Global Engineering Design

Daniel Nosenchuck
Department of Mechanical and Aerospace Engineering
Princeton University

Abstract

In recognition that the engineering design process has radically changed and is increasingly coupled to the global economy, the Design Curriculum has been restructured to introduce students to elements of design in a global context. In conjunction with large international product firms, student design teams are challenged to design products for the worldwide market. A competition down-selects one or more teams for subsequent travel abroad for hands-on interaction with engineers and management of leading international product firms, with the opportunity to explore possible technology-transfer.

1. Introduction

It is no longer debated, but implicitly assumed and often explicitly stated, that leading engineers will need to be prepared to function in the increasingly interconnected global environment. It will be the exception, not the rule, when engineering enterprise can be wholly executed within national boundaries. To prepare engineers for the complex, and often mysterious, climate of international design and engineering, a new facet to the design curriculum at Princeton is in the process of being developed. An overarching emphasis on global engineering is being placed on the design curriculum. The objective is to expose students to the complete process in which designs are taken to their logical conclusion by the international corporate sector. To ensure that the students 'buy into' the process, they are given the opportunity to have their designs evaluated for commercial potential, with the serious potential of mass-market production.

One challenge of the present approach to tackling design in the global context, is to create a course structure that emphasizes timeless fundaments, while exploring the entrepreneurial elements that surround engineering and design. A traditional approach has been to couple design courses with local industries that have particular problems to solve. While this approach is generally sound, it does several potential drawbacks:

1. The problems tend to be limited in scope, and narrowly defined, often represented by a modest subsystem, such as a hinge or a latch, which needs to be modified to meet a new specification.
2. Most often, the industrial interactions are within a single group or division.
3. Global issues such off-shore marketing, procurement, manufacture and distribution generally do not receive serious consideration, and often do not factor significantly into judging outcomes of the design process.
4. Critical elements that are key factors to success in the international environment, such as communications and cultural issues, are often neglected.

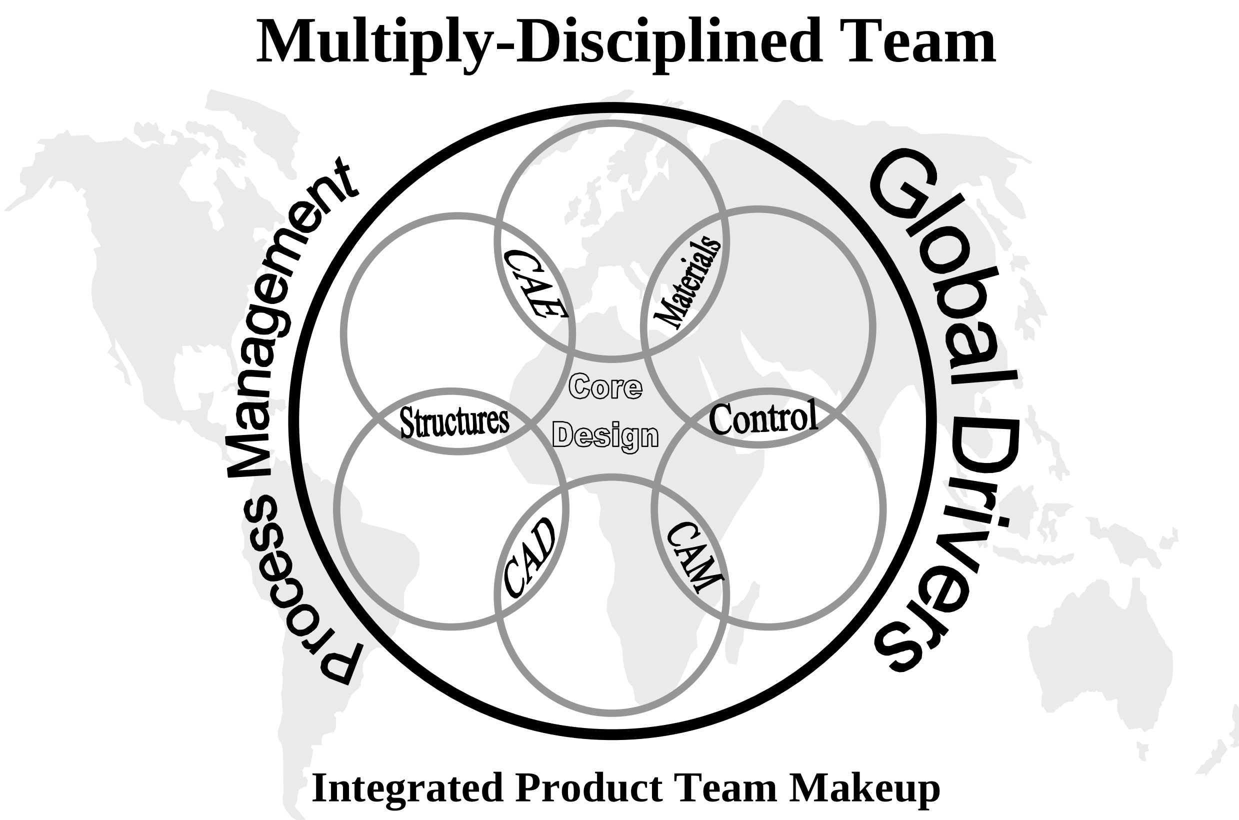
The current approach focussed on identifying leading international industries whose products represent an appropriate scope for an undergraduate design course. It is crucial that needs and capabilities of both the design program and that of industry are accounted for in the industrial selection process. Such needs may include the desire for an industry to have a strong connection to the roots of the intellectual property creation process, while the academic program strives to provide industrial interactions and opportunities for students. The final objective is to forge partnerships between the University and global industry, with industry commitments to make available high-level personnel to the program.

2. Design Sequence Overview

A two-term sequence is offered in the Junior year to Mechanical and Aerospace Engineering students. The first course, Engineering Design is required of both majors. The second-semester elective course, Mechanical Design, for Mechanical Engineering majors is a direct follow-on of the first course.

Engineering Design is an aggressive and intensive course, with a strong emphasis on modern computer-oriented tools and processes. Lectures revisit and emphasize fundamental engineering concepts and principles, such as basic materials, structures, thermal sciences, and dynamics. General design-related material (e.g. mechanisms, design-process management approaches) and project-specific topics are presented in class. The Parametric design, analysis, and fabrication methodologies are introduced in the accompanying laboratory. Parametric Technology Corporation suite of applications form the basis of the CAD/CAE/CAM toolset (CAD: Pro/Engineer (parametric solid modeling); CAE: Pro/Mechanica (FEA) and Pro/Motion (dynamics/kinematics); CAM: Pro/Manufacture (CNC toolpath generation)) introduced and applied in the laboratory.

A key objective in design is to give students an early introduction into teaming. Integrated Product Teams (IPTs) are formed with the aim of creating a heterogeneous, yet coherent mix of skills and interests. Figure 1 illustrates a notional multiply-skilled six-member IPT comprised of students who have multiple skills, which interact with other team members. Such a skill mix is unlikely to occur in most class populations. To facilitate this, students specialize in the laboratories. After an introductory three-week sequence, in which all students are exposed to basic CAD solid-modeling concepts and are given a brief introduction to machine-shop practices, the laboratories are split into two sections. Students who express interest in pursuing simulation are given further instruction and practice in parametric design, with an introduction to finite-element simulation (emphasis on materials and structures). Those that prefer prototype manufacture concentrate on manual and automated machining procedures. In practice, an IPT is formed with approximately half the members from simulation and the rest specializing in manufacture. A typical laboratory sequence is given in Figure 2. The first half of the semester culminates in a first design project, which is selected to apply analysis and simulation methods and design procedures, while providing a moderate challenge to students as they first begin to exercise their creative and engineering skills. For the past several years, a so-called ‘Heavilift’ crane has been assigned. Students are given several pounds of aluminum and plastic, a fixed vertical steel I-beam, motor transmission, and cable. They must then design a high strength-to-



Integrated Product Team Makeup

Figure 1

weight structure to lift approximately 1,000 lbs. a significant horizontal distance from the I-beam. They attempt to maximize lift height while minimizing lift time.

After intensive instruction and practice with design tools and procedures, students are then presented with a design challenge to develop a product that could be developed, produced, and marketed in an international context. They have six weeks for basic design preparation, analysis, simulation, prototype and test. Student IPTs develop an ab initio design. Teams focus on issues that surround both the technical aspects of their designs, beginning from first principles, and then broadly consider the elements pertaining to global marketing, manufacture and distribution. A competition is held during final exam period. Industrial partners participate in judging the competition. One or more teams are then invited to tour global facilities, present their design(s) at either corporate, engineering, or manufacturing headquarters to the CEO and senior technical staff. Teams are then encouraged, and motivated, to further refine their designs and engage in further study of relevant global and international issues they will face on their field exercise.

Laboratory Schedule

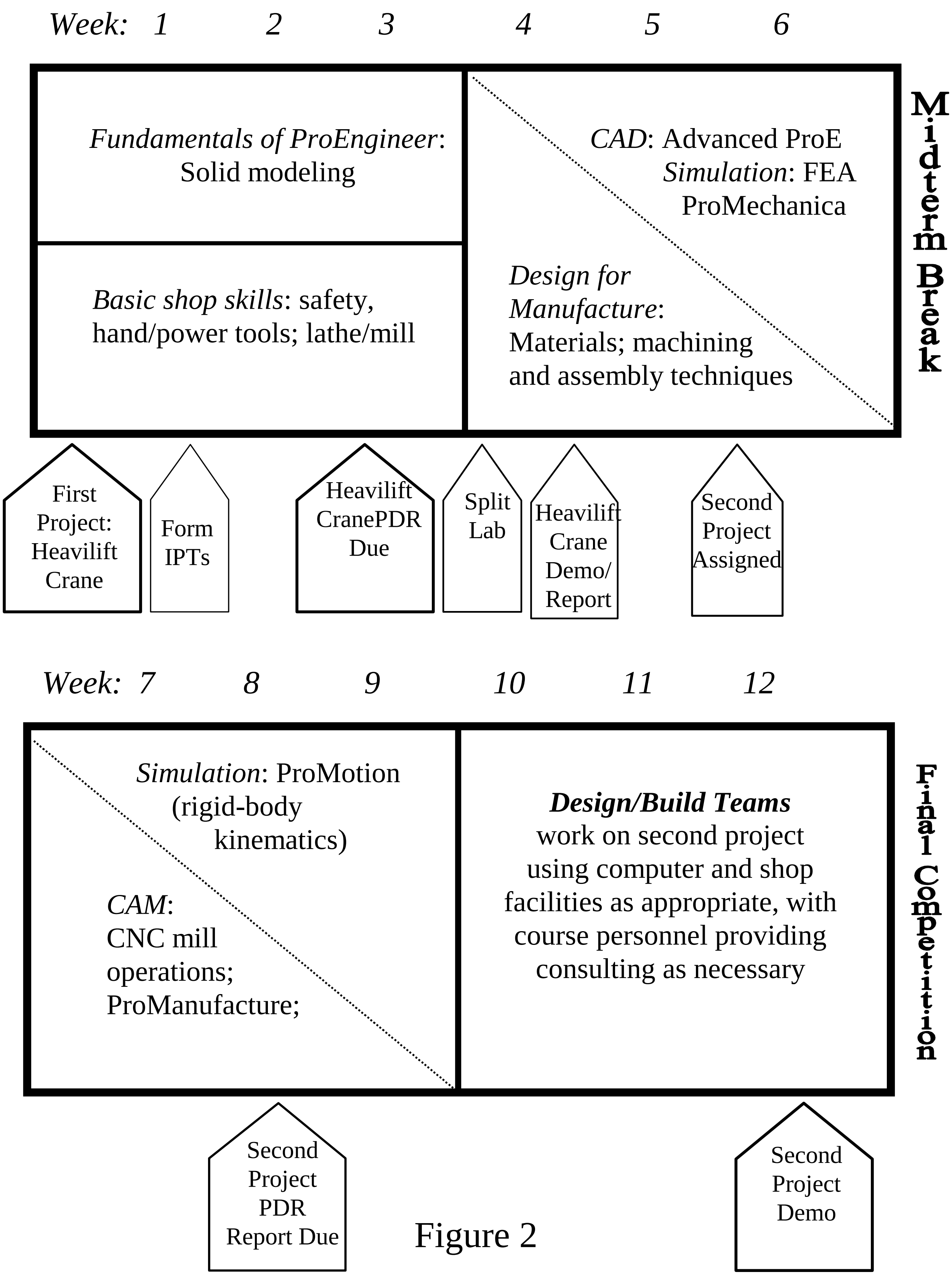


Figure 2

The outcome for the industrial partner is a decision on whether to proceed with a commercial prototype to evaluate market potential. The outcome for the student is first hand contact and interaction with global engineering.

3. Virtual Global Corporate Structure

The structure used to couple the design curriculum with global enterprise is that of a virtual global corporation. A working definition is that a virtual corporation is that which is formed with personnel and facilities that are coupled as if they were part of an actual corporation[†]. In this model, loosely adapted from pre-existing concepts[1], a company is formed to create, market, develop, manufacture, and distribute one or more related products. The virtual corporation is formed with diverse existing worldwide assets without regard to locale. The company has a highly horizontal structure, exists only to support a particular product, rapidly adapts to changing requirements imposed by the market, and uses technology as its strategic strength. For this model to be relevant to an academic design curriculum, the only critical presumption is that the process originates in the US with the creation of the basic intellectual property, which may be a patent that follows from a design produced by student IPTs. The remainder of the notional corporation is established with the distributed corporate assets held by one or more of the industrial partners. For example, links are created between the IPTs centered in the design program and the appropriate partner corporate divisions (e.g. marketing, engineering/prototype, manufacturing and distribution). The Internet is used as a key backbone for the communications and management infrastructure. Thus formed, the virtual corporation, with significant inputs from the industrial partner, participates in the design process from conception through initial prototype article. If warranted, licenses covering the intellectual property between the University and the industrial partner permit subsequent industrial design, prototypes, production tooling, mass-market manufacture and global product distribution.

4. An Example of Global Product Design

A modest effort to investigate the viability of global element in the design curriculum was begun in 1996. An initial partnership was established with The Manica Group, one of the world's largest manufacturers of small- and personal-care appliances (e.g. Revlon, Clairol, ConAir, Remington, National Panasonic). In consultation with the partner a product was identified as a design challenge for the class: an ultraquiet, powerful hairdryer that could find broad market acceptance in Oriental, European, and domestic markets. The level of technology to produce such a product was felt to be appropriate to cover a broad range of engineering elements, including structures, materials, dynamics, thermal sciences (fluid mechanics, heat transfer), aerodynamics, acoustics, power transmission, and control. The scope of the project involved first-principle design through analysis, simulation and prototype generation. The objective was to create a works-like model that would warrant further product development, based on the determination of a panel of industrial judges.

The virtual corporate structure that was put in place is conceptually represented in Figure 3, along with a notional initial product market. The basis for the corporation predominantly lies

[†] The legal aspects of virtual corporations go beyond the scope of the design curriculum at present.

among the international components of Manica. The elements of the virtual corporation, which had a direct role in the initial exercise in global product design, were:

1. Princeton University (U.S.): Design and intellectual-property creation
2. Manitai (Taiwan): Engineering, prototype fabrication and test; tooling
3. Manica-Thai (Thailand): Manufacture
4. Manica-Hong Kong (China - Hong Kong at the time): Purchasing and procurement

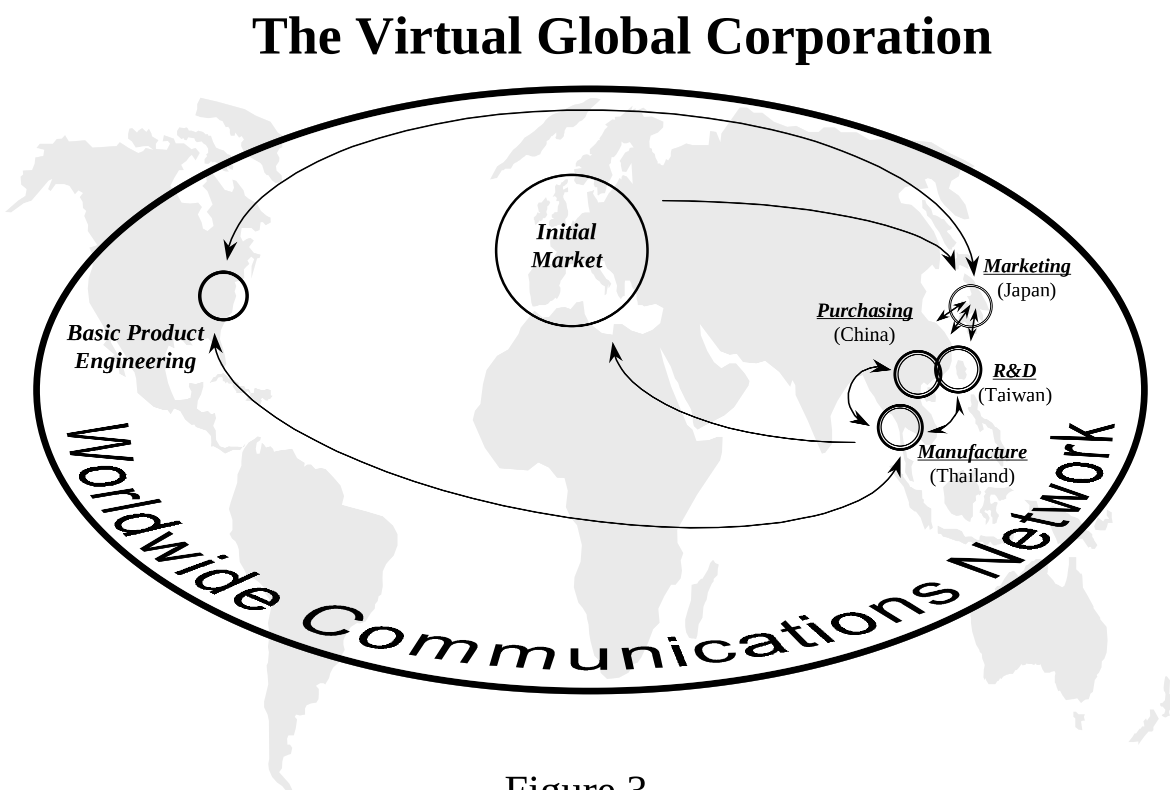


Figure 3

Seven IPTs were formed, with 4-5 members each. As noted above, an effort was made to form IPTs with a member distribution balanced between simulation and manufacture. After a typical Preliminary Design Report and Final Design Reporting cycle, a competition was held among the teams. A panel of four industrial judges (CEOs and Chief Engineers from The Manica Group and Schawbel (Boston, MA, a domestic small-appliance design firm) met with the students, listened to presentations, and observed demonstrations. Objective criteria (volume flow, power, noise) were used along with professional discretion (relative to estimates of marketability and manufacturing costs) to select a 'winning' team†. The team was then offered an expense-paid trip to visit The Manica Group in the Far East, for first-hand observation of procedures, and to

† To ensure that industrial concerns did not cloud the academic criteria, final course grades were assigned prior to the judging.

experience the corporate, cultural, and geographic diversity of operations that characterize global product firms.

The IPT was also encouraged to further develop their technology prior to the trip so that a final evaluation of commercial potential could be made during on-site discussions and prototype demonstrations at Manica. During a 12-day trip to the Far East[2,3] the IPT visited two components of The Manica Group: 1. Manica Hong Kong (purchasing headquarters) where the students had discussions about the concepts and workings of a free-trade and duty-free port, and 2. Manica-Thai, Pathumthani, Thailand (manufacturing headquarters). The latter site formed the main focus of the trip. The CEO[†] had direct contact with the students over a period of five days to ensure their questions were fully answered, and that they were provided with broad exposure to the personnel and facilities in the virtual corporation which the students had remotely interacted with from abroad. In addition to numerous technical, management, marketing, supply and distribution discussions at Manica, the student IPT members presented a seminar on ‘Global Design’ and conducted a panel session on ‘An Engineering Education at Princeton’ at the Asian Institute of Technology (AIT). AIT is a graduate school for science and technology originally created by SEATO, and located in Bangkok. At AIT, students were exposed to a view of globalization complementary to that held in the US. Meetings with a senior financial leader[‡] also provided perspective on the challenges faced, and opportunities present, for technical enterprise in Southeast Asia.

Subsequent to the trip, Manica created and evaluated an industrial prototype of the IPT’s quiet hairdryer concept. At present, patent and licensing discussions with the University are underway.

5. Further Curriculum Development

Additional emphasis will be placed on elements of global engineering, such as finance, infrastructure and process management, along with cultural issues. This will necessitate moving the current activity of engaging in a global design project in the first semester (Engineering Design) into the second semester of the Junior year (Mechanical Design). Since at present, the second semester is an elective, it is anticipated that the course will be limited enrollment, with <u>all</u> students participating in a global product design exercise and associated international travel and corporate visits. The competitive element of the course will be maintained, but the competition will be held and judged in international engineering settings. Outcomes assessment metrics will be developed to determine the efficacy of the global design engineering program elements.

[†] Gilbert Wong, President and CEO, The Manica Group

[‡] Banthoon Lamsam, President, Thai Farmers Bank

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Biography

DANIEL NOSENCHUCK is an Associate Professor of Mechanical and Aerospace Engineering at Princeton University. He received a BS in both Mechanica and Aerospace Engineering from Syracuse University in 1976, and an MS (1977) and Ph.D. (1982) from the CalTech. He was a charter-year recipient of the NSF PYI award (1984-89), a member of the DoD/IDA Defense Science Study Group (1989-1991), and was a Boeing Welliver Fellow (1995). He received an EMMY award (1984) for his work on the visual effects for the ABC TV-Movie 'The Day After.'