Industry Lessons Learned and Application to Engineering Education

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Significant change is taking place in the way aerospace products are designed and developed. These changes involve not just technology but represent some fundamental 'Gre-engineering" of design and development processes. In addition, much of this "re-engineering" is representative of actions that are being implemented throughout all of U.S. industry. McDonnell Douglas Aerospace (MDA) has found that this new way of doing business has significant implications in the educational requirements for our technical workforce. These changes should be understood by universities and new working relationships must be developed, among industry, universities and governments.

Substantial and continuing reductions in government expenditures on military and space programs, increased global competition, and a downturn in commercial aviation sales, are the primary factors driving change in the product design and development process. These have forced the aerospace industry to focus sharply on reducing development time and producing higher quality, lower cost products that satisfy all customer requirements.

McDonnell Douglas Aerospace (MDA) has been learning from companies that have succeeded in creating high quality, reduced cost products within short time-to-market intervals. We are applying "Best Practices" from these successful companies to our high performance aircraft and missile product lines. One of the key finds of MDA's implementation of "Best Practices" is a requirement for significant amounts of education and training in not only new tools and techniques but also in the processes we use to design, develop, and produce our products. Engineering education should also be modified to include these new fundamentals.

In the past, we had only partially integrated our product design and manufacturing processes. Additionally, the processes within both design and manufacturing had also been largely serial in nature. Each sub-process has been populated by engineering specialists. Initial designs were created and forwarded to these specialists for analyses of attributes such as weight, mechanical integrity/strength and reliability/maintainability. The annotated designs were then returned for modification and update. This process was iterated several times until an acceptable design was created. Traditionally, this updated design was then forwarded to manufacturing specialists who established fabrication and assembly sequences and instructions, processing requirements, tooling requirements, design and fabrication of tooling, and quality assurance measurement and inspection requirements. The process has been lengthy and product/process changes originated at many points in the development path. In many cases, even though the product could be manufactured, time spans have been quite long and the products have suffered multiple defects.



Applying a New Process

MDA has been solving this problem by implementing "concurrent engineering" to simultaneously and collaboratively design and develop the product and its manufacturing processes. Two (2) major elements in the application of concurrent engineering are the creation of product teams and the availability of clearly defined and documented process descriptions. The ability to effectively function in this new environment requires education and training in specific sets of skills and knowledge.

The purpose of "concurrent engineering" is the economical development and manufacturing of products that satisfy customer requirements and expectations The definition of customer requirements and, more importantly, the identification of priorities among these requirements and the establishment of relationships between customer requirements and product attributes is a critical first step in the design process. This requires some understanding of factors that drive customer preferences, including legislative constraints. Furthermore, designers must be able to synthesize systems that incorporate requirements from a large number of specialty disciplines.

Design engineers must learn the fundamentals of the manufacturing processes applicable to their areas of expertise. These include issues such as materials properties, materials forming and processing, machining, fastening techniques, tool design and electronics packaging and fabrication. Additionally, the costs and cost trade-offs involved in the manufacturing process must be addressed. Training and education in economic issues should include topics such as scheduling techniques, inventory control techniques. cycle time reduction principles, and the use of manufacturing process models and simulations.

Training and education in issues related to group dynamics is the second important element of effective team work. Communication skills, both written and spoken must be developed. This includes training in the specific topic of effective presentations. There are skills to be learned relative to conducting meetings, team leadership, and effective listening. Lastly, there are skills involved in compromise, creativity, and team member selection that should be learned to maximize the benefits of team operation.

There are also a set of specific tools that MDA has found to be of particular benefit in reducing both development and production cycle-time and product defects. They can be taught in a modern engineering curriculum. These are: 1) Quality Function Deployment (QFD), 2) Risk Management, 3) Design for Manufacture and Assembly (DFMA), 4) Design for Manufacturability (Six Sigma), 5) Variability Reduction (Taguchi), and 6) Statistical Process Control (SPC). These tools contain elements that inherently encourage the integration of the design and manufacturing processes.

The New Process Achieves Results

MDA has been applying the principles and tools outlined herein to most of its product lines. An ongoing redesign activity on the F- 15 program illustrates the quantified benefits of these approaches. Formers in the center fuselage of the aircraft were assembled from numerous sheet metal pieces held together with mechanical fasteners. These formers have been redesigned as single piece machining. The product and process design was refined by a team of design, manufacturing, and tool design experts with an emphasis on



simplification. The resulting product has 38% fewer parts, 49% fewer fasteners, 45% fewer fastener types, uses 559'0 fewer fabrication and assembly tools, and can be assembled in 75% less time with a 29% reduction in defects.

The F/A- 18E/F Hornet has shown similar cost-effective results. The F/A- 18E/F is much larger than previous models but has 33% fewer parts and an associated large reduction in fastener count. The simplification in airframe structure was accomplished by a systematic application of DFMA. For example, one-piece bulkheads replace a sheet metal buildup that had 90 separate parts. The new bulkheads cost \$3,700 less than their sheet metal predecessors and reduced production time by twenty (20) days.

Educational Requirements

While the new processes and tools have been demonstrably effective, MDA has found that their effective and rapid implementation is constrained by a lack of knowledge and training within our technical workforce. We are investing heavily in education to change the situation. We have an extensive internal training program, known as the Voluntary Improvement Program (VIP), involving courses prepared and presented by MDA technical specialists after normal working hours. For example, MDA has recently completed the development of a comprehensive program for training our Manufacturing Engineers. The specific curricula have been defined from an extensive "shopping list" of candidate subjects. The current program, representing a semester's worth of full time college credit hours, was developed for today's work environment. Manufacturing Engineers are expected to perform at complex levels in team environments. MDA's program is directed at providing a broad background knowledge of design requirements, the manufacturing process in its entirety, and specific team performance skills.

We also provide university tuition and book expense reimbursement to over 3500 employees in the St. Louis area alone. During 1995, 560 of these employees earned degrees or certificates.

In evaluating the capabilities of our employees who are recent graduates from engineering schools, MDA sees several prominent shortcomings.

- 1. New hires must serve excessively long apprenticeships before they become fully productive.
- 2. Too few of our engineering graduates have any idea of how to work in teams or how to manufacture anything. Fewer still seem to understand the process of large-scale, complex system integration, which characterizes so much of what we do in our industry.
- 3. Those students who are judged the "best and brightest" on the basis of grade point average are frequently those who have worked hardest in a highly competitive academic environment of separate, specialized courses, and are often least prepared to work cooperatively in teams to engineer an integrated complex system which is economically and operationally viable.

There is evidence of an increasing awareness, throughout both industry and the university community, of the need for changes in engineering education. Organizations such as the American Society for Engineering Education (ASEE) and the Accreditation Board for Engineering and Technology (ABET) have taken



leadership roles in identifying changes and proposing actions for implementation. The Boeing Company has taken an aggressive approach to creating change and has developed several innovative approaches to implementing their visions.

During the latter half of 1993, The Boeing Company began an initiative to improve relations with universities and to enhance engineering education at the national level. Boeing proposed to invite a group of "working level" faculty members from a cross section of engineering disciplines and universities to meet with a group of company personnel to address two questions:

- 1. What are the issues that must be addressed in order to be effective in improving the quality of engineering graduates?
- 2. What is the best use of company resources to enhance engineering education?

This resulted in two Boeing-University Workshop meetings in February and July 1994. The primary results of these meetings were:

- 1. Establishment of a Faculty Fellowship Program intended to bring into the company ten faculty members each year for a two-month period to demonstrate what the graduates of their program actually do in professional engineering and manufacturing practice.
- **2.** Establishment of a \$50,000 per year Boeing Outstanding Educator Award for individuals or team who have made durable contributions to an educational program.
- 3. Development of a list of the desired attributes of an engineering graduate as viewed from a Boeing perspective.

In parallel with these workshops, various individuals within Boeing had been supporting efforts by the ASEE and ABET at the national level. It became clear that these initiatives were all reaching very similar conclusions regarding what needed to change. In addition to a third Workshop meeting in March 1995, Boeing also hosted a Government-Industry -University Roundtable meeting of representatives of all the major elements in "the engineering education problem." The intent was to bring together a broad range of representatives of the major stakeholding groups to begin a dialogue aimed at creating specific programs and actions which would lead to implementation of the recommendations by Boeing, the ASEE, and ABET.

Expanding Education Initiatives

MDA has joined with The Boeing Company in their attempts to change engineering education because we share a common experience-based perception of issues that must be addressed. We have done so in order to expand the aerospace industry participation in changing education and to begin developing a "single-voice" message from industry. MDA has sponsored and held an Industry Workshop on January 10-11, 1996. The objective of this workshop was to reach a consensus on overall objectives, define success criteria associated with those objectives, and develop plans for completing the success criteria. Executives from the following companies participated in the workshop.



- ABEX-NWL
- Aero Vironment
- Allied Signal
- Boeing
- GE Aircraft Engines
- Honeywell
- Hughes Electronics Co.
- Kaiser Aerospace
- Lockheed Martin

- McDonnell Douglas
- Northrop Grumman
- Parker Bertea
- Raytheon Aircraft Co.
- Rockwell International
- Solar Turbines Sunstrand Aerospace
- TRW Space and Electronics Group
- Williams International

The workshop produced agreement on pursuing three major results: 1) a "New Partnership" among Industry, Universities, and Government; 2) a timely industry voice to ensure relevant curricula; and 3) a balance between education and research in our colleges of engineering. Specific success criteria were defined for each of these targeted results. For example one of the success criteria for result 2 above was support for changes in the accreditation criteria recently proposed by ABET. Plans were developed for meeting each of the success criteria. These plans provide the structure needed to establish a truly unified voice for the aerospace industry and maintain momentum in pursuing engineering education change. Continuing action on these plans will be a major element of Industry-University -Government Roundtables to be sponsored by Boeing and Lockheed Martin to be held in 1996.

The large-scale design and development process changes taking place in the aerospace industry have been proven to be effective by results experienced by MDA. These are permanent changes which have revealed shortcomings in both the skills of our current technical workforce and in the education received by our engineering school graduates. Several initiatives to change engineering education. championed by professional societies, universities, or companies in various industry segments, have begun in the past few years. In many instances, these initiatives (e.g., modifications to the ABET criteria) describe changes that have been validated by MDA experiences on their aircraft and missile product lines.

MDA has joined with The Boeing Company to work towards developing a unified aerospace industry voice in three critical change areas: 1) Industry -University-Government Partnership, 2) developing relevant university curricula, and 3) balancing education and research. Several other major aerospace companies have recently joined with MDA and Boeing in developing implementation plans for achieving results in these areas,

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Biography

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