Autonomous Vehicle GNC

- Introductions
- Overview
- **Autonomous GNC**
  - Basic Control
  - ION Robotic Mower
  - **Global Challenge**
- Lego® Mindstorms Intro
- Lego® Mindstorms Challenge

- GNC issues for autonomous vehicles
- Basic Control (Mikel - 30 minutes)
- Sensors description
- Outer Loop
- Inner Loop

- ION Robotic Lawn Mower – (Jade - 1 hour)
- Miami University's Approach

- **A Global Challenge (Carrie & Casey - 1 hour)**
  - **Autonomous Competitions**
  - **Vehicle Design**
  - **Sensor Integration**
  - **Mission Planning & Implementation**

A Global Challenge

Scientists across the planet search for autonomous navigation solutions everyday…

…but without a fresh and knowledgeable workforce, the solution will continue to elude us

How can we inspire more people to pursue science and engineering career fields?

Engineering Dilemma in the U.S.A.

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- Students are not performing well in STEM
  - Of our 4th& 8th grade students…
    - Only 1/3 are proficient in math
    - Less than 1/3 are proficient in science
- Fewer than 6% of high school seniors plan to pursue an engineering degree
- S&E undergraduate degrees are growing by 1.5% a year
- S&E employment opportunities are growing by 4.2% a year
  - By 2016 we project a 17% increase (5M S&E jobs)
- Currentworkforce is maturing
  - 27% will reach retirement age in the next 12 months



Worldwide Engineering Dilemma

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Region/Country	All Fields	STEM Fields	Percent STEM
All Regions	9,057,193	2,395,238	26.4%
Asia	3,224,593	1,073,369	33.3%
China	929,598	484,704	52.1%
India	750,000	176,036	23.5%
Japan	548,897	351,299	64.0%
South Korea	239,793	97,307	40.6%
Middle East	445,488	104,974	23.6%
Europe	2,682,448	713,274	26.6%
France	309,009	83,984	27.2%
Spain	211,979	55,418	26.1%
United Kingdom	282,380	72,810	25.8%
Central/Eastern Europe	1,176,898	319,188	27.1%
Russia	554,814	183,729	33.1%
North/Central America	1,827,226	341,526	18.7%
Mexico	321,799	80,315	25.0%
United States	1,305,730	219,175	16.8%
South America	543,805	96,724	17.8%
Brazil	395,988	61,281	15.5%
Africa	1,719,254	240,193	19%

*CIA World Fact Book 2009

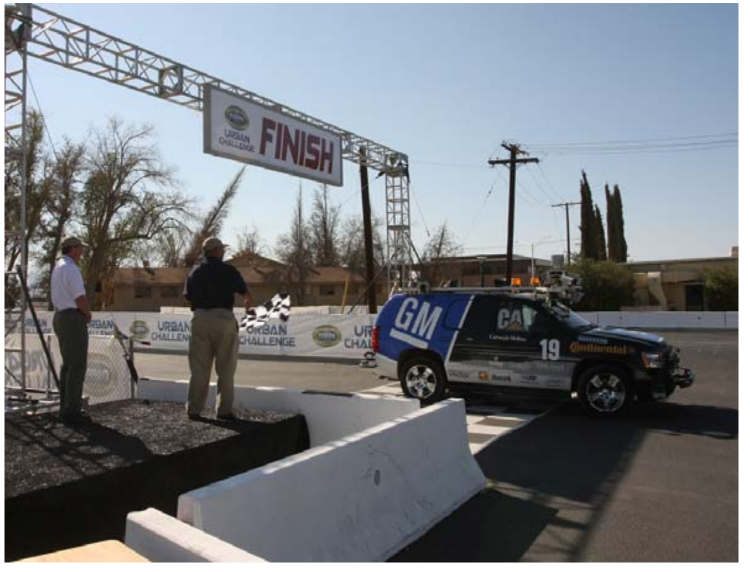
Worldwide Engineering Dilemma

Country	Population	Enrollment in Tertiary	Enrollment in Tertiary S&E	
Cameroon	18,879,301	6658	1079	16%
Côte d'Ivoire	20,617,068	306400		
Eritrea	5,647,168	264822	38028	14%
Ghana	23,887,812	80222	22999	29%
Malawi	15,028,757	67839	7985	12%
Nigeria	149,229,090	45128		

***CIA World Fact Book 2009**

Autonomous Competitions

- DARPA Grand and Urban Challenges
- ION's Robotic Lawnmower Competition
- ION's Mini-Urban Challenge



DARPA Challenges

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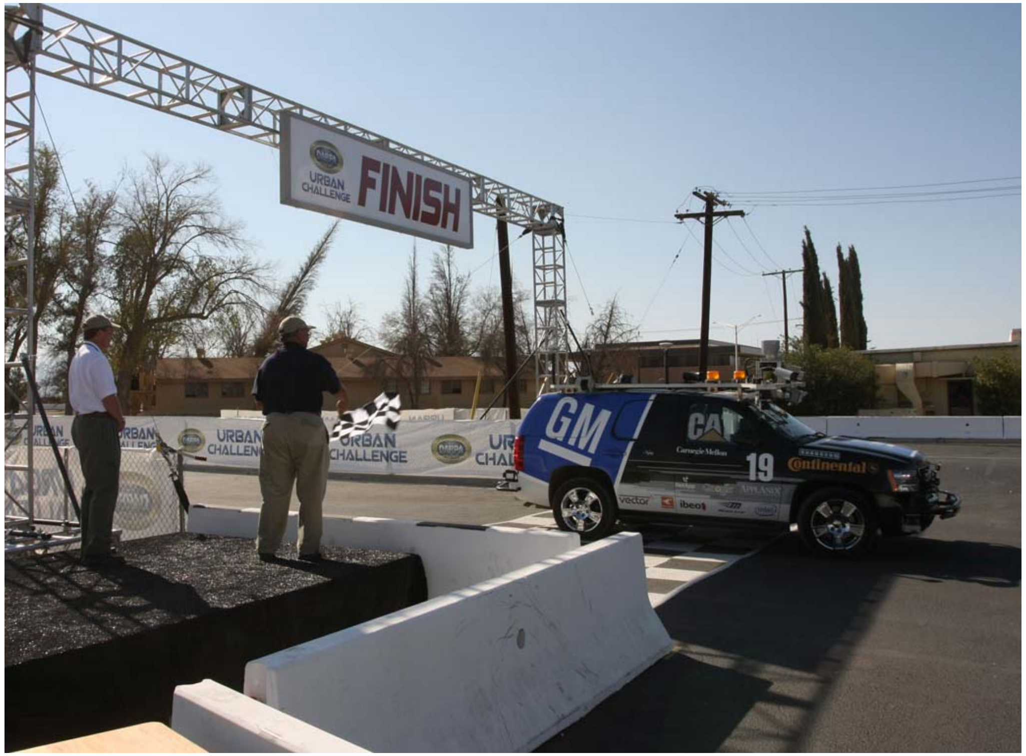
Advanced Degrees & Industry

Initiated to leverage American ingenuity to accelerate the research and development of autonomous ground vehicle technology, so it could be applied to military requirements and save American lives on the battlefield



Robotic Lawnmower Competition

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Collegiate

Purpose is to design and operate a robotic unmanned lawnmower using the art and science of navigation to rapidly and accurately mow a field of grass

Mini-Urban Challenge

- Introductions
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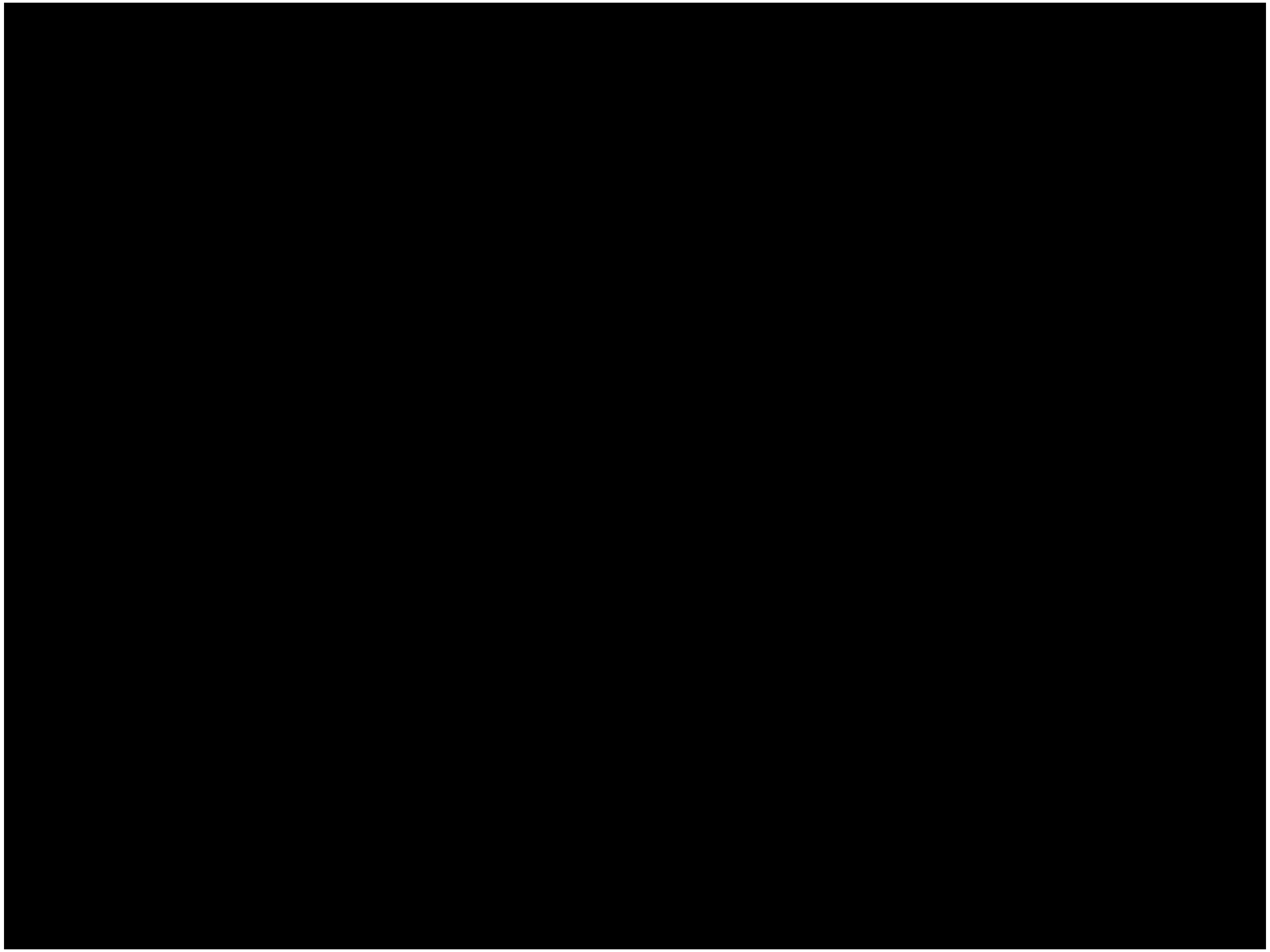
High School

Purpose is to challenge high school students to design and operate a robotic unmanned car built from a LEGO® MINDSTORMS® kit that can accurately navigate through a LEGO® city

Mini-Urban Challenge



movie

3 Components of Autonomous Navigation

- Introductions
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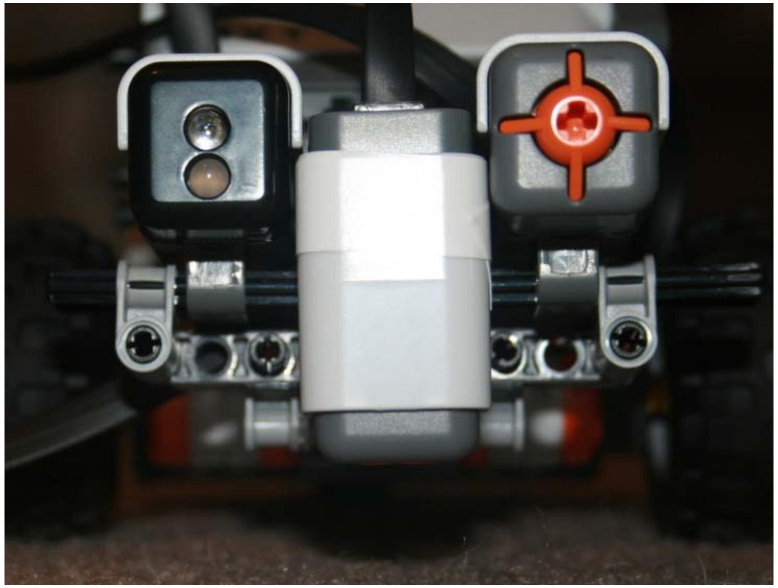
1. Vehicle Design

2. Sensor Integration

3. Mission Planning & Implementation



Vehicle Design

Junior – Stanford University

DARPA Urban Challenge 2007

Vehicle Design

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Cutter
Case Western Reserve
Robotic Lawnmower Competition 2009

Ohio University
Robotic Lawnmower Competition 2009

Vehicle Design

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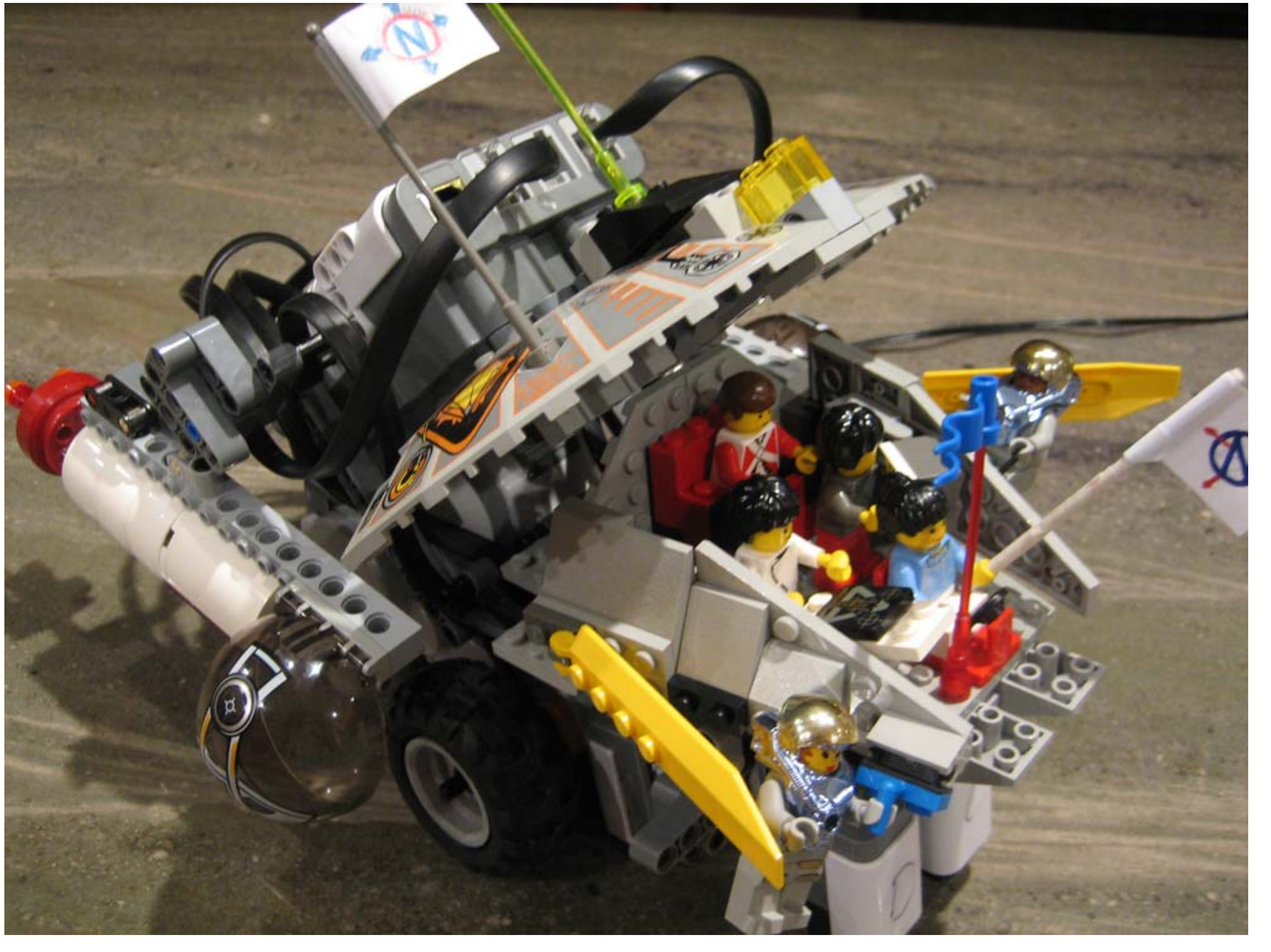
StarCruiser – Talawanda High School

Mini-Urban Challenge 2009



Sensors

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Sandstorm – Carnegie Mellon

DARPA Grand Challenge 2005

Sensor Simulation

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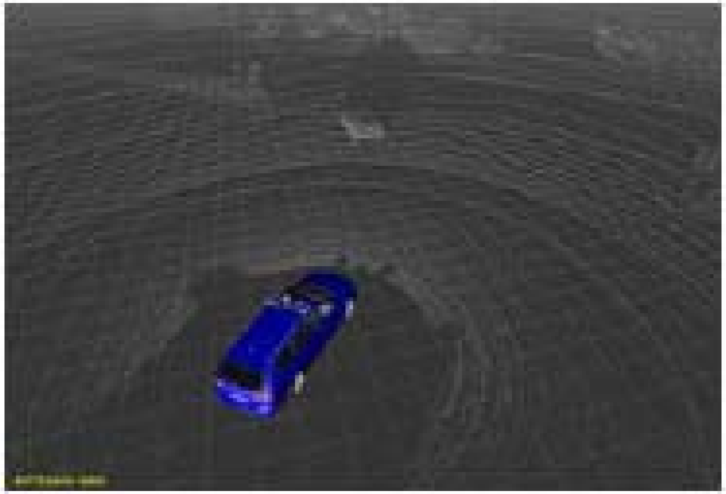
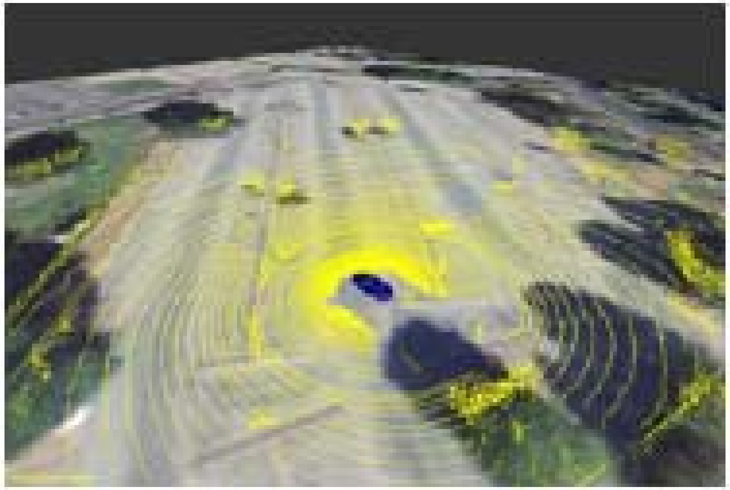
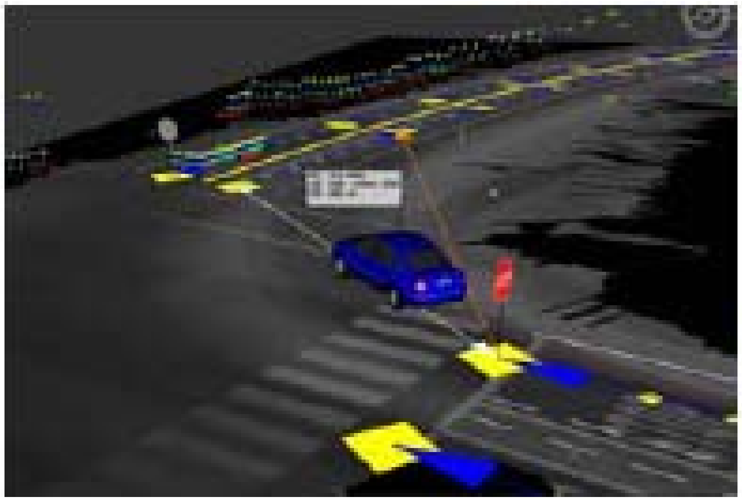




Velodyne LIDAR



IBEO Range Scan

Boss – Carnegie Mellon

Sensors

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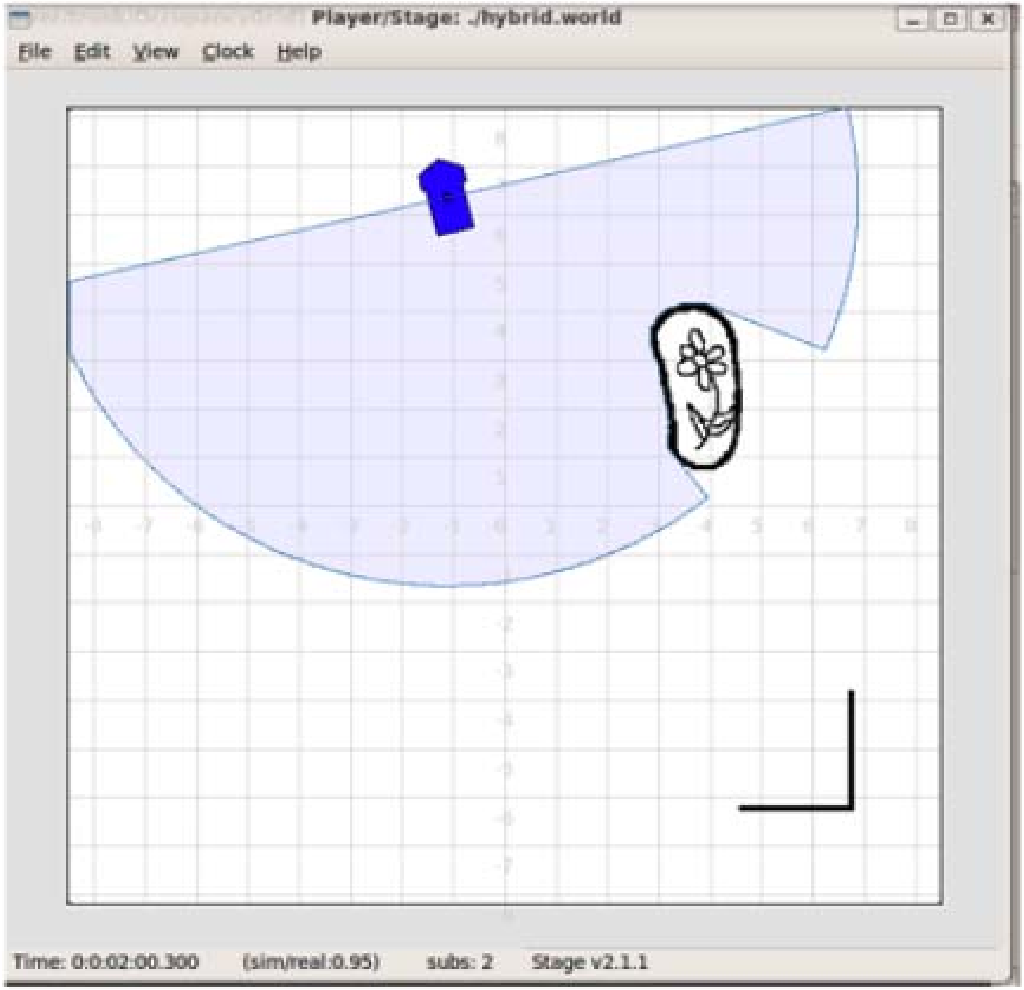
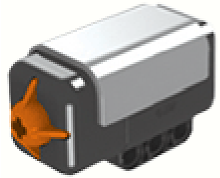
University of Waterloo

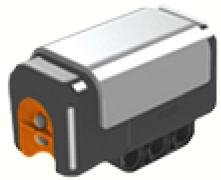
Robotic Lawnmower Challenge 2009

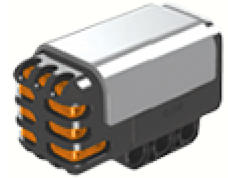


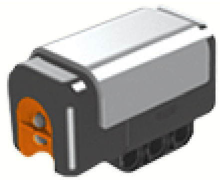
Sensors

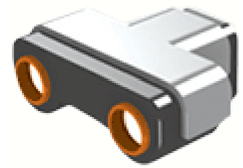
Mini-Urban Challenge
LEGO® Mindstorms Sensors

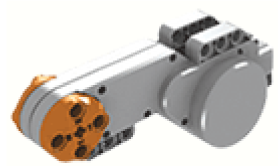
Touch - 

Black & White - 

Sound - 

Color - 

Ultrasonic - 

Servo - 

Mission Planning & Implementation

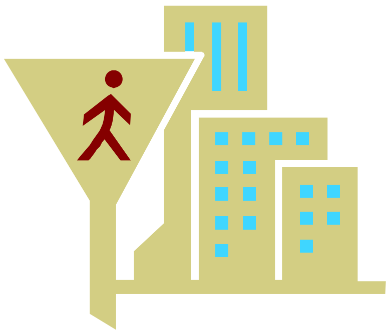
DARPA Grand Challenges

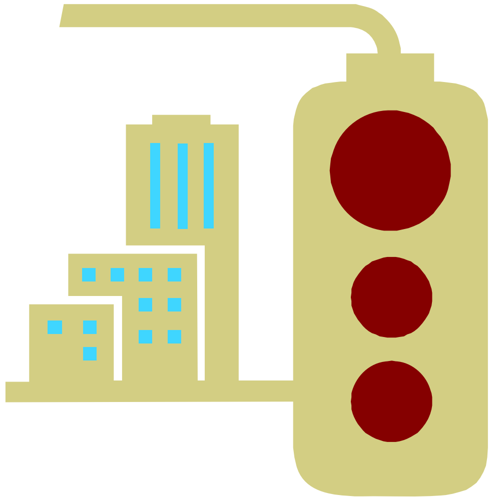
Route Network Definition File (RNDF)

•Lists thousands of waypoints along the course in accessible road segments

Mission Data File (MDF)

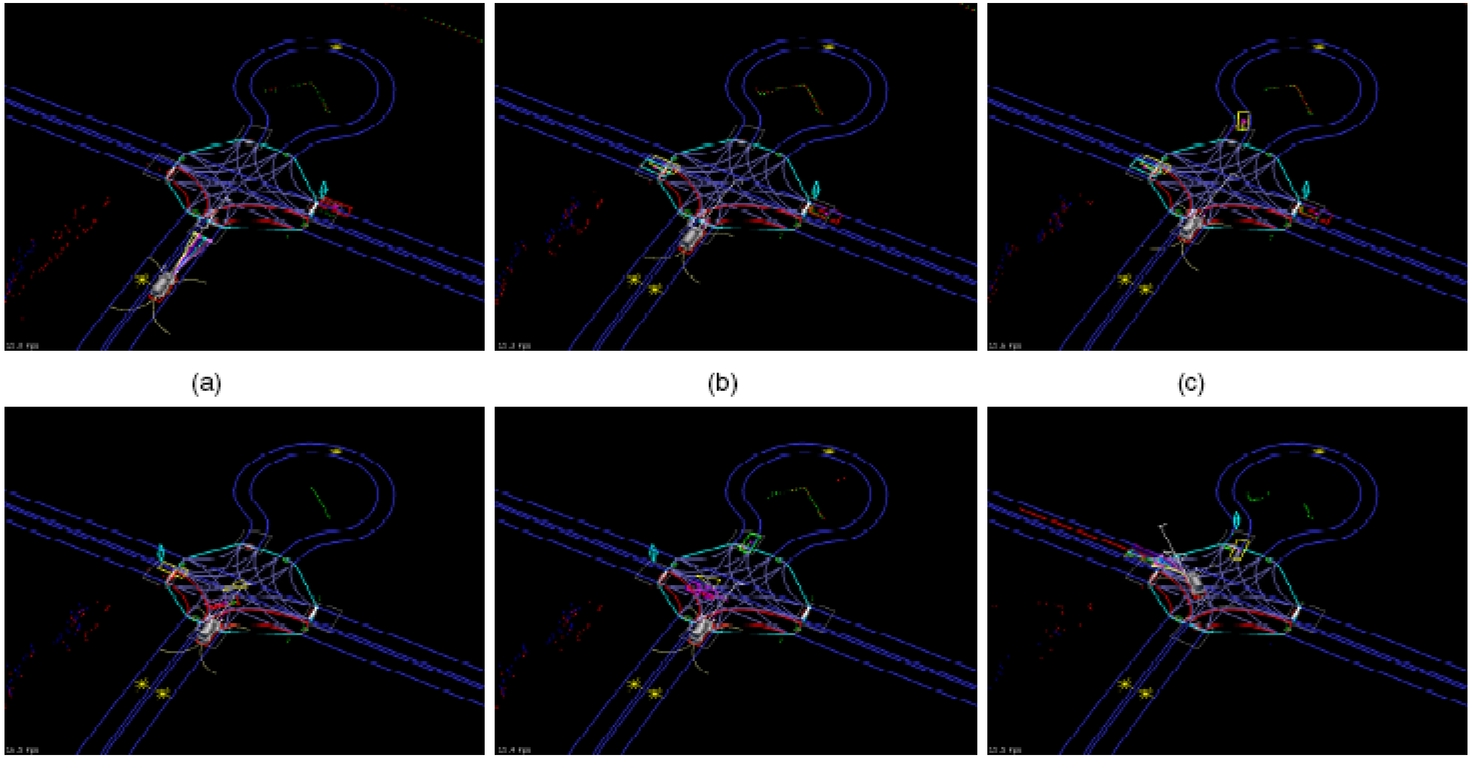
•Lists the sequence of checkpoints to be visited in order by the vehicle





Mission Planning & Implementation

DARPA Urban Challenge
Intersection Navigation
Boss – Carnegie Mellon

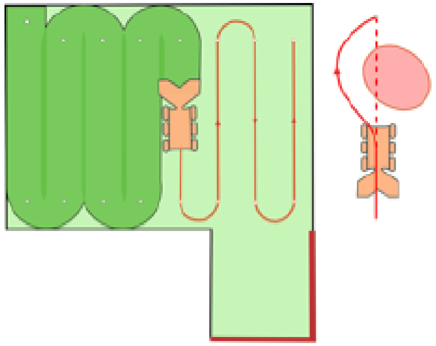


(a) (b) (c)

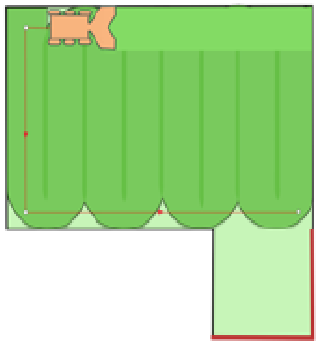
(d) (e) (f)

Mission Planning & Implementation

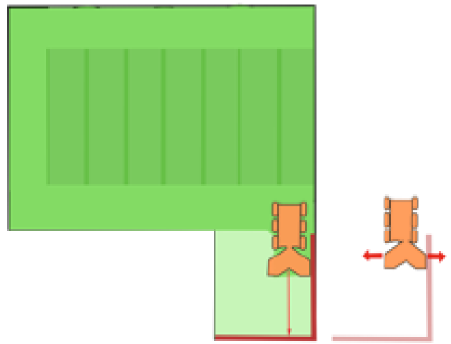
Robotic Lawnmower Competition
Route Planning



Stage 1: Lane Following



Stage 2: Edging



Stage 3: Cornering

1) Lane Following - First divide the entire field into lanes that our robot will follow. This is the most thorough and aesthetically pleasing way to mow the lawn

2) Edging - Afterwards we pass around the border of the field, the fence and possibly around any obstacles we've seen. This is to ensure that we don't have to worry about how to deal with corners and edges during the lane following stage

3) Cornering - Since the cutting base is trailed behind the chassis, it is necessary to drive backward into the fenced in portion of the course

Mission Planning & Implementation

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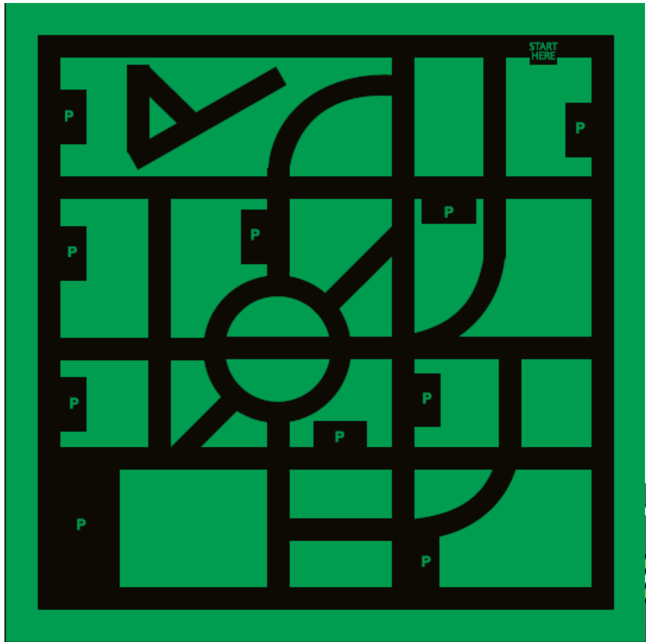
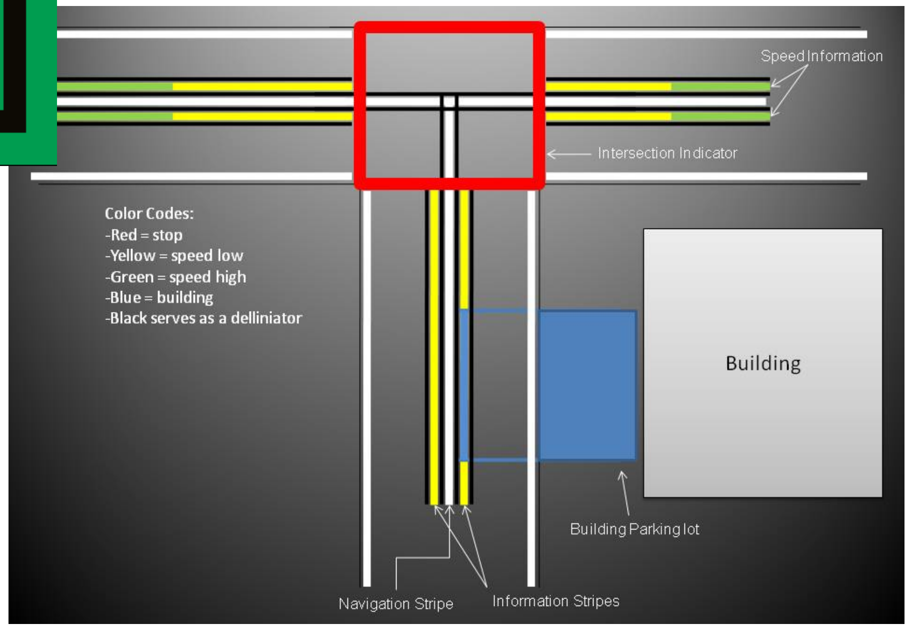
City Layout



Intersection



Competition Benefits

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DARPA **– "Free" work and technology**

ION **– Get young people exciting about science, engineering, and navigation**

Students

- **Mentoring from professionals**
- **Exposure/preparation for future opportunities**
  - **Sensor integration**
  - **Path optimization**
  - **Programming**
  - **Teamwork**
  - **Presentation skills**

Mini-Urban Challenge Sponsors

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The Institute of Navigation
Air Force Research Laboratory
Lockheed Martin
Garmin
Argon ST
Calgary
Javad GNSS
COUNT
NAVSYS Corporation
UrsaNav
Boeing
John Deere
Rockwell Collins
Rakon
Overlook Systems
LEGO® Company

Mini-Urban Challenge Update

- 2 Regional Competitions down, 2 to go…
- National Competition in June
- Submitted a DARPA Proposal…
- Working with Disney's Epcot Center
- Planning to expand to an additional 4 regions next year

International Competitions Eventually?

Questions?

Resources

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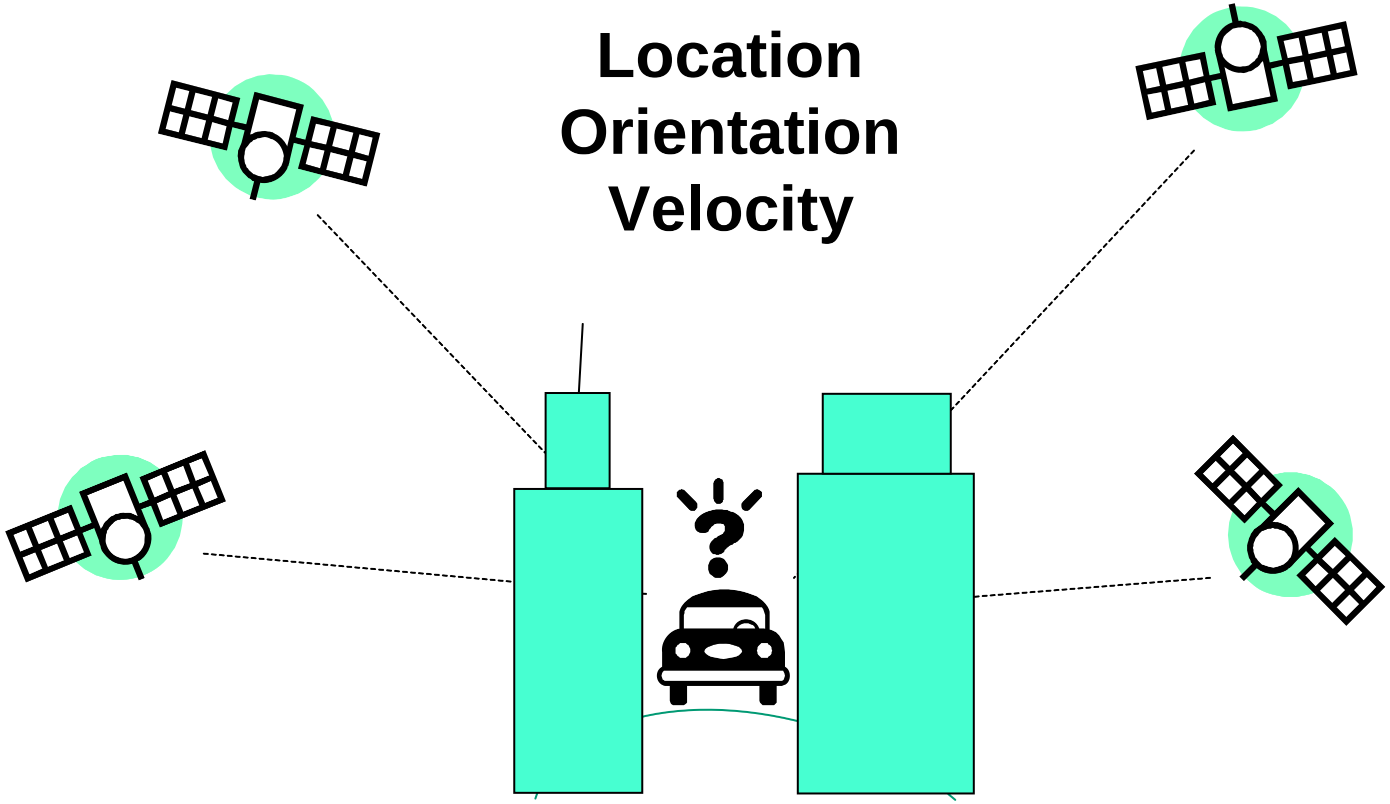
- http://www.darpa.mil/grandchallenge/index.asp
- **Chris Urmson. 2007. "Tartan Racing: A Multi-Modal Approach to the DARPA Urban Challenge"**
- **Sebastian Thrun. 2007. "Stanford's Robotic Vehicle "Junior:" Interim Report"**
- **William Whittaker. 2005. "DARPA Grand Challenge 2005 Technical Paper"**
- **Stanford Racing Team. 2005. "Stanford Racing Team's Entry in the 2005 DARPA Grand Challenge"**
- **DARPA Urban Challenge. 2007. "RNDF and MDF Formats"**
- **http://www.miniurbanchallenge.com**

Trip/Mission Planning

GPS/INS provides us with…

Location
Orientation
Velocity



Other sensors are necessary when the GPS signal is blocked

Driving Etiquette 101

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Because our robot won't be the only car on the road, it needs to follow the same rules as everyone else:

- Speed limits (GPS &/ wheel encoders)
- Staying in the correct lane (GPS & LIDAR)
- Intersections (GPS, LIDAR, Radar, Camera)

These rules need to be absolute, otherwise people could get hurt or worse…

Mechanics

Tartan Racing

- COTS system from EMC for low level, closed-loop control of the motors for the steering column and brake/gas pedals
- A real-time embedded control unit provides higher level control for vehicle functions such as velocity and curvature management

What is Engineering

Engineering is:

-Calculations and Equations
-Inspiration and Team Work
-Creativity/Fun
-Good Job/Money

Students should consider a career in engineering if:

-They have an innate curiosity about how things work
-They like to solve problems
-They enjoy working in a team
-They want to create things that will change the way people live

Mini-Urban Challenge shows students what it is like to work through a typical engineering problem

The Engineering Approach

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1-State the Problem

2-Redefine the Problem

3-Identify Constraints and Set General Specifications

4-Identify Alternative Solutions

5-Analyze the Alternatives

6-Select the Most Viable Alternative

7-Iterate the cycle until you find a solution

Fundamentals of Team Work

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What makes a team effective?

The team must have a clear goal.
The team must have a collaborative climate.
The team must have a clear goal.
The team must have high standards that are understood by all.
The team must receive external support and encouragement.
The team must have principled leadership.

Stages of Team Growth:

Forming
Storming
Norming
Performing