

North American Aerospace Project: A Template for Preparing Portable Design/Build Projects

Ed Crawley¹, Robert Niewoehner², Jean Koster³ and Peter Gray²

¹MIT

²USNA

³University of Colorado

The North American Aerospace Project (NAAP) is a NASA/industry sponsored effort to accelerate penetration of the project-based educational concept of “Conceiving, Designing, Implementing, and Operating” (CDIO) into US Aerospace Engineering programs. NAAP is developing innovative educational approaches, tools, methods and concepts specialized for the education of the future aerospace engineers.

Corresponding Author: Ed Crawley, crawley@MIT.EDU

Introduction: A project relevant to industry needs

Aerospace generally, and aeronautics particularly, is a key sector of the US economy, contributing significantly to the gross domestic product, positive balance of trade, and national security. Yet the sector is facing a systemic challenge – maintaining a world-class workforce. Over the next decade, the demographics of the sector suggest that there will be a significant shortfall in technically competent engineers and other technical specialists necessary to keep this sector healthy, and preserve the nation’s aeronautics core competencies.

From a national policy perspective, this need has been clearly recognized. The *National Aeronautics R&D Policy* instructs that “executive departments and agencies with responsibility for aeronautics-related activities should continue to invest in educational development of the future aeronautics workforce...” The *NASA Strategy Plan of 2006* references the need for NASA’s own Strategic Management of Human Capital, and in the section on Strategic Communications: Education Initiatives reinforces NASA’s responsibility to “strengthen NASA and the nation’s future workforce” and to “Attract and retain students in STEM Disciplines”. The NASA goals include taking “responsibility for the intellectual stewardship of the core competencies of aeronautics” which certainly includes their retention by the workforce. The importance of STEM workforce is paramount to other organizations as well, including the NAE, the AIAA and the AIA.¹

Our consortium has proposed a solution that is designed to have widespread systemic influence on the university preparation of the aeronautics workforce. The

program seeks to strengthen US university programs that prepare aeronautical engineers, and to develop and disseminate curricular materials and methods in a form that is easily transferred to and adopted by others, to use in reforming and strengthen their programs. Our architecture will furthermore encourage participation from the extended community of aerospace programs, adding their innovations to a readily accessible library.

Impacting the knowledge and skills of graduates

Over the past eight years, a growing number of international engineering schools have formed a collaboration to develop a new vision of engineering education called the CDIO Approach (www.cdio.org).² CDIO is designed to deliver the knowledge and skills needed by industry. It provides an education stressing engineering fundamentals, set in the context of the **C**onceiving, **D**esigning, **I**mplementing, and **O**perating process.

The CDIO approach identifies and implements 12 Standards of Effective Practice. Critical to them is the extensive use of Project-Based Learning (called here PjBL to distinguish it from the more general Problem Based Learning). A key innovation is the integrated use of PjBL in both the earlier and later years of the undergraduate education. Such use of PjBL has been shown to increase the acquisition of deeper knowledge and develop in students desired product and team skills.^{3,4} Such active learning approaches attract and retain more students in engineering. Interestingly, it has been demonstrated that exposure to Project-Based Learning in the first and second year preferentially retains women (and potentially minorities) in engineering,⁵ and exposure in the junior and senior years influences the career choices of students away

from non-engineering paths, back to careers in engineering.

In the ongoing effort, we are developing modularized curricular materials around aerospace PjBL.

Sustaining the program

In order to address the aerospace workforce agenda over the next decade, innovations must be sustainable - in terms of faculty members' time, skills and interests, the financial resources, and the effort required to identify appropriate industrial projects. The first element of sustainability is to directly produce project-based materials that are easily available and ready to use. We are developing and refining modules for project-based learning of aeronautical knowledge and skills that are well described, and available in a standardized format on the Web. A project module includes instructor notes, activities, material descriptions, student activities and learning assessment tools. We are deploying a Web-based mechanism by which the aeronautics industry becomes involved in defining the projects for a given school year, without having to interact individually with each of the hundreds of programs across the nation. Finally, we are addressing the most fundamental issue, the skills of the faculty in delivering project-based learning. A Faculty Development Workshop has already been created and already delivered at our participating institutions.

A broad-based approach with national impact

The project is led by three core universities: MIT, the US Naval Academy, and the University of Colorado, Boulder. But, we are already engaged in the North American CDIO region with three other universities, and recently been joined by several others. About 10 major aeronautics programs have expressed strong interest, motivated significantly by strong industry endorsements. We have an inclusive approach, and invite all to participate. As described below, we have entered into partnership with many of the leading US-based aerospace companies, and will work through them to engage their "feeder" programs around the nation. Our hope is that in two to three years, 20 to 30 of the major programs around the nation will be involved in the CDIO in Aerospace Education network. We view this goal as achievable, with over forty universities and 70 programs are now involved in the international CDIO Collaborative spanning all fields of engineering.

Technical Approach - Forming an alliance

The project has assembled a national team of educational scholars, developers, deliverers and customers. We have formed an integrated project team, built around a core group of the three key North

American CDIO programs in aerospace: MIT, the US Naval Academy, and the University of Colorado, Boulder. This core group was joined by four other existing CDIO programs in the US and Canada: Arizona State University, Daniel Webster College, California State University at Northridge, and École Polytechnique de Montréal.

We have agreements from the Boeing, General Electric Aviation, Lockheed Martin, Northrop-Grumman and Orbital Sciences and Raytheon to join us, and form an industry-university steering group for the program. These industries are contributing direction, participation in project learning, and supplemental funding.

Developing aeronautical project-based learning and assessment materials

The core of the technical effort is the development of design-implement-operate laboratories and project-based experiences. We are developing a set of at least six learning experiences for the first and second year of aeronautical instruction, and about six third/fourth year learning experiences. Working in close coordination, and with the guidance of the industry-university steering group, each of the three core universities has developed one experience at the freshman/ sophomore, and one at the junior/senior year level this past year, and will develop a like number in the coming year.

First and second year project-based experiences

It is important to begin the education of engineering students with an authentic experience in engineering, often delivered through a project-based subject in the first or second year. We are developing two types' experiences. In one model, the laboratory or project-based experience is a simple but rather complete aeronautical vehicle, at the scope that can be successfully developed by students, but with an interdisciplinary perspective. In the second freshman/sophomore model, the laboratory project will be based on the design and development of an important aeronautical subsystem.

Third and fourth year project-based experiences

We are developing third and fourth year experiences of two types. In one, the entire class work as one team in the execution of the project. In the second, smaller groups work in teams of 6-10 on the project. In most cases, the projects have a real customer, and deliverable "flying" article. Projects are interdisciplinary spanning modern aerospace disciplines (aeronautics, propulsion and structures, avionics, software, control and autonomy). The projects build awareness of other issues, including financial, regulatory, environmental and public policy, although this broader

interdisciplinary scope may not be a primary focus of every project.

The underlying innovation in these projects is the incorporation into the mainstream curriculum of the design, building and testing of realistic, in fact in some cases real, aerospace vehicles and systems.

Three upper-class projects are being readied for publication and will be available in early 2010. The project teams will then move to documenting 3 additional projects by the summer of 2011.

Develop dissemination and faculty development support materials

Two important barriers to adoption of innovative instructional approaches such as project-based learning are the lack of well-developed examples from which individual faculty can draw, and the lack of confidence and competence of university instructors in such approaches.⁶ We develop a comprehensive approach to dissemination of our results, which include making the curricular materials that we develop openly available on the web, and creating Faculty Development Workshops and Master Teacher Seminars.

Pedagogic Foundation

Contextual learning is a proven concept that incorporates much of the most recent research in cognitive science.^{7,8,9} According to contextual learning theory, learning occurs when students process new knowledge in such a way that it makes sense to them in their own frames of reference. This approach to learning and teaching assumes that the mind naturally seeks meaning in context, that is, in relation to the person's current environment, and that it does so by searching for relationships that make sense and appear useful.¹⁰ A contextual learning approach assists students in learning how to monitor their own learning so that they can become self-regulated learners.¹¹

Capabilities and experience of the team

The three lead institutions, MIT, USNA and CU Boulder, have each undergone significant curricular transformation as a consequence of adopting CDIO, and are viewed as important contributors to educational reform. The Department of Aeronautics and Astronautics at MIT developed the CDIO Syllabus and revised its undergraduate program in the context of CDIO. The Naval Academy has been a CDIO collaborator since 2002, contributing a strong emphasis on engineering operations, particularly manned and unmanned flight test. The Aerospace Engineering Sciences Department at the University of Colorado has redesigned the undergraduate curriculum to include laboratory experiments and design projects according to the CDIO Syllabus in 2000. In the sophomore and

junior years the fundamentals are taught enhanced by experimental labs and small design projects. All courses in these two academic years make extensive use of the Integrated Teaching and Learning Laboratory. Senior design projects teach standard professional aerospace systems engineering practices, elements of conceptual and detail design, elements of fabrication, integration, verification and test.

Collectively, the three universities have already been working together for three years through their close working relation in the North American CDIO region. To date, the collaborative has influenced over 70 university engineering department programs worldwide, which graduate close to 10,000 engineering students annually.

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