

# Project-Based Teaching: CS/EE/ME 75 and the DARPA Grand Challenge



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http://team.caltech.edu

### CS/EE/ME 75, 2004-05: Alice

#### **Team Caltech**

- 50 undergraduates for ~1 year
- Course credit through CS/EE/ME 75
- Summer team: 36 full time undergrads, 3 grad students + 2 faculty + 6 volunteers

#### Alice

- 2005 Ford E-350 Van
- Sportsmobile 4x4 offroad package
- 5 cameras: 2 stereo pairs + roadfinding
- 5 LADARs: long, med\*2, short, bumper
- 2 GPS units + 1 IMU (LN 200)





 4 seats w/ computer workstations

- 6 P4, 3 GHz computers
- 1 AMD64 quad

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### Outline

- I. CS/EE/ME 75: Introduction to Multi-Disciplinary Systems Engineering
- II. Class Project: DARPA Grand Challenge
- III. Lessons Learned and Discussion





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### **CS/EE/ME 75: Multi-Disciplinary Systems Engineering**

### **Course Goals**

- Provide an introduction to team-based *multi-disciplinary* engineering
- Introduce tools for coordinating work
   across a large group of engineers
- Design, build and document a complex engineering system

### Approach

- Select a major project each year (ideally with some prize money)
- Link work in individual classes to CS/ EE/ME 75 project
- First two terms focused on design (through individual classes)
- Bring entire team together third term (and summer) to complete the project

### Features

- Potential to provide integrating project across multiple depts (linked to courses)
- Participation across skill levels (Fr to Sr)





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# What We Teach

### **Project Planning Tools**

- How do you plan and execute a large, complex project?
- Timeline charts (milestones)
- GOTChA charts goals, objectives, technical challenges, approach

### **Project Management Tools**

- Documentation wiki
- Task tracking bugzilla
- Code management subversion, YaM

### **Decision Making**

- Let students make the decisions on the decision (with lots of questions)
- Allow mistakes (best way to learn!)

### **Modeling and Testing**

• Simulations, data logging & analysis

#### Project GOTChA Summer 2005

Main GOTChA		Timeline [W15]	Test Plan [W18	5] 300 mi, 35 mph	0B 샵, 0N 샵		
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GOTChA V		Ve	eh/Emb	Planning	Terrain	IPT	
Updated: 19 Jun 05		Goals Obj	ectives To	ech Challenges	Approach		
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#### Infrastructure/cross-cutting teams

Build/maintain project-level technology

### The "Classroom"





# Non-traditional classroom setting

- Lots of small group meetings
- Interaction in the shop and out in the field
- Interaction with race officials (DARPA)

### Challenges

 Lots of work in the evenings and on weekends

### 2007 DARPA Grand Challenge (Urban Challenge)

### **Autonomous Urban Driving**

- 60 mile course, less than 6 hours
- City streets, obeying traffic rules
- Follow cars, maintain safe distance
- Pull around stopped, moving vehicles
- Stop and go through intersections
- Navigate in parking lots (w/ other cars)
- U turns, traffic merges, replanning
- Prizes: \$2M, \$1M, \$500K









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### **Urban Driving**



#### Video from 29 Jun 06 field test

- Front and side views from Tosin
- Rendered at 320x240, 15 Hz
- Manually synchronized

#### Some challenges

- Moving obstacle detection, separation, tracking and prediction
- Decision-making
- Lane markings (w/ shadows)





### Key technical areas (focus of new research)

- Reasoning: decision making in presence of uncertainty
- Sensing technologies: characterization, detection, tracking, fusion
- Planning technologies: route, traffic, path

# Mapping and Planning





### 2006-07 Team Caltech

Race Teams [edit] Integrated Product Team Team Leader: Bichard Murray							
Instr: Richard Murray Coord: Dominic Rizzo Operations Team [edit]	Instr: Joel Burdick Coord: Noel duToit Navigation Team [edit]	Instr: Andrew Howard Coord: Pete Trautman Sensing Team [edit]	Instr: TBD Coord: Nok Wongpiromsarn Mission Team <sup>[edit]</sup>	1 PD 8 GRA 3 visitors			
<ul> <li>Ken Fisher+</li> <li>R Grogan+*</li> <li>Daniel Alvarez</li> <li>Arthur Chang</li> <li>Iain Cranston*</li> <li>Matthew Feldman*</li> <li>Nicholas Fette*</li> <li>Noele Norris*</li> </ul>	<ul> <li>Stefano di Cairano</li> <li>Vanessa Carson</li> <li>Lars Cremean</li> <li>Melvin Flores</li> <li>(Sam Pfister)</li> <li>Tom Duong*</li> <li>Luke Durant*</li> <li>Jessica Gonzalez</li> </ul>	<ul> <li>Mohamed Aly</li> <li>Laura Lindzey+</li> <li>Jeremy Ma</li> <li>Sam Pfister</li> <li>Daniele Tamino</li> <li>Justin McAllister</li> <li>Kenny Oslund</li> <li>Christopher Rasmussen</li> </ul>	<ul> <li>Vanessa Carson</li> <li>Aditya Khosla</li> <li>Scott Goodfriend</li> <li>Chess Stetson</li> <li>Josh Feingold</li> <li>Bob Rasumussen</li> <li>Michael Kaye</li> <li>Julia Braman?</li> </ul>	1 alum 29 UGs  52 members			
<ul> <li>Glenn Wagner</li> <li>Albert Wu</li> <li>(Johnny Zhang)+</li> <li>William David Carrillo*</li> <li>Jimmy Paulos?</li> <li>Daniel Talancon?</li> </ul>	<ul> <li>Ryan Lim</li> <li>Ghym Loveness</li> <li>Russell Newman*</li> <li>Chris Schantz*</li> <li>Francisco Zabala</li> <li>David Waylonis*</li> <li>Steven Gray*</li> <li>Brent Goldman?</li> <li>Jerry He+?</li> <li>Celia Peina?</li> </ul>	<ul> <li>Yi Wang</li> <li>(Francisco Zabala)</li> <li>Johnny Zhang</li> <li>Joe McDonnell?</li> <li>Brandt Belson?</li> <li>Philipp Boettcher?</li> <li>Miles Robinson?</li> </ul>	<ul> <li>Edward Chen?</li> <li>Steve Chien?</li> <li>Jay Conrod</li> <li>Mitch Ingham?</li> <li>(secondary asgnmt)</li> <li>* = CS/EE/ME 75</li> <li>+ = paid position</li> </ul>				

### **Lessons Learned**

### **Course Goals**

- ✓ Provide an introduction to team-based multi-disciplinary engineering
- ✓ Introduce tools for coordinating work across a large group of engineers
- ✓ Design, build and document a complex engineering system

### Things that worked particularly well

- Students were incredibly smart, responsible and fun to work with
- Students learned a lot about engineering (success and failures)

### Things that could be improved

- Better integration into Caltech courses
- Better teaching of design tools
- More effective use of reviews
- Better use of modeling and simulation
- More participation by women (currently about 10-15%)

### Challenges for this year

 Competition is much harder ⇒ more challenging to integrate undergraduates



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## Summary

### CS/EE/ME 75: great course for teaching engineering

- Requires interaction between CS, EE, ME (and more)
- Learn about working in teams to tackle a truly hard problem

### Urban Challenge serves as a great course project

- Requires system level approach
- Combination of implementation of known techniques
   and development of new research ideas

# A lot of fun (especially if you like going without sleep...)











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