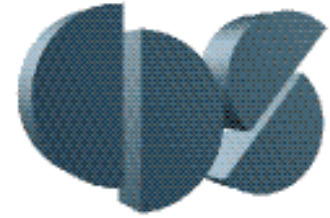




# 2007 Urban Challenge Information Session



Joel Burdick    Richard Murray    Pietro Perona  
Engineering and Applied Science  
California Institute of Technology

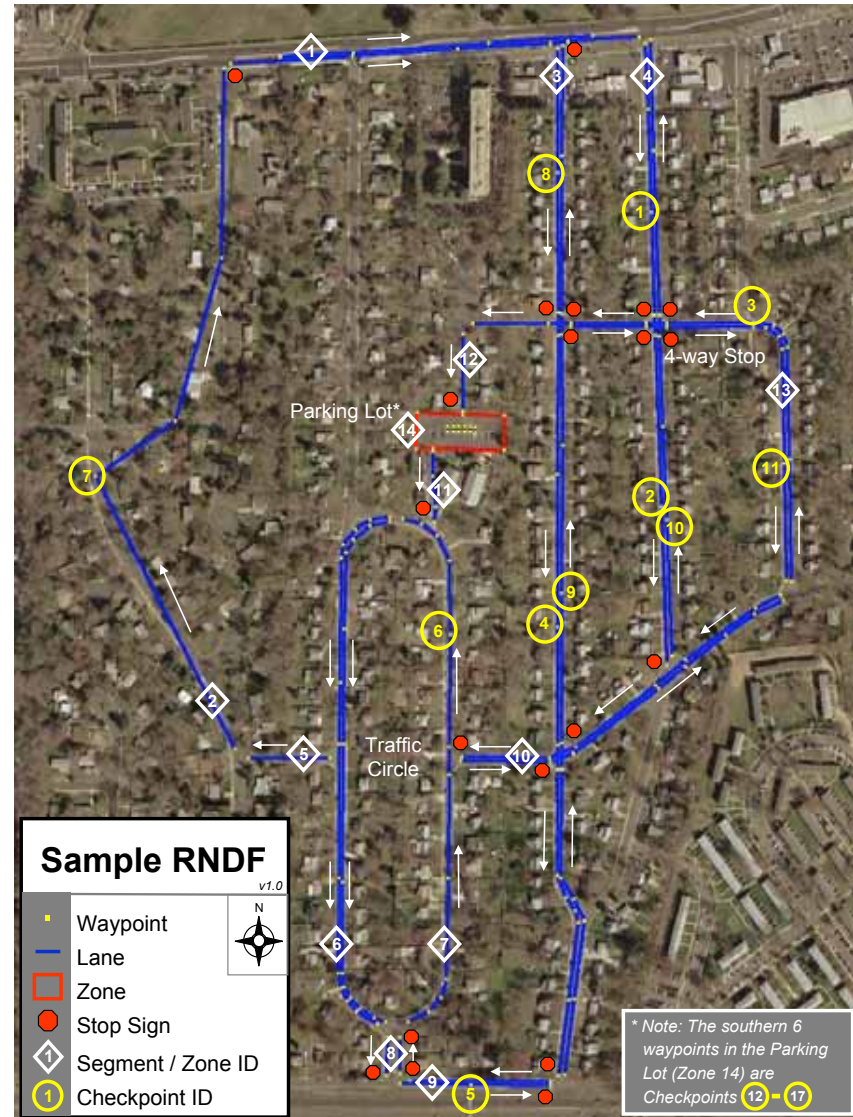
## Goals

- \* Describe what the 2007 Urban Challenge is all about
- \* Discuss current state of project (quick overview of Alice)
- \* Describe how different groups can participate in the challenge
- \* Answer questions and collect feedback on Caltech participation
- \* Collect interest sheets to estimate participation from different groups

# 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, \$500K, \$250K



# Urban Driving

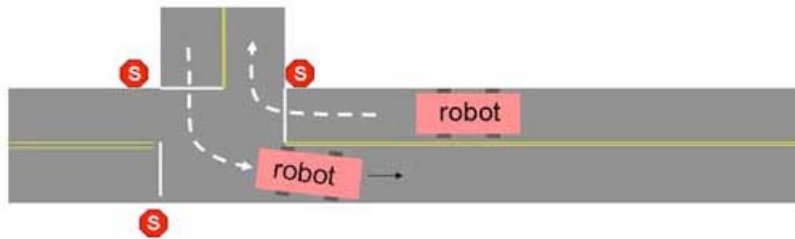


# Basic Navigation



## Basic Navigation

Vehicle stays entirely within travel lane around corners.

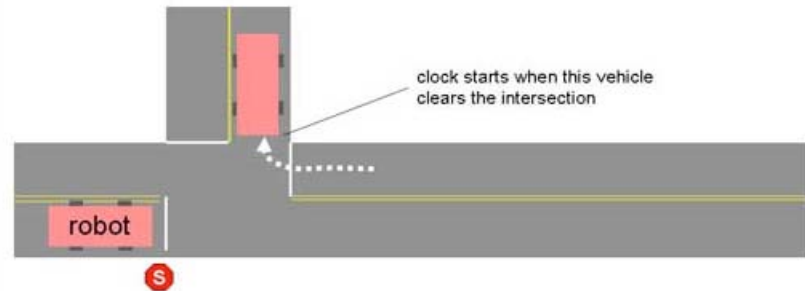


Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06



## Basic Navigation

Vehicle exhibits less than 10 seconds of delay when intersection is clear.

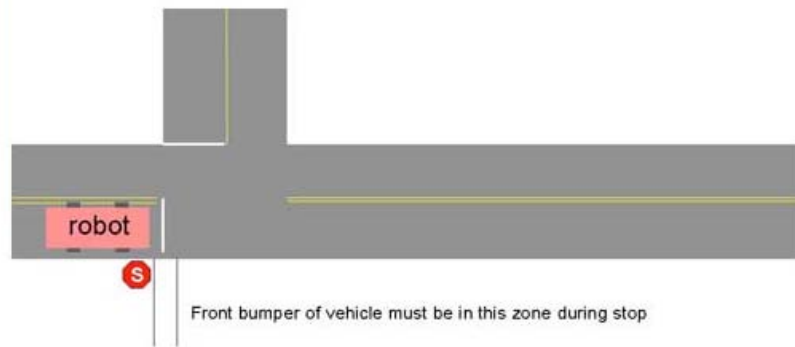


Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06



## Basic Navigation

Vehicle stops within 1 meter of stop line.

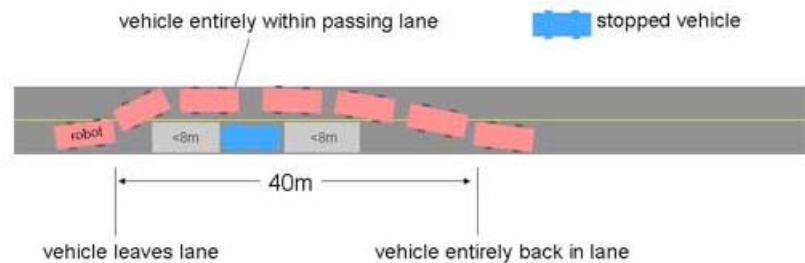


Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06



## Basic Navigation (selected)

Vehicle completes passing maneuver in 40-meters or less maintaining 8-meter safety buffer



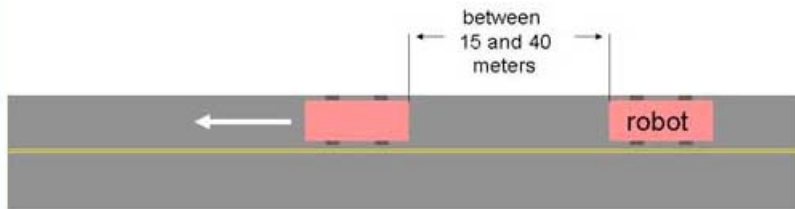
Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06

# Basic Traffic



## Basic Traffic

Vehicle maintains 15 meter safety buffer at 15 mph.

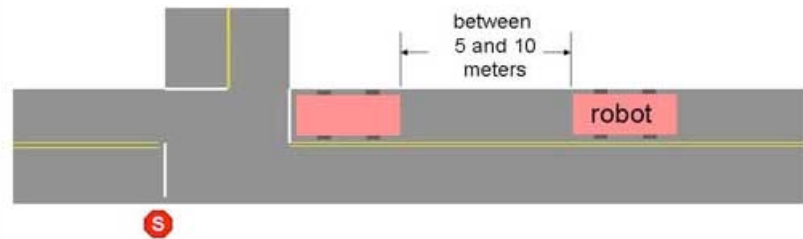


Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06



## Basic Traffic

Vehicle stops between 5 and 10 meters behind stopped lead vehicle.

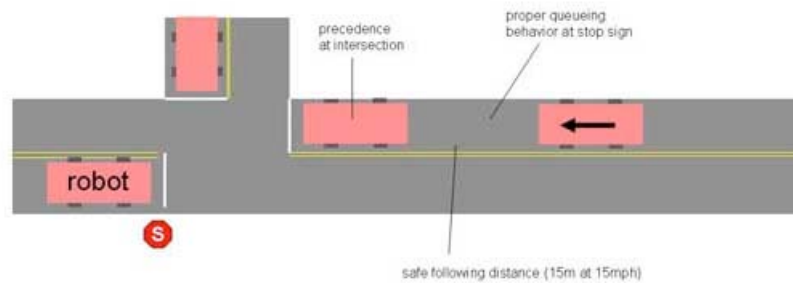


Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06



## Basic Traffic

Vehicle exhibits correct precedence order at intersection.



First to reach stop line is the first to leave.

Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06

# Advanced Navigation

**DARPA GRAND CHALLENGE** **Advanced Navigation**

A U-turn may be effected through one or more three-point turns.

● Waypoint  
● Entry waypoint  
● Exit waypoint

Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06

**DARPA GRAND CHALLENGE** **Advanced Navigation**

Vehicle re-plans when primary route is blocked.

Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06

**DARPA GRAND CHALLENGE** **Advanced Navigation**

Vehicle exhibits correct parking lot behavior with less than 10 seconds excess delay.

Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06

**DARPA GRAND CHALLENGE** **Advanced Navigation**

Road-following situations

- Curbs, berms, vegetation
- Street lines may be missing
- Winding roads
- Sparse waypoints - may not be in center of road

Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06

# Advanced Traffic

**DARPA GRAND CHALLENGE** **Advanced Traffic**

- Vehicle should pull into traffic when oncoming vehicles leave a gap of at least 10 seconds.
- Vehicle maintains 8 meter safety gap.

The diagram shows a road with a curve of radius  $R \sim 150$  feet. A robot is shown merging into the traffic from a straight section. A 'BUILDING' is located on the right side of the road. Other robots are shown further along the curve. A '10 seconds' gap is indicated between oncoming vehicles. An '8 meter gap' is shown between the merging robot and the vehicle ahead.

Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06

**DARPA GRAND CHALLENGE** **Advanced Traffic**

Vehicle makes a left turn across moving traffic and proceeds with less than 10 seconds excess delay.

The diagram illustrates a robot making a left turn across a road with moving traffic. A '10 seconds' delay is indicated between the start of the turn and the point where the robot is fully in the traffic lane.

Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06

**DARPA GRAND CHALLENGE** **Advanced Traffic**

Vehicle navigates parking area in the presence of moving traffic

The diagram shows a robot navigating a parking area. A 'K-rail' is visible. Other vehicles and obstacles are present in the area.

Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06

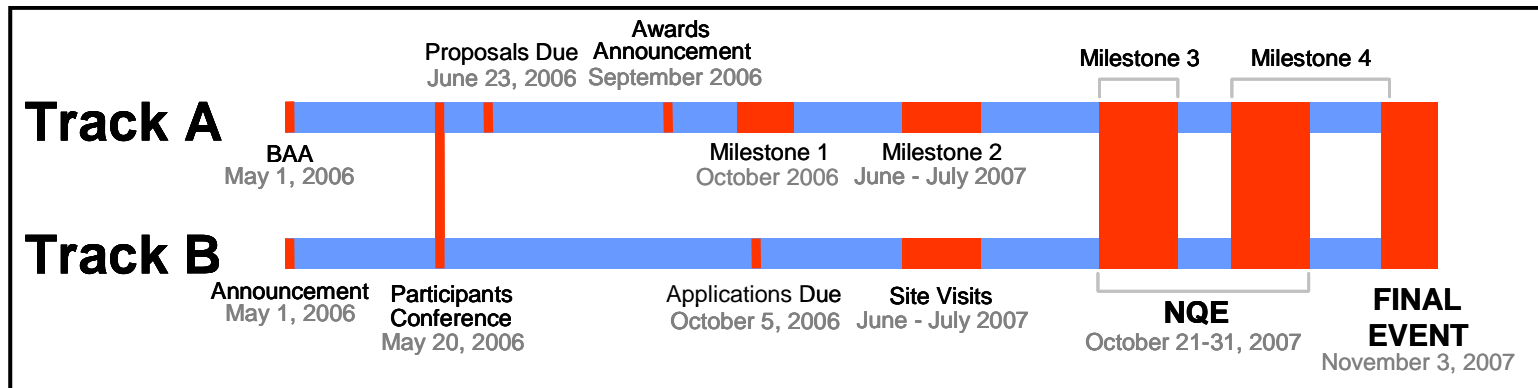
**DARPA GRAND CHALLENGE** **Advanced Traffic**

Vehicle exhibits safe behavior at all times to avoid collisions and near collisions.

The diagram shows a robot avoiding a collision with another vehicle. The text 'Accident avoidance' is written below the diagram.

Approved for Public Release, Distribution Unlimited, DARPA Approval 7279, 19 May 06

# 2007 Urban Challenge Participation



## Track A: \$1M grant from DARPA

- Proposal due 23 June 2006; up to \$1M + any additional fundraising
- Award based on technical approach, management and funding plan, strength of team

## Track B: no DARPA funding; similar to last year (application, site visit, NQE, GCE)

- \$50K award for getting to NQE, \$100K award for getting to race
- Application due 5 Oct, with video, technical paper due in Feb 07; site visits in Jun 07

## Changes from last year

- Use of government resources OK with permission from sponsors

**All participants in the race are eligible for 1st, 2nd or 3rd prize cash**



# Team Caltech

## Team Caltech

- Started in 2003, for DGC04
- Over 100 undergraduates + grad students, faculty and volunteers

## Alice

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

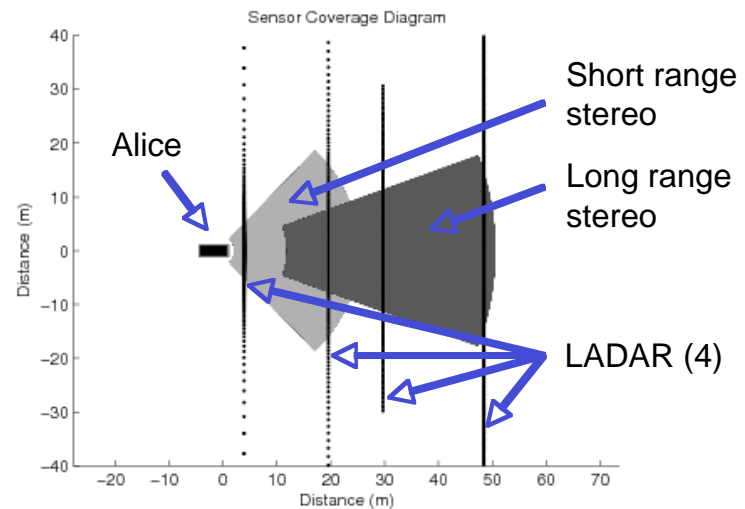


## Computing

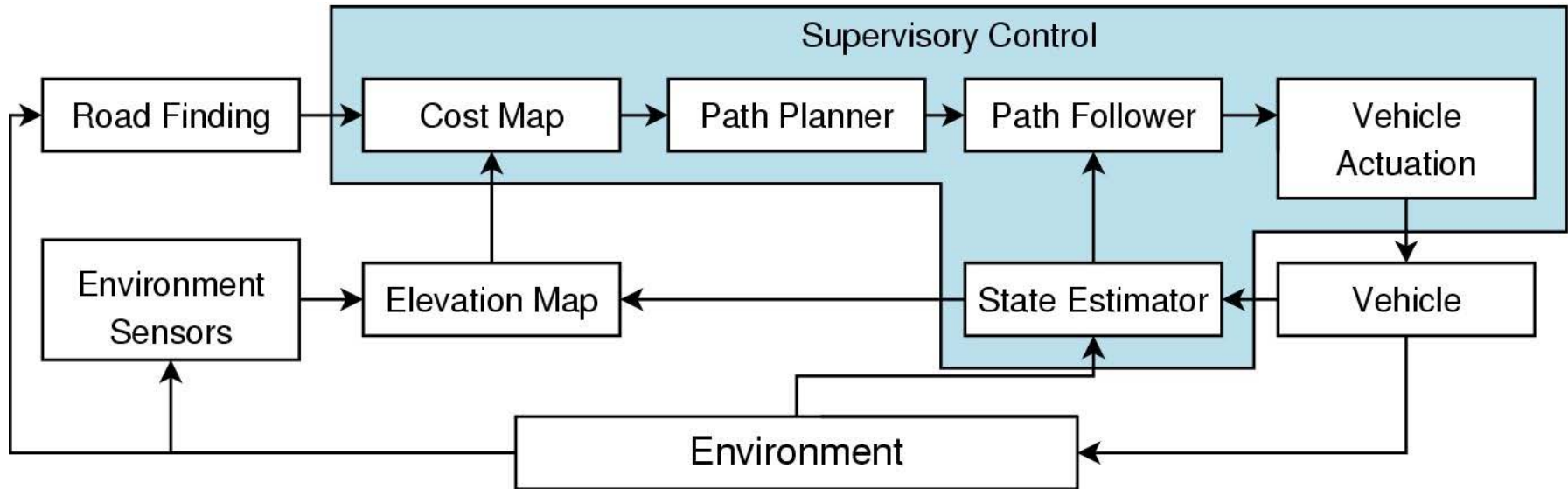
- 6 Dell PowerEdge Servers (P4, 3GHz)
- 1 IBM Quad Core AMD64 (fast!)
- 1 Gb/s switched ethernet

## Software

- 15 programs with ~100 exec threads
- 100,000+ lines of executable code (good programmer does <100/day)



# How Alice Drives

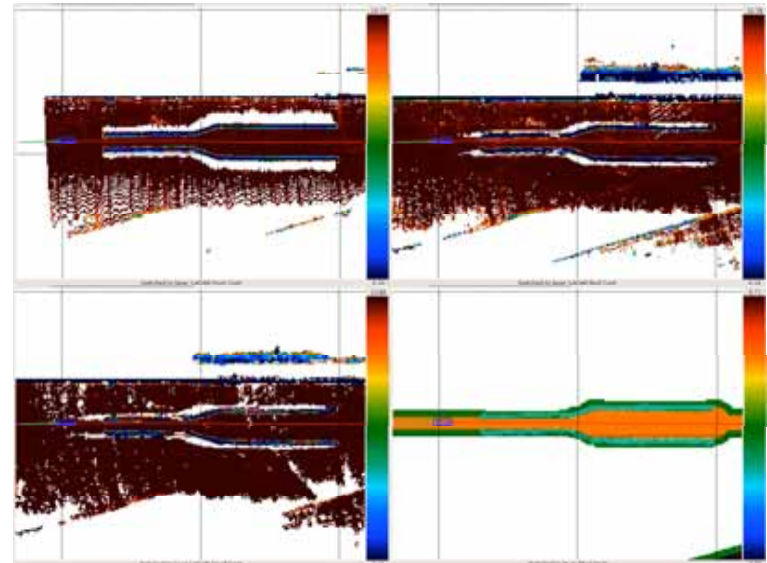


## Current architecture

- Optimization-based motion planning based on fused terrain data
- Supervisory controller handles contingencies (device failures, unseen obstacles, etc)

## What's missing

- Can't currently handle moving obstacles (assumes environment is static)
- No understanding of rules of the road

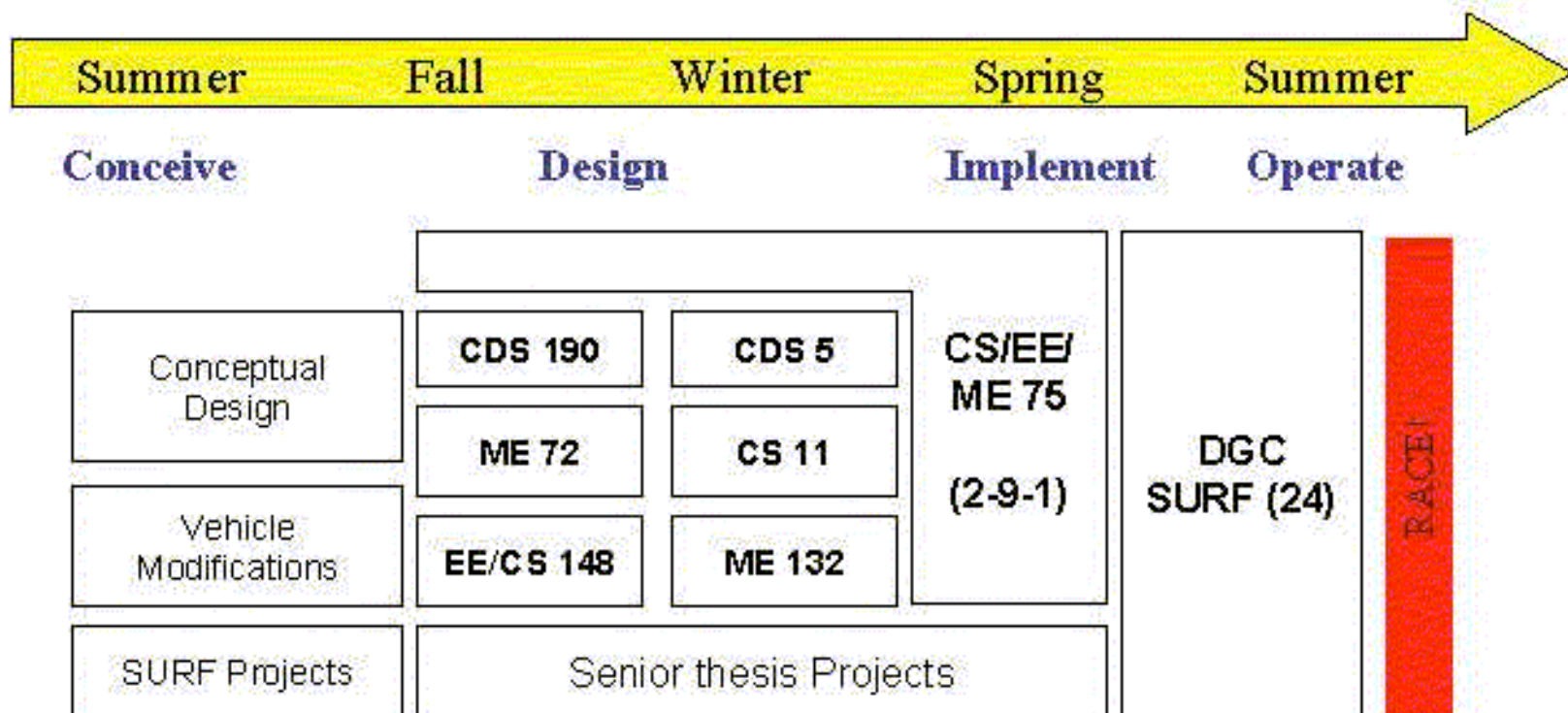


# Team Caltech and the Urban Challenge

## Possible mechanisms for Caltech participation in the Urban Challenge

- Undergraduate-only team (similar to last year): tie to courses, SURF program
- Mixed graduate/undergrad team: integrate current research from Caltech students
- Student-oriented team with lab/industry partners: include JPL and industry partners

## CS/EE/ME 75 Course Structure



# Planned Next Steps (DRAFT)

## Summer 2006

- 13 undergraduates + 3-4 grad students working in SURF + grad research projects
  - Demonstrate basic navigation and traffic abilities (already planned)
- Conceptual design study: read literature, study rules, work through design examples
  - Need to make decisions about basic architecture no later than 1 Sep
  - Would like to evaluate key technologies to assess readiness as well
  - Should be possible for most people who are interested to participate in study
- Fundraising: submit DARPA proposal (23 Jun) + identify partners and support
- Go/no go decision by 15 September based on interest, funding, and plan

## Academic year 2006-07

- CS/EE/ME 75 + linked courses: design and implementation
  - CS/EE/ME 75 focused on team activities; other work done through courses
  - Example: CDS 110 - control design for gimbaled sensor platform + sensor fusion
  - Integrate with graduate research and partner (JPL + industry) technical work
- Demonstrate advanced navigation by Jan 07, advanced traffic by Apr 07
- End of academic year goal: 60 mile demonstration in mock city, with resets

## Summer 2007: optimized design and testing

# How To Participate

## Undergraduates

- Summer design study
- CS/EE/ME 75 and linked courses
- Senior theses and 2007 SURF
- Work study (subject to funding)

## Graduate students/postdocs/faculty

- Implement graduate research projects on Alice (subject to advisor approval)
- TA positions for CS/EE/ME 75 + possible DARPA-funded graduate research
- Integrate DGC07 technical challenges into course HW, projects (linked courses)

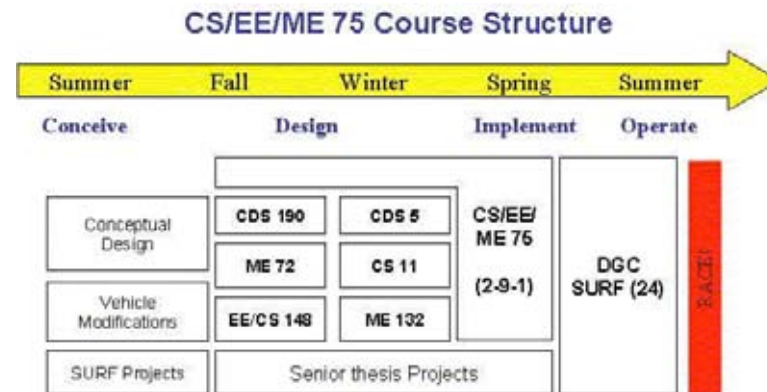
## JPL researchers and engineers

- Participate on design reviews, provide expert advise, participate on design teams, ...
- Exploring joint activities with various group and section leaders (starting this summer)

## Industry Partners, Alumni

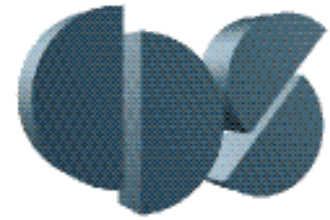
- Technical: feedback through reviews, advise to students, design work, etc
- Monetary: funds to support students, equipment donations, facilities and test sites

## Non-Caltech individuals and groups: talk to Richard





# 2007 Urban Challenge Information Session



Joel Burdick    Richard Murray    Pietro Perona  
Engineering and Applied Science  
California Institute of Technology

## Goals

- \* Describe what the 2007 Urban Challenge is all about
- \* Discuss current state of project (quick overview of Alice)
- \* Describe how different groups can participate in the challenge
- \* Answer questions and solicit feedback on Caltech participation
- \* Collect interest sheets to estimate participation from different groups