Session 3325

A Venture Capital Fund to Encourage Entrepreneurship and Rapid Product Development with Multidisciplinary Teams in the Junior Engineering Clinic

Anthony J. Marchese, John L. Schmalzel, Shreekanth A. Mandayam and T.R. Chandrupatla
Rowan University
201 Mullica Hill Rd.
Glassboro, NJ 08028-1701

Abstract

The Junior Engineering Clinic I, part of the innovative 8-semester Engineering Clinic sequence taken by all engineering students at Rowan University, provides the venue for multidisciplinary student teams to engage in semester-long design and development projects. The majority of these projects are funded by local industry, faculty research grants or departmental budgets. Clearly, projects such as these are central to developing the design, problem solving and project management skills that are lacking in the traditional engineering coursework. Often missing, however, in the industry and faculty sponsored design projects, is the spirit of invention, innovation and entrepreneurship. The spirit of entrepreneurship is best promoted by providing students with the opportunity to propose their *own* original enterprises. Accordingly, an NCIIA grant has created a venture capital fund, specifically ear-marked for the development of original inventions by multidisciplinary student teams within the Junior Engineering Clinic. To qualify for funding, student teams must propose, plan and implement an original, semester-long product development enterprise. Funding of up to $2500 per student team per semester is competitively awarded based on student-generated proposals to the venture capital fund. To be funded, the team must be multidisciplinary, including engineering students from at least two of the engineering departments and at least one non-engineering major. Each team must submit a business plan and must be organized into a corporate structure. Finally, the team must propose an original product idea that can be successfully designed, developed and prototyped in a single semester. The latter criterion is possible given the unique rapid prototyping facilities in place at Rowan University, which include a stereolithography machine, a multi-jet modeling rapid concept modeler and a rapid circuit prototyping system. The spirit of cooperation between the four engineering departments is evident in the first funded project, which consists of a pressure relief system designed to prevent residential roof damage during high wind loading. This project was proposed by two students from the Department of Civil Engineering who have assembled a team that includes students from the Department of Mechanical Engineering and the Department of Chemical Engineering.

Introduction

In 1992, the local industrialist Henry M. Rowan made a $100 million donation to the then Glassboro State College in order to establish a high-quality engineering school in southern New Jersey.

This gift has enabled the university to create one of the most innovative and forward-looking engineering programs in the country. The College of Engineering at Rowan University is composed of four departments: Chemical Engineering; Civil Engineering; Electrical and Computer Engineering; and Mechanical Engineering. Each department has been designed to serve 25 to 30 students per year, resulting in 100 to 120 students per year in the College of Engineering. The size of the college has been optimized such that it is large enough to provide specialization in separate and credible departments, yet small enough to permit the creation of a truly multidisciplinary curriculum in which laboratory/design courses are offered simultaneously to all engineering students in all four disciplines. Indeed, the hallmark of the engineering program at Rowan University is the interdisciplinary, project-oriented Engineering Clinic sequence[1,2].

Table 1. Overview of course content in the 8-semester Engineering Clinic sequence.

Year	*Clinic Theme (Fall)*	*Clinic Theme (Spring)*
Frosh	Engineering Measurements	Competitive Assessment Lab
Soph	Total Quality Management	Multidisciplinary Design Project
Junior	Product/Process Development	Product/Process Development
Senior	Multidisciplinary Capstone Design Project	

The Engineering Clinic is a course that is taken each semester by every engineering student at Rowan University. In the Engineering Clinic, which is based on the medical school model, students and faculty from all four engineering departments work side-by-side on laboratory experiments, design projects, applied research and product development. Table 1 contains an overview of course content in the 8-semester engineering clinic sequence. As shown in the table, while each clinic course has a specific theme, the underlying concept of engineering design pervades throughout.

The 4-year, 24-credit Engineering Clinic sequence offers students the opportunity to *incrementally* learn the science and art of design by continuously applying the technical skills they have obtained in traditional coursework. This just-in-time approach to engineering design education enables students to complete ambitious design projects as early as the sophomore year. And, by the junior year, students are well equipped to embark on a completely original, entrepreneurial enterprise. This paper describes an innovative venture capital system that allows students to competitively apply for funding opportunities to embark on such an enterprise. The venture capital fund was created by a grant from the National Collegiate Inventors and Innovators Alliance, an initiative of the Lemelson Foundation.

The Venture Capital Fund for the Junior Engineering Clinic

The Junior Clinic features a mixture of projects funded by industry and faculty research interests. Clearly, projects such as these are central to developing the design and problem solving skills that are lacking in the typical engineering curriculum. What is often missing, however, in the industry and faculty-created design projects, is the spirit of invention, innovation and entrepreneurship. The spirit of entrepreneurship is best promoted by providing students with the opportunity to propose their *own* original enterprises. Accordingly, we have created a venture capital fund, specifically ear-marked for the development of original products by multidisciplinary student teams within the Junior Engineering Clinic.

Funding for student teams is competitively awarded based on student-generated proposals to the venture capital fund. To be funded, a student proposal must describe an enterprise that meets the following criteria:

- The team must be multidisciplinary, including engineering students from at least two disciplines and at least one non-engineering major.
- The team must be organized into a corporate structure and must submit a detailed business plan.
- The team must appoint a project director from the College of Engineering, an advisor from the College of Business, and an advisor from industry.
- The enterprise must consist of an original product idea that can be successfully designed, developed and prototyped in a single semester.

The latter criterion is possible given the unique set of rapid prototyping resources in place at Rowan University created in part by two separate NSF grants. The Competitive Assessment Laboratory (NSF DUE-9850563) features dedicated test stations for the complete engineering assessment of consumer products. Stereolithography: A Distributed Partnership (NSF DUE-9751651) has created a rapid prototyping center featuring a 3-D systems SLA-250 stereolithography machine, an Actua 2100 multi-jet modeling (MJM) rapid concept modeler, and a QuickCircuit rapid circuit prototyping machine. In addition to the externally funded projects described above, the College of Engineering has committed $500,000 to developing a state-of-the-art fabrication facility featuring advanced CNC (milling, turning, punch) and manual machine tools.

The Junior Engineering Clinic is taken by a total of approximately 100 students distributed equally from each of the four engineering disciplines. However, all of the students do not embark on the entrepreneurial endeavor described above. The competitive proposal process, which rewards only those with original and thoroughly planned ideas, requires a significant effort at the start of the semester. In short, it is much easier for students to get "hired" into an industry or faculty sponsored project. However, with the availability of real funding, and the prospect of managing their own funds for a semester, interested and committed students with good ideas and entrepreneurial spirit choose to submit proposals.

Example: Hurricane Roof Vent

In the Junior Engineering Clinic I, students from each of the four departments work on semester-long, faculty-sponsored multidisciplinary design projects. Students are chosen for these projects using a job fair model in which students are competitively hired based on the skill sets and manpower required for each project. In Fall 1998, in addition to the faculty sponsored projects, a Request for Proposals was sent to all students inviting them to propose an original idea for an invention that could be developed in one semester using the resources described above. Funding for the student projects was made possible by an NCIIA Level II Grant awarded in July 1998.

After a review of the submitted proposals, an award of $2500 was given to a multidisciplinary team of engineering students to develop their original idea. The original idea consisted of a pressure relief system to prevent residential roof damage during high wind loading. This project was proposed by two students from the Department of Civil Engineering who assembled a team that included students from the Department of Mechanical Engineering and the Department of Chemical Engineering. As part of the development project, students performed wind tunnel testing (see figure above) with scale models developed using stereolithography. The students also modeled the flow of air over (and into) a house during high speed wind loading using the computational fluid dynamics code FLUENT, and have built a full-scale pressurized test bed to develop the pressure relief mechanism.

The original idea for the project was developed by a Rowan civil engineering student during a summer internship at a local civil engineering firm. Through on-the-job research and investigation he came upon the idea for the Hurricane Roof Vent, which seemed like an obvious solution to the serious problem of roof damage during high speed wind loading. Upon his return to class in Fall 1998, he decided to pursue his idea and submit a proposal to the venture capital fund described above. As part of his proposal, he formed a strong and multidisciplinary group consisting of three students from the Department of Civil Engineering and one each from the Departments of Chemical Engineering and Mechanical Engineering. The proposal was not only original, but very well written and thoroughly researched. The students were funded for the fully requested amount of $2500.

The students began their project by performing research on both the problem and their specific proposed solution. They quickly found literature on wind-induced internal pressures in buildings[3,4] and documentation of the many cases of severe roof damage due to internal pressurization. To their surprise, a patent search did not reveal any significant prior related to a pressure relieving roof vent. To complete design, testing and fabrication of a prototype in one-semester required an accelerated team effort, particularly since the students really did not have a full grasp of the fluid mechanics principles responsible for generating the pressure differential across the roof.

The students quickly learned that, to be effective, they had to work on several projects in parallel. The chemical engineering student was charged with modeling the fluid mechanics using FLUENT. A civil engineering student and a mechanical engineering student were put in charge of wind tunnel testing. This task involved developing 3-D solid models using Pro Engineer, manufacturing the models using stereolithography, instrumenting the models with manometers and testing them in a 12"x12" 0-100 MPH wind tunnel. The two remaining civil engineering students focused on design and construction of a full scale prototype of the roof vent.

Computer Simulation

To better understand the fluid mechanical mechanisms of roof damage and to determine the required vent area, the flow of air over and into a house during high wind conditions was modeled using the commercial CFD code FLUENT. There are several possible mechanisms for roof damage during high winds. The first mechanism is caused by the flow of wind over the roof, creating local negative pressures above the roof. The second mechanism is caused by flow of air into the house (for example, through broken windows), creating a positive pressure below the roof. In either case, the pressure gradient between the inside and outside of the house can potentially create forces strong enough to cause severe structural damage.

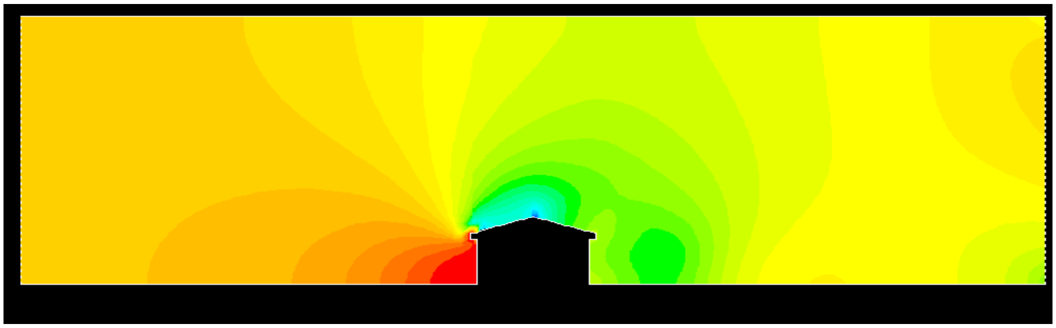

Figure 1. Pressure contours for flow over at house (U=100 MPH)

Prior to embarking on this Junior Clinic Project the chemical engineering student involved had no previous experience in CFD. With limited assistance from several faculty members, the student learned how to use the program Geomesh to generate the required grid structure and to simulate the flow field using FLUENT. The first simulation was performed to determine the pressure distribution that results from flow of wind (U_∞ = 100 MPH) over a perfectly sealed house. A shown in Figure 1, it is evident that the highest pressure is located on the supporting wall of the windward side of the house and the lowest pressure is located on the windward exterior face of the roof. Assuming that the pressure within the house remained at atmospheric conditions, the pressure differential created by merely the flow over the roof might be great enough to cause the roof to tear free from the remaining structure. Further simulations (not shown) were performed for conditions in which the integrity of the windward side of the house was broken (i.e. a window was broken). These results showed an even higher pressure difference across the roof due to a positive pressure within the house.

Wind Tunnel Testing

A second means of determining the possible pressure difference on a roof in a hurricane, experimental data were obtained from two separate scale models mounted in a wind tunnel. The model

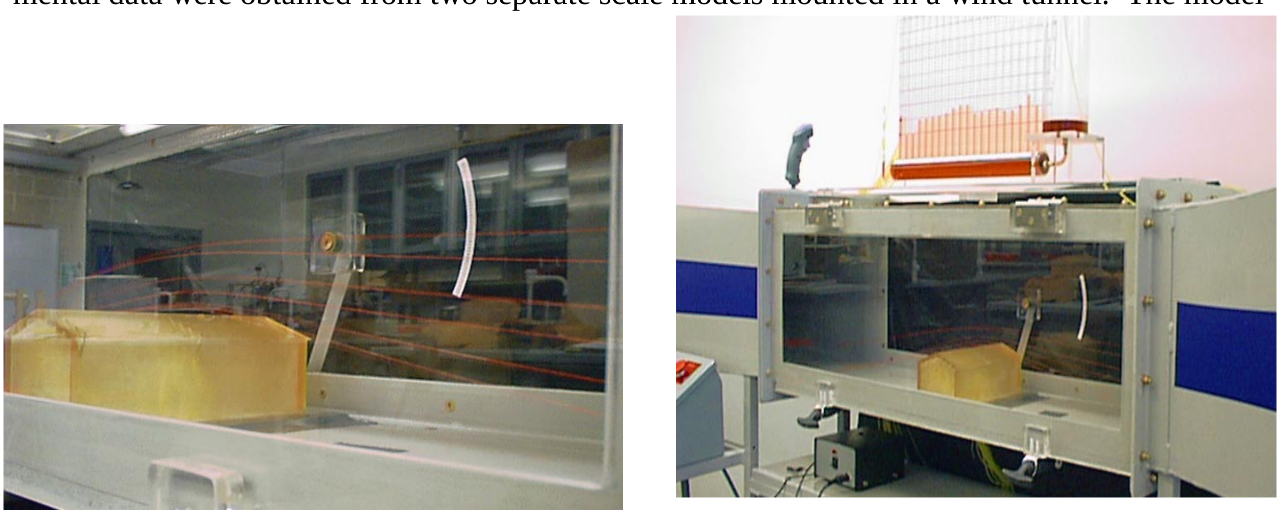

Figure 2. Wind tunnel models in test configuration.

was oriented so that the wind flowed normal to the ridge along the top of the roof. Values for "model pressures" were measured in inches of water. Through scaling, the experimental measurements were used to calculate actual pressure differences over a full size roof.

Figure 3. Stereolithography machine.

To expedite the process, Pro Engineer was used to generate 3-D solid models of the wind tunnel scale models. The scale models were $1/50^{th}$ the size of a standard house with a four to twelve pitch roof. The first was air tight, allowing no wind into the house. This model was used to measure the negative pressures on the outside of the roof. Eight holes were placed from front to back along one edge of the house and another eight from front to back along the middle. A second model was built identical to the first, but with a square hole on the windward wall equal to two percent of the total surface area of the wall. This hole was positioned in the center of the windward wall to provide symmetry, which would aid in the assumptions about pressures on both edges.

The 3D solid models created using Pro Engineer were manufactured using a 3-D Systems SLA-250 stereolithography machine (See Fig. 3). The stereolithography machine utilizes laser technology to solidify a digital model from a vat containing a liquid photopolymer. By using stereolithography to build the scale models, it was possible to manufacture each part with all of the pressure taps built in.

Funding for the stereolithography machine was made possible by an NSF ILI grant (NSF DUE-9751651). The grant has established a joint rapid prototyping facility located at the Center

for Integrated Manufacturing (located at Camden County College) and Rowan University. Engineering students at Rowan design solid models of their designs using workstation-based computer-aided design tools and ftp their designs to Camden for fabrication. Student teams from each institution interact via video conferencing and e-mail. The project is particularly unique in that it features a partnership between the Center for Integrated Manufacturing (C.I.M.) and Rowan University. This partnership brings together technology students from a 2-year community college with engineering students from a 4-year engineering program.

Prototype Design and Construction

The key to a successful invention is to determine the potential market as early as possible. In the case of the Hurricane Roof Vent, the students had to decide whether the product would be:

- an "after market" item that could be retrofitted into any existing residential roof, or
- a product that could only be installed in new home constructions.

Figure 4. Hurricane roof vent test bed.

As a first approach, the students chose the former embodiment. Accordingly, for their design to be seriously considered, it would have to be able to fit into the existing truss system of the typical roof. In addition, the retrofit would need to completely weatherproof. Given these constraints, the students decided to build a full-scale, pressurized test bed consisting of a section of roof. Using this test bed, the students had the ability to test various configurations of the roof vent for sealing and venting capability.

Design of the test bed started with general size estimations and calculations. Since roof trusses are generally spaced two feet on center from each other, this spacing was chosen for the test bed. After much deliberation, the dimensions of 6’ x 1.5’ x 4’ were chosen for the prototype housing, with a 30 degree pitch. These dimensions would keep the prototype relatively small and mobile while still being large enough for the necessary applications.

The majority of the materials for the test bed were purchased at Home Depot using funds from the NCIIA grant. To generate the pressure differential across the roof, a high-pressure blower was purchased. The test bed was instrumented with a pressure transducer and tests were conducted to determine the pressure differential required to open the vent.

Results and Future Work

In one semester, the students were able to perform wind tunnel testing, computer simulation and fabrication of a test bed to aid in the design of their original invention. The students have requested a no-cost extension to continue work on this project. The design of this device is an iterative process that relies on wind tunnel data, computer simulation and prototype fabrication. The students hope to have a fully working prototype in Spring 1999.

Conclusions and Assessment

The students who worked on this project were given much autonomy and, since the project was their own original idea, they took ownership on day one. Some comments from the team members are included below:

> "…we feel that our semester in Junior Engineering Clinic was a wonderful experience. This project has allowed us to gain experience in many new and interesting areas."
>
> "We feel extremely fortunate to have been able to participate in a one hundred percent independent research project. It gave us the opportunity to work on our own, under your advice."
>
> "I can say that I have learned more in this clinic than in a previous engineering course."
>
> "We strongly recommend the entrepreneurial option to all other engineering students."

The only down side to the project was that, since it required so much research, it was very difficult to build a working prototype in only one semester. It is planned in the future to still try to complete the projects in one semester, but students will have the option of applying for a no-cost extension at the discretion of their project advisor.

Acknowledgments

The venture capital fund is supported by a grant from the NCIIA. Resources used in this project were supported in part by NSF under the grant number DUE-9751651. Special thanks to the Rowan engineering students Clay Emerson, Chris Berg, Megan Matricardi, Greg Rueblinger and Michael Hayden in preparing this paper.

Bibliography

1. Marchese, A.J., Hesketh, R. P., Jahan, K. (1997) Design in the Rowan University Freshman Engineering Clinic. *Proc. Conf. Amer. Soc. Eng. Edu.*, Session 3225, 1997.

2. Schmalzel, J., Marchese, A. J., and Hesketh, R. P. (1998). What's Brewing in the Engineering Clinic? *Hewlett Packard Engineering Educator*, Vol. 2, No. 1., p. 6.

3. Liu, H. and Saathoff, P. J. *Journal of Structural Engineering* **108**: 2223-2234 (1982).

4. Stathopoulos, T. and Kozutsky, R. *Journal of Structural Engineering* **112**: 2012-2026 (1986).