# AC 2007-2449: DEVELOPMENT OF A CAPSTONE DESIGN PROGRAM FOR UNDERGRADUATE MECHANICAL ENGINEERING

**Stephen Laguette, University of California-Santa Barbara**

Stephen Laguette received his MS in Mechanical Engineering from UCLA in 1977. His career has included executive R&D management positions with a number of medical device companies. He has been responsible for the creation of complex medical devices with over fourteen US patents issued in a variety of surgical fields including General Surgery, Plastic Surgery, Urology, Neurosurgery, ENT, Voice Restoration, and Ophthalmology. As the Director of Device Research for Advanced Medical Optics (AMO), a major ophthalmic medical device company, he directed all research activities, the identification of new technologies, and the review of new business opportunities for the corporation. His responsibilities included transitioning projects into development and potential commercialization. He identified and successfully created research programs with leading academic institutions and formed strategic alliances with other high technology companies. He is currently a Lecturer at the University of California, Santa Barbara in the Department of Mechanical Engineering and the Technology Management Program in the College of Engineering. He remains active in the field of medical devices as a consultant for new ventures and investment firms.

# Development of a Capstone Design Program for Undergraduate Mechanical Engineering


## Abstract

In September 2004, the University of California, Santa Barbara, Department of Mechanical Engineering initiated a Capstone Design course requirement for Senior Mechanical Engineering students. The course has transitioned from a three unit course typically taken in the final Spring quarter of the curriculum to a two unit course taken each quarter of the academic year for a total of six units. Students work in teams under the direction of a faculty advisor to tackle a Mechanical Engineering design project. Engineering communication, such as reports and oral presentations are covered. The course emphasizes a practical, hands-on experience, and integrates analytical and design skills acquired in the companion ME courses. The course objectives are (1) design problem solving, creative thinking, project planning and teamwork through a challenging design and build project; (2) to provide experience in fundamental engineering reporting and communication including project plans, design reviews, and project reports. To address the transition of the three unit, one quarter design course into a six unit, three quarter Capstone Design course, an Academic Coordinator with over twenty-five years of engineering management experience has developed a Capstone Design program that has integrated companion courses, industry partnership and financial support, with faculty partnership and support. A Capstone Design program has now been developed and has become an integral and important component of the Mechanical Engineering curriculum. This program now allows the students to address more significant and practical design projects.

Senior Capstone Projects for 2005/06 included:

- An improved cranial closure system for use in neurosurgery.
- Mechanisms for the deployment of satellite solar panels.
- A spacecraft platform to be used in NASA sponsored research

These projects were supported by gifts from local industry and faculty support.

This paper will address the transition and development of the Capstone Design program at University of California, Santa Barbara


## Introduction

The transition and development of a Capstone Design program at the University of California, Santa Barbara, Department of Mechanical Engineering for Senior undergraduate Mechanical Engineering students has become an important component of the engineering curriculum and student experience.

The development of the Capstone Design program was assisted by the efforts of an Academic Coordinator with over twenty-five years of engineering management and design experience.

Prior to development of the program, student projects were informally created with little structure.

From an academic perspective, companion courses are integral with the program and include the following courses:

- ME153 Introduction of Mechanical Engineering Design typically taken at the end of the Junior year in the Spring quarter. The course now provides an introduction to design processes, project management, and engineering reporting. (3 units)
- ME156A Mechanical Engineering Design I typically taken at the beginning of the Senior year in the Fall quarter. The course addresses the rational selection of materials and system design concepts. (3 units)
- ME156B Mechanical Engineering Design II typically taken in the Senior year in the Winter quarter. The course addresses machine elements, joint design, machine dynamics, and composite materials. (3 units)

The cornerstone of the program is ME189 A, B, and C Capstone Mechanical Engineering Design Project that is taken in the Senior year for 2 units each quarter. The course was created to provide the students an experience of working as a project team to address a practical and significant design and build project. The importance of working as a team is emphasized with individual roles and responsibilities.

Students work in teams of three to five under the direction of a faculty advisor to tackle an engineering design project. Engineering communication, such as reports and oral presentations are covered. We emphasize a practical, hands-on experience, and integrate analytical and design skills.

The ME Capstone Design Projects include the following types of projects:

1) **Industry Partner** projects are supported by gifts to the program. Students have an opportunity to work on practical design projects and to interact with outside engineers.
2) **Research Partner** projects are supported by research or University funding to support current University research projects. Students have an opportunity to work with leading international researchers, graduate students, and research laboratories.
3) **Student Organizations and Design Competitions** include the SAMPE Bridge and Wing Competitions, the Mini-Baja Car race, and Engineers Without Borders. Our student teams have successfully competed and have won several prestigious awards.
4) **Student and Faculty Created Projects** include creative and challenging projects such as the award winning Laryngoscope with internal suction, a solar-powered surf board, and athletic training equipment.

**Capstone Design Projects Course Objectives**

The Senior design projects are developed with the support of local industry, interested faculty, student organizations, and interested students. The projects reflect the academic integrity and

excellence of the Mechanical Engineering department. A committed faculty and Industrial Advisory Board are instrumental in this process.

It is important to provide a broad selection of projects in terms of technical considerations, fields of interest, student and faculty interests. Students select their projects and create their project teams from a list of projects that is provided prior to the start of the Fall quarter.

The topics covered by the course include:

- Formation of Teams
- Development of a Project Plan
- Design Research
- Development of Concepts and Designs
- Design Development
- Prototyping
- Design Analyses
- Testing and Evaluation
- Final Design
- Engineering reporting including presentations, design reviews, and technical reports

In-progress grading is used for the Fall and Winter quarters. A final grade is determined in the Spring quarter after completion of the project and all course deliverables. After determination of the final grade, this is reflected retroactively for the Fall and Winter quarters. Although there is a broad selection of projects, common course deliverables and expected completion dates provide a structured format for the student efforts and faculty evaluations.

Fall Quarter Activities (ME189A) (23% of Final Grade)

- Project selection, Formation of Teams
- Design Research
- Development of Concepts and Designs
- Start Project Binder (3% of Final Grade)
- Development of Project Plans (5% of Final Grade)
- Development of Product Design Specifications (5% of Final Grade)
- Project Presentation (10% of Final Grade)

Winter Quarter Activities (189B) (33% of Final Grade)

- Design Development activities
- Project Planning activities
- Prototyping
- Design Analyses
- Testing and Evaluation
- Project Binder (3% of Final Grade)
- Preliminary Design Review (15% of Final Grade)
- Engineering Project Report (15% of Final Grade)

Spring Quarter Activities (189C) (44% of Final Grade)

- Design Development Activities
- Project Planning activities
- Prototyping
- Final Design
- Testing and Evaluation
- Complete Project Binder (4% of Final Grade)
- Completion of Design Project (25% of Final Grade)
- Final Report or Poster (15% of Final Grade)

**Industry Partner Program**

The ME Capstone Design Projects added the Industry Partner Program for the 2005/06 student projects. This program was successfully started with the generous gifts and support of local industry.

Through the Industry Partner Program, a design project is addressed by a team of three to five Senior ME students. Ideally the work will begin in September from a concept or need and will be completed by June with fabrication, testing and evaluation.

Typical projects for consideration would be the development of novel test fixtures, product line extensions, product improvements or small projects that may have been delayed by other company priorities. It is desirable to maintain limited contact and communication with the company. Each team will have a faculty adviser to assist with technical direction. Students may require access and limited involvement with the company technical staff and engineers. It is not intended to burden an already busy company staff and personnel.

The students will have the opportunity to work on a practical design project and to interact with outside engineers. The company will have the ability to work directly with some of our brightest and most capable students. This provides an opportunity for the Industry Partner for potential new hires.

To provide funding for the project and program, the Industry Partner is requested to provide a gift of $5,000.00 to the design projects. As a gift the funds go directly to the student projects and budgets and are not subject to university overhead. This level of funding was selected as it provides adequate funds for a typical student project and is easily within the discretionary budget of most company middle-management engineering managers.

As an Industry Partner, the company is invited to our afternoon Research Lecture series. The company will have access to the most current research being conducted here at the university as well as guest lecturers and visiting scholars from around the world.

An example of an Industry Partner project for 2005/06 includes efforts with a leading medical device manufacturer to design and develop an improved cranial closure system for use in

neurosurgery. In addition to student efforts with the company, efforts included interaction with the Chief of Neurosurgery and residents at a local teaching hospital.

Figure 1. Current Cranial Closure System

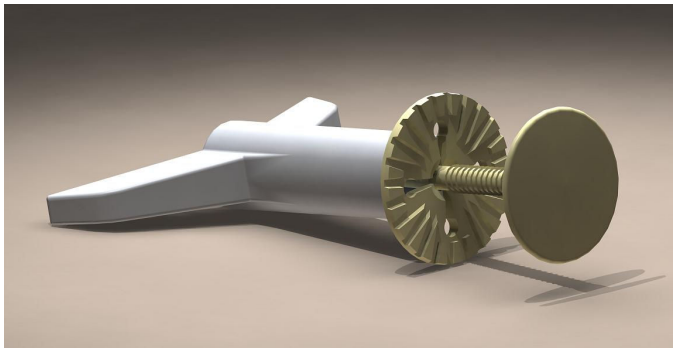


Figure 2. Student project – Rapid Cranial Closure System

**Research Partner Projects**

Research Partner projects are supported by research or University funding to support current University research projects. Students have an opportunity to work with leading international researchers, graduate students, and research laboratories. Students interested in potential graduate school opportunities will find these projects challenging.

Typical projects for consideration include the design and development of prototypes, novel test fixtures, and support activities that require design and build efforts

It is desirable to maintain contact and communication with the researcher. Each team will have a faculty adviser to assist with technical direction. Students may require access and limited involvement with graduate students.

The students will have the opportunity to work on a practical design project with a research interest and to support the efforts of leading researchers. The researcher will have the ability to have projects completed to support research efforts at minimal expense. These projects are intended to be supported by research funds.

Figure 3. Cosmic Foreground Explorer (COFE) supported though NASA and conducted through the Physics department.

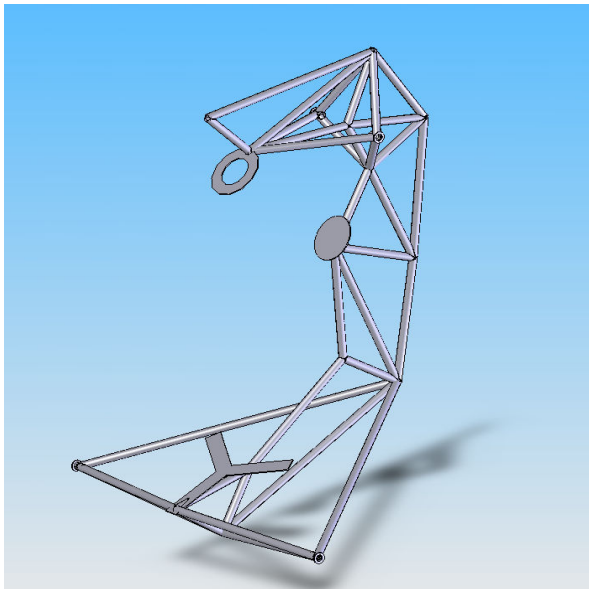


Figure 4. Student team – Modular Gondola design

**Student Organization and Design Competitions**

To provide students interested in design competitions or projects involving student organizations, several projects are provided for student considerations. These projects provide interested students the experience of competing against other schools on a national and international scale. We have successfully competed in the SAE Mini-Baja car competitions and SAMPE Bridge and Wing competitions. These projects are supported through limited departmental funds and student fund raising efforts.

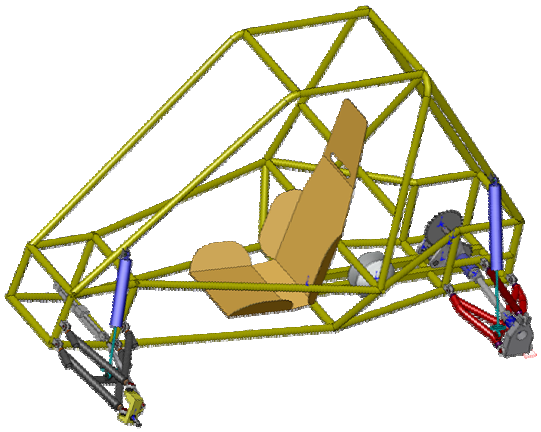


Figure 5. SAE Mini-Baja Car competition

Additionally, projects may be used to support student organizations and outreach programs. These projects have included Engineers Without Borders and student outreach programs for educational purposes. These projects are funded through limited departmental funds and student fund raising efforts.

Figure 6. Jatropha nut press in Mali.

**Student and Faculty Generated Projects**

To provide an opportunity for students interested in creating their own design project, students may propose a project for consideration. These projects are submitted for review and approval and must provide sufficient Mechanical Engineering design challenges and fit with course deliverables. These projects are supported with limited departmental funds.

Examples of 2005/06 student projects include a Laryngoscope with integral suction for use by emergency health care professionals in trauma situations. This project was created by a Senior ME student who had experience as an emergency field technician. Reflecting the entrepreneurial environment of the University and surrounding community, the student team also competed in a business plan competition in our Technology Management Program. Based upon their practical approach and clear market need, the student team won this competition and have used the funds to patent their design.

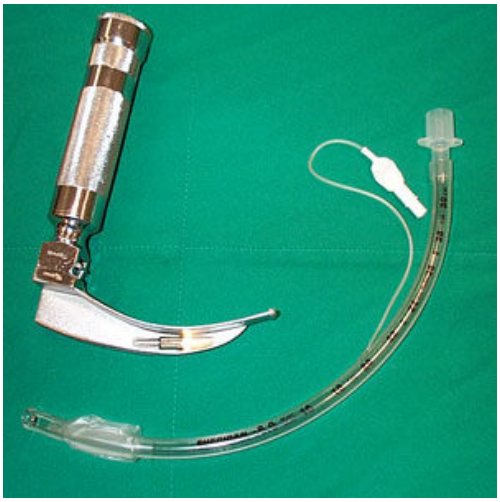


Figure 7. Current Laryngoscope with endotracheal tube

**Design Projects Poster Competitions**

A poster competition is conducted in June at the completion of the academic year. All student teams must complete their project for review and evaluation prior to the poster competition. The teams must also document their project efforts through a final engineering report or poster. Most teams select the completion of a poster and compete in the event. The poster competition includes judges from select faculty and local industry executives not directly involved with any of the projects under consideration. The teams, projects, and posters compete for Most Innovative Design, Most Marketable Design and Best Technical Presentations. The winning posters are then on display in the department and enter the Wall of Fame for intended permanent display.

In addition to the Senior Capstone Design Projects, the projects completed by the Junior ME class under ME153 are also on display and complete under a separate poster competition. These projects are limited in scope and budget and are completed in a timeframe of about four to six weeks. Interestingly, these projects provide for a very creative atmosphere. This also provides the Junior class an opportunity to view the Senior projects on display and expectations for their Senior year.

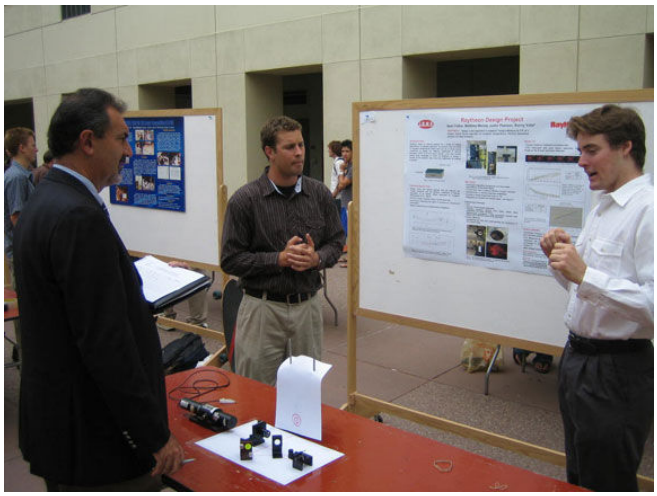
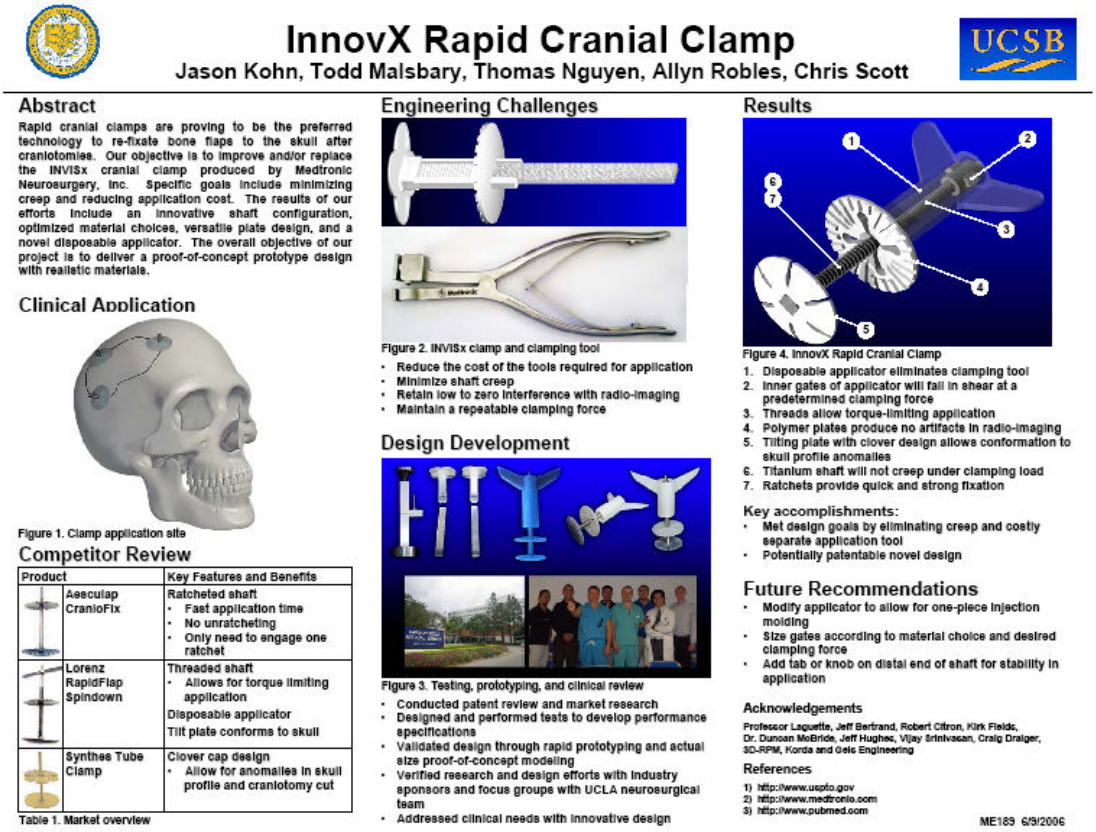


Figure 8. Design Projects Poster Competition



# InnovX Rapid Cranial Clamp

Jason Kohn, Todd Malsbary, Thomas Nguyen, Allyn Robles, Chris Scott

UCSB

## Abstract

Rapid cranial clamps are proving to be the preferred technology to re-fixate bone flaps to the skull after craniotomies. Our objective is to improve and/or replace the INVISx cranial clamp produced by Medtronic Neurosurgery, Inc. Specific goals include minimizing creep and reducing application cost. The results of our efforts include an innovative shaft configuration, optimized material choices, versatile plate design, and a novel disposable applicator. The overall objective of our project is to deliver a proof-of-concept prototype design with realistic materials.

## Clinical Application

Figure 1. Clamp application site

## Competitor Review

| Product | Key Features and Benefits |
|---|---|
| Aesculap CranioFix | Ratcheted shaft<br>• Fast application time<br>• No unratcheting<br>• Only need to engage one ratchet |
| Lorenz RapidFlap Spindown | Threaded shaft<br>• Allows for torque limiting application<br>Disposable applicator<br>Tilt plate conforms to skull |
| Synthes Tube Clamp | Clover cap design<br>• Allow for anomalies in skull profile and craniotomy cut |

Table 1. Market overview

## Engineering Challenges

Figure 2. INVISx clamp and clamping tool

- Reduce the cost of the tools required for application
- Minimize shaft creep
- Retain low to zero interference with radio-imaging
- Maintain a repeatable clamping force

## Design Development

Figure 3. Testing, prototyping, and clinical review

- Conducted patent review and market research
- Designed and performed tests to develop performance specifications
- Validated design through rapid prototyping and actual size proof-of-concept modeling
- Verified research and design efforts with industry sponsors and focus groups with UCLA neurosurgical team
- Addressed clinical needs with innovative design

## Results

Figure 4. InnovX Rapid Cranial Clamp

1. Disposable applicator eliminates clamping tool
2. Inner gates of applicator will fail in shear at a predetermined clamping force
3. Threads allow torque-limiting application
4. Polymer plates produce no artifacts in radio-imaging
5. Tilting plate with clover design allows conformation to skull profile anomalies
6. Titanium shaft will not creep under clamping load
7. Ratchets provide quick and strong fixation

### Key accomplishments:

- Met design goals by eliminating creep and costly separate application tool
- Potentially patentable novel design

## Future Recommendations

- Modify applicator to allow for one-piece injection molding
- Size gates according to material choice and desired clamping force
- Add tab or knob on distal end of shaft for stability in application


## Acknowledgements

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ME189 6/9/2006

Figure 9. Capstone Design Project Poster

## Future Directions

Although the program has been successful in many ways, there still remains opportunities for significant improvements. These include:

- Increase the number of Industry Partner projects with increased funding
- Increase the involvement of Faculty and Research Partner projects
- Develop a dedicated Design Lab Studio
- Introduce interdisciplinary teams with involvement of other departmental Capstone design projects

## Acknowledgements

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