

**AC 2007-2535: ADVANCED AEROSPACE MANUFACTURING EDUCATION
PROJECT**

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Advanced Aerospace Manufacturing Education Project

Abstract

The Aerospace manufacturing industry segment is facing problems of a “graying” workforce. In addition they face the challenges of increasing productivity and integrating new materials accentuating the need to attract new engineers to the manufacturing workplace.

This paper describes a project funded by the National Science Foundation to examine the changing needs of the aerospace manufacturing industries, and to develop curricula materials to address those needs. These materials will be in the public domain and fit into existing engineering and manufacturing technology programs. The project is a joint venture between El Camino College, Wichita Area Technical College, Oregon Institute of Technology and Purdue University, and is supported by the Society of Manufacturing Engineers, The Boeing Company, Northrop Grumman Corp., Bell Helicopter, Lockheed Martin Corp., and other leading aerospace companies.

The first phase of this project involved conducting interviews with new manufacturing engineers and their managers, and results of these interviews are included.

Introduction

El Camino College, Wichita Area Technical College, Oregon Institute of Technology, and Purdue University have joined with leading aerospace manufacturing companies and professional societies to develop model curricula materials for manufacturing technicians and engineers working in the aerospace industry. This effort is funded by the National Science Foundation (NSF). These curricula will cover the gamut of the needs for manufacturing technologists in the aerospace industry and will also provide a common fluency in aerospace manufacturing procedures, processes, and terminology. The need for a pool of skilled technology workers in this industry is highlighted by the aging of the existing workforce and demands for increased manufacturing efficiency with an increasingly complex product. The civilian and military aerospace industries share some common problems thereby making this a national problem. This project brings together United States aerospace companies representing over 85% of the workers employed in this segment, four of the leading academic institutions involved in training and education of manufacturing technologists, and one of the leading professional societies serving this segment of industry. In addition, many leading international suppliers of equipment and services to the industry have pledged their support.

A proposal to fund this project was submitted to NSF under the Advanced Technological Education program. The proposal was not funded, but the project team was encouraged to immediately submit a planning grant to further develop the proposal. A planning grant was awarded under the same proposal number in August 2005, leading to a revised proposal which was funded for 3 years beginning in 2006.

Estimates of current employment in the aerospace sector, including its supply chain, range as high as 790,000 production workers ¹. It is also important to note that the production jobs in aerospace are compensated well. Aerospace production workers earn approximately 1.3 times the average hourly earnings for all manufacturing workers and 2.2 times that of hourly earnings for retail workers ². Total payroll for the US aerospace industry is in excess of \$98 billion dollars. The aerospace industry is nationwide, with California, Texas, and Washington states having the largest employment and with significant clusters in other states like Alabama, Arizona, Georgia, and Kansas ³.

It is important that a pool of workers exists that have the correct set of skills for this industry. The tools and techniques used in aerospace manufacturing are changing rapidly. It is important that the workforce not only have the technical skills to operate and maintain the equipment, but also an understanding of teamwork and modern manufacturing concepts such as lean manufacturing.

The traditional hand/master mechanic methods of manufacturing can no longer attain the demanding tolerances (Outside Mold Line (OML) +/- .005) that are inherent in modern aircraft. The complex systems that comprise a modern air vehicle require sophisticated technologies and components to attain the specified requirements for fabrication and assembly.

In addition, the national defense implications of the aerospace industry place additional importance on having a well trained and educated pool of manufacturing workers. The US cannot afford to lose the means to produce weapons to defend itself, and cannot depend on production of weapons systems in other countries for political and military reasons. In addition to the national defense considerations the aerospace industry contributed a trade surplus approximately \$31 billion to the US economy in 2004 ⁴.

The aerospace industry is unique in many areas that differentiate it from other manufacturing industry models, methods, processes and technologies. The types of varied materials, the cost of fabrication of the components, assembly tolerances, coatings and systems testing has generated the need for highly sophisticated types of manufacturing technology systems that are only produced by a limited number of manufacturer's world wide.

Project Plan

The goal of this project is to develop an educational model that is effective in preparing manufacturing technology practitioners for the aerospace industry. This group includes operators, mechanics and assemblers that are generally prepared with a two-year degree, and manufacturing engineers that are generally prepared through a four-year degree program. The project objectives are to:

1. Identify the competencies required of operators, mechanics, and assemblers working in the manufacturing area in the aerospace sector.
2. Identify the competencies required of manufacturing engineers working in the aerospace manufacturing sector.
3. Identify common technology and business practices in which both groups must be fluent.

4. Identify likely new technologies that will be incorporated into aerospace manufacturing and the training needed to implement it.
5. Develop curricula materials to prepare both groups.
6. Assist in the development of an assessment and certification tool to validate the preparation of aerospace manufacturing technologists.
7. Disseminate the model curricula to interested faculty.

The project will be divided into three phases, corresponding to the years in which the project will be funded.

The first phase of the project will set the baseline for the needs of the industry. These needs may be identified as specific technical requirements unique to aerospace manufacturing, general education (math, science, and communications) and manufacturing operations related issues (team work, lean manufacturing, quality assurance).

The needs assessment will consist of several elements. First a polling instrument has been developed to assess aerospace industries on current and near future needs. Leading aircraft manufacturers, as well as their suppliers, will be polled to estimate current and future needs, and new technologies.

In this phase faculty of El Camino College, Wichita Ares Technical College, Oregon Institute of Technology, and Purdue University will do on-site-visits to various aerospace manufacturing plants to gain first hand knowledge of the working environment and needs of the workforce.

Results of these efforts will be collated and reported to the Aerospace Manufacturing Consortium. The Aerospace Manufacturing Consortium is a group of aerospace manufacturers, their major suppliers, and representatives from academia that have come together to seek common solutions to manufacturing automation problems⁶. The Aerospace Manufacturing Consortium will schedule sessions at its quarterly meetings to allow the principal investigators to report and to receive feedback from other participants. An industrial advisor board has also been established, drawn from member of this consortium.

The final outcomes of the first phase of the project will be to outline model curricula and materials for manufacturing technologists at the two- and four-year levels. It is anticipated that much of this material will be in the form of modules that may be used as examples or case studies in an engineering or technology curriculum.

Phase 2 consists of defining the curricula materials. Using the information gathered in the first phase, the investigators will develop materials to help faculty introduce students to some of the unique aspects of aerospace manufacturing.

Phase 3 is the dissemination phase, where the curricula and the assessment tools will be packaged for use at community colleges, universities, and to industries.

The principal tool for dissemination will be regional meetings, where local industry and education personnel are invited to attend. Stipends to cover travel will be offered. These presentations will likely be in conjunction with Aerospace Manufacturing Consortium meetings,

Society of Manufacturing Engineers events, the Aerospace Outlook Conference and at trade shows to offer an extra incentive to the participants.

It is expected that the curricula material resulting from this project will be in two forms. First there will be complete courses that are geared to meet specific needs of the aerospace manufacturing sector. An example of this might be a course in composite materials. The materials developed would include a syllabus, lesson plans, text recommendations, etc.

Second, and probably the largest segment, will be modules to be used as part of subjects that are currently taught. For example, there may be a module designed for use in a statics or engineering mechanics course that illustrates basic principles with examples from aerospace manufacturing. These materials could be used with other textbooks to introduce students to problems and issues in the aerospace manufacturing segment.

In the seminars, these materials will be distributed and discussed.

The anticipated outcomes of the seminars are that the participants will

- receive the materials to be used in the courses and modules,
- discuss pedagogical concerns
- establish contacts with other educators servicing this industry segment
- be prepared to offer course materials developed through this project.

Phase 1 Progress

The first phase of the project is largely information gathering. A survey tool was designed to facilitate information gathering from industry. Three groups were targeted by this survey. The first group was engineers and technicians with 0 to 3 years of work experience. The focus of questions for this group was on their initial experiences in the workplace and how that related to their education.

The second group was the direct supervisors of the new engineers and technicians discussed above. The questions here focused on the job requirements and on how well new employees were prepared to address those job requirements. The last group was senior technical personnel and the questions asked of them were designed to glean information on new technologies that may be introduced into aerospace manufacturing in coming years.

Interviews were conducted both individually and in a focus group setting. Of the two, the focus groups tended to be more productive as participants fed off of each others comments.

The questions from for the interviews are presented below.

Interviews with personnel – typical questions

Senior Technical Personnel

What are important new technologies?

What are important skills for new engineers?

What are important skills for new manufacturing technicians?
What technical challenges do you see in the next 5 to 10 years?

Supervisor/Manager of engineers

What technical skills do new engineers need?
How often the skills above are employed?
What non- technical skills do new engineers need?
How often the skills above are employed?
Of the above, how well are students prepared to accomplish these directly out of school?
Does your company provide a system of training/ orientation/ mentoring to new engineers?
How long does this last?
What skills does this training/orientation seek to impart?
How is success monitored for the individual?

Supervisor/Manager of manufacturing technicians

What technical skills do new manufacturing technicians need?
How often the skills above are employed?
What non- technical skills do new manufacturing technicians need?
How often the skills above are employed?
Of the above, how well are students prepared to accomplish these directly out of school?
Does your company provide a system of training/ orientation/ mentoring to new manufacturing technicians?
How long does this last?
What skills does this training/orientation seek to impart?
How is success monitored for the individual?

Engineers with 0-2 years of experience

What do you do on a day to day basis?
What skills did you have to learn on the job?
How well did your education prepare you for the job you are now doing?
What were the most valuable courses taken? Why?
What were the least valuable courses taken? Why?
Would it have been helpful to have examples taken from aerospace manufacturing in your course work?
If so, what examples would you choose from your current job?

Results

Much of the work to date on this project has been in gathering information from industry personnel. Approximately 100 individuals from the three target groups discussed above have been interviewed.

Some significant finds are listed below.

For the new engineers;

- Day to day duties of new engineers
 - Although the duties of the engineers varied widely (from wiring design to fixture design) there were some common elements.
 - Most were tasked with problem solving, or troubleshooting, day to day problems
 - All were tasked with some form of communication/ liaison, typically either between design engineering and the shop floor, or the shop floor and the customer
 - Most were tasked with some form of documentation, such as parts lists, wiring lists, drawings
 - Dimensional analysis was often cited
- Skills the engineers had to learn on the job
 - Company specific software packages
 - Specific CAD systems
 - Working with large assembly drawings (mostly small part drawings in school)
 - “Social” skills – mentoring & helping others, dealing with union rules, influence without authority
 - In response to what percentage of their day to day duties did they learn on the job, the response ranged from 60% to 90%, with an average of about 80%
- On how well their education prepared them for the job
 - On a numerical scale of 0 (bad) to 10 (excellent) most rated education in the 7 to 8 range
 - Those with more experience (around 2-3 years) rated their education higher than those with less than one year
 - Very few dealt with PLC programming and robotics, but several cited a need for NC programming
 - Most agreed that school prepared them well for problem solving, but did not supply the “tool set” they needed for everyday activity
 - Over prepared in some areas & under prepared in other, thermodynamics cited as an example of being over prepared
 - School problems worked with a limited set of real world hardware; “Lego set” vs. the multitude of fasteners, etc in the workplace
- Most valuable courses taken
 - Design or project based courses, particularly with presentations required
 - Lab based courses
 - Computer modeling, CAD, geometric dimensioning and tolerancing
 - Internships very important
- Least valuable courses taken
 - General agreement that all the courses taken had some value
 - Some courses that the engineers would like to have had
 - Composites – manufacturing as well as design
 - Material selection and analysis
 - Lean Manufacturing systems & 6 Sigma
 - More statistical tools
 - Estimating, cost & time
 - Several cited redundancy. For example, taking English literature and then technical writing. Much of the same material.

- Would aerospace examples be helpful in education
 - Yes, should be embedded from the beginning
- What examples would you choose from your current job?
 - How large systems are assembled, not just design of components
 - Aerospace fasteners
 - Designing/ selecting seat mounts (analyzing load conditions, selecting standard hardware, etc.)
 - Make an assembly from a group of CAD models, analyze for make/buy decision, write assembly instructions

For the supervisors of the new engineers -

- What technical skills are required of new engineers?
 - CAD, solid modeling
 - Senior project / internship experience
 - Fluent with Microsoft Office, MS Project, data analysis with Excel, VBA
 - Process analysis / mapping, troubleshooting, root cause analysis
 - How to find information they don't know
 - Basic manufacturing processes
 - Fatigue analysis, material analysis/ selection
- What non-technical skills are required of new engineers?
 - Project management, time & cost estimation
 - Effective written communication
 - Ability to work with different groups, e.g., customers, management, vendors, shop floor, other nationalities
 - Earned value / cost value management
- How well prepared are students for these tasks?
 - Recent new hires have been good, well prepared
 - New hires are sent through a refresher course in engineering fundamentals
 - Training lasts 4 to 6 weeks
 - Typically mentored for 6 to 9 months
 - Gaps include-
 - Fabrication experience/ knowledge
 - Manufacturing work experience
 - Knowledge of moving line assembly
 - Product life cycle
 - Internships are particularly helpful, the more hands on fabrication, the better
 - Ergonomic design considerations
- What are the key technical challenges over the next 5 to 10 years
 - Automation
 - Robotics
 - CNC
 - Assembly
 - Non contact metrology
 - Business in a global environment
 - Effective web conferencing
 - Cultural awareness
 - Materials

- New titanium alloys
- Composites
- Both design parameters and manufacturing
- Retrofit of composite structure airframes

Conclusions and Future Work

The immediate path forward in this project is;

- Continue gathering and collating information,
- Introduce and discuss the raw data with other educators in forums such as the Society of Manufacturing Engineers, and the American Society of Engineering Educators,
- Gather information on educational programs that might use this material and search for gaps or opportunities,
- From the information and discussions above, begin to select topics for and formulate instructional modules,
- Deliver the first of the modules in 2008.

It can be seen from the data above that the term “manufacturing engineer” has broad meaning in the aerospace industries, as in other industries. This would tend to validate the idea of developing industry specific modules that would interest students and educators in several engineering disciplines, not just in programs titled Manufacturing Engineering.

For example, a topic that was mentioned was aircraft fasteners. A module could be developed that examines the issue of fasteners from a selection and design criteria approach. Parts of this could be used in general courses on manufacturing processes, in courses on supply chain management, as well as in courses in machine design.

The next steps in the process are to finish the interview process and to perform an analysis on the curriculum of schools that are currently supplying graduates to the aerospace manufacturing segment. After that we will select the initial curriculum modules to address.

This material is based upon work supported by the National Science Foundation under Grant No. 0603221. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

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