<td>Cadmium</td>
<td>Chromium</td>
</tr>
<tr>
<td>Cyanides</td>
<td>Mercury</td>
<td>Tetrachloroethylene</td>
</tr>
<tr>
<td>MEK</td>
<td>MIBK</td>
<td>Trichloroethylene</td>
</tr>
<tr>
<td>Nickel</td>
<td>Toluene</td>
<td>Trichloroethane</td>
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<td>Xylene</td>
<td>Dichloromethane</td>
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The research and development (R&D) teams of the Boeing Company involving chemical cleaning, welded ducts, and tube cleaning have done a phenomenal work in designing systems and developing new chemicals to replace those target 17 chemicals.

**Boeing Company Improves Processes through Lean/Pull Manufacturing System**

The use of integrated manufacturing production system (IMPS) is a strategy for the factory with a future (FWAF). This strategy is based on a linked-cell manufacturing system (L-CMS). The L-CMS provides for a continuous flow (or smooth movement) of materials through the factory floor (plant). The linked-cell...
manufacturing system was invented at the Toyota Motor Company by the vice president for manufacturing, Taiichi Ohno, but he never gave it a name. Now, U.S. companies call it “lean or pull manufacturing system”.

The “lean manufacturing or IMPS” method is being installed by Boeing plant in Renton for the airplane doors and at Auburn for the fabrication of welded ducts. This is an optimal layout for manufacturing and assembly. It was strongly recommended by me that Boeing should continue to implement the lean manufacturing or IMPS technique on a small scale like the door assembly and the welded ducts first and succeed before expanding the lean manufacturing concept to other parts of the company.

Concluding Remarks:
Personal Benefit Arising from the Boeing Fellowship

As a direct result of the Boeing Fellowship, I have developed two new courses in the Department of Industrial Engineering at my University and have written two books for those courses. The two courses are Concurrent Engineering and Environmentally Conscious Design and Manufacturing. The topics for the books developed and used to teach these courses are 1. Systems Approach to Concurrent Engineering and 2. Environmentally Conscious Design and Manufacturing.

References

Anonymous, Montreal Protocol on Substances that Deplete the Ozone Layer (Final Act), 1987.


Acknowledgements

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