



# Autonomous Vehicle GNC

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

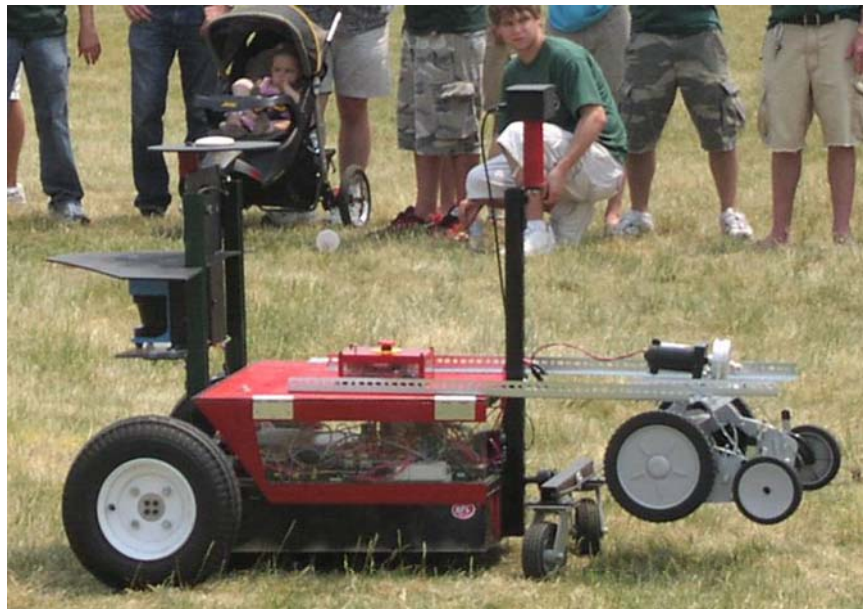


- **GNC issues for autonomous vehicles (Mikel - 20 min)**
  - Basic Control
- **ION Robotic Lawn Mower – (Jade – 40 min)**
  - **Miami University's Approach**
- **A Global Challenge (Carrie and Casey – 1 hour)**
- **Mindstorm Robots at de Universite de Cocody (30 min)**



# ION Robotic Lawn Mower: Miami RedBlade

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  - Mindstorm Robots
- Lego®  
Mindstorms  
Intro
- Lego®  
Mindstorms  
Challenge

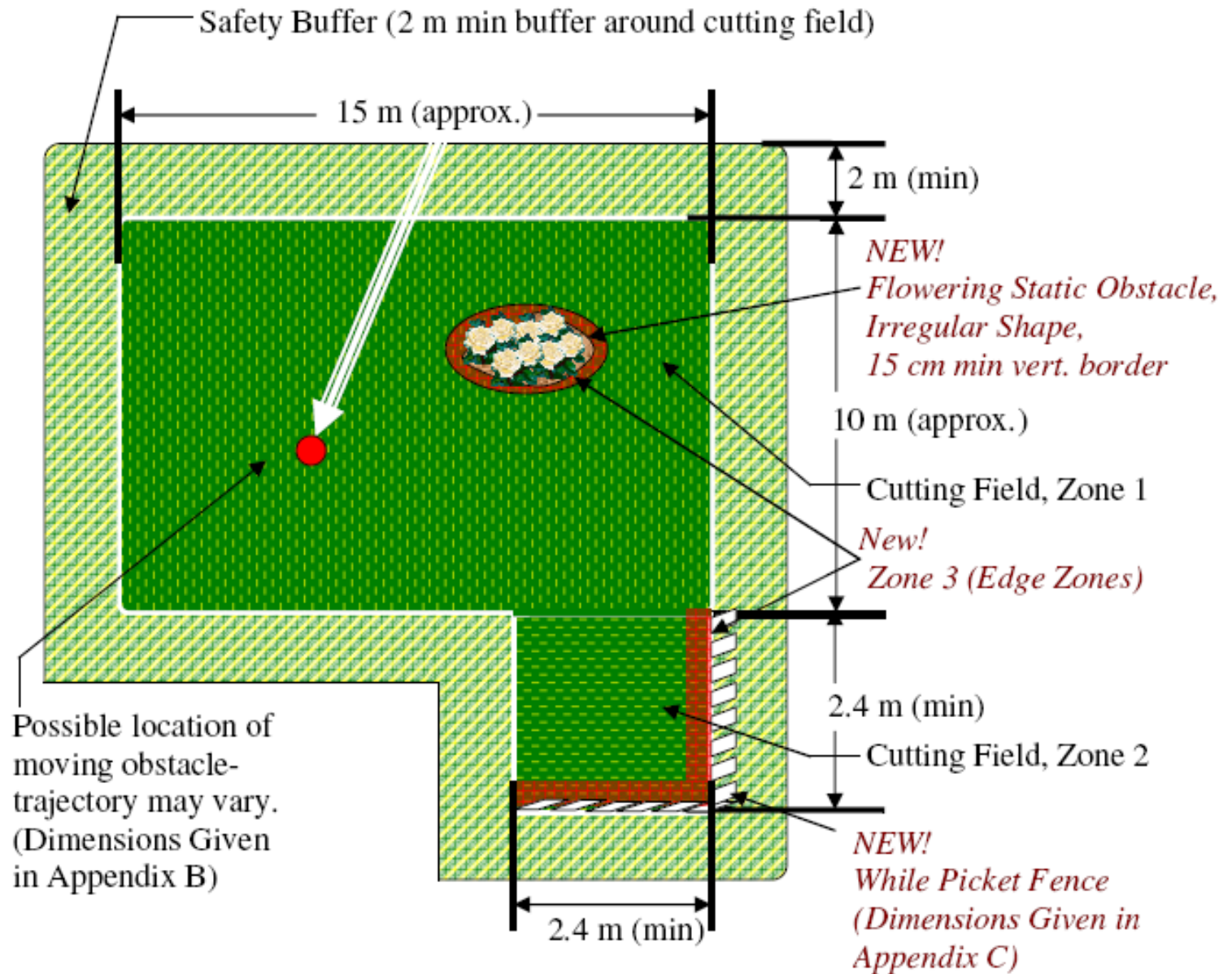




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# Competition Rule Evolution

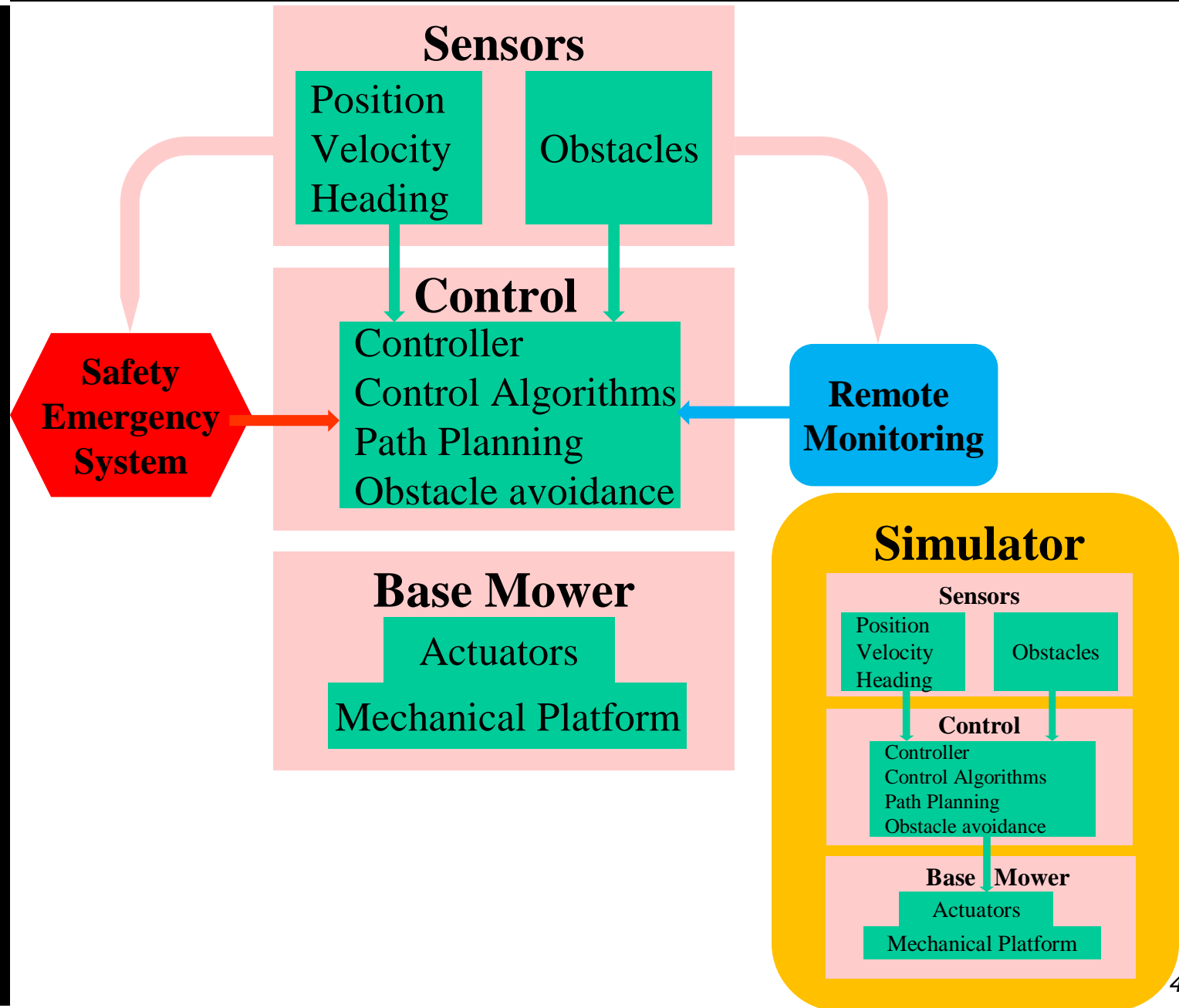




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# Red Blade Design Components





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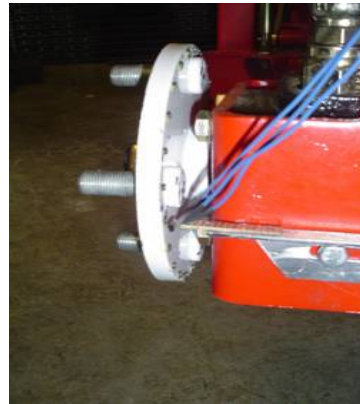


# RedBlade I: Hardware

**Garmin GPS16**  
2 \* \$145



**Hall Sensor**  
\$40



**HRM3200 Compass**  
\$350 (Donation)



**PH Servos**  
\$1200 (Donation)



**Freewave Modem**  
\$3000 (Donation)



**Snapper Mower**  
\$5000 (Donation)

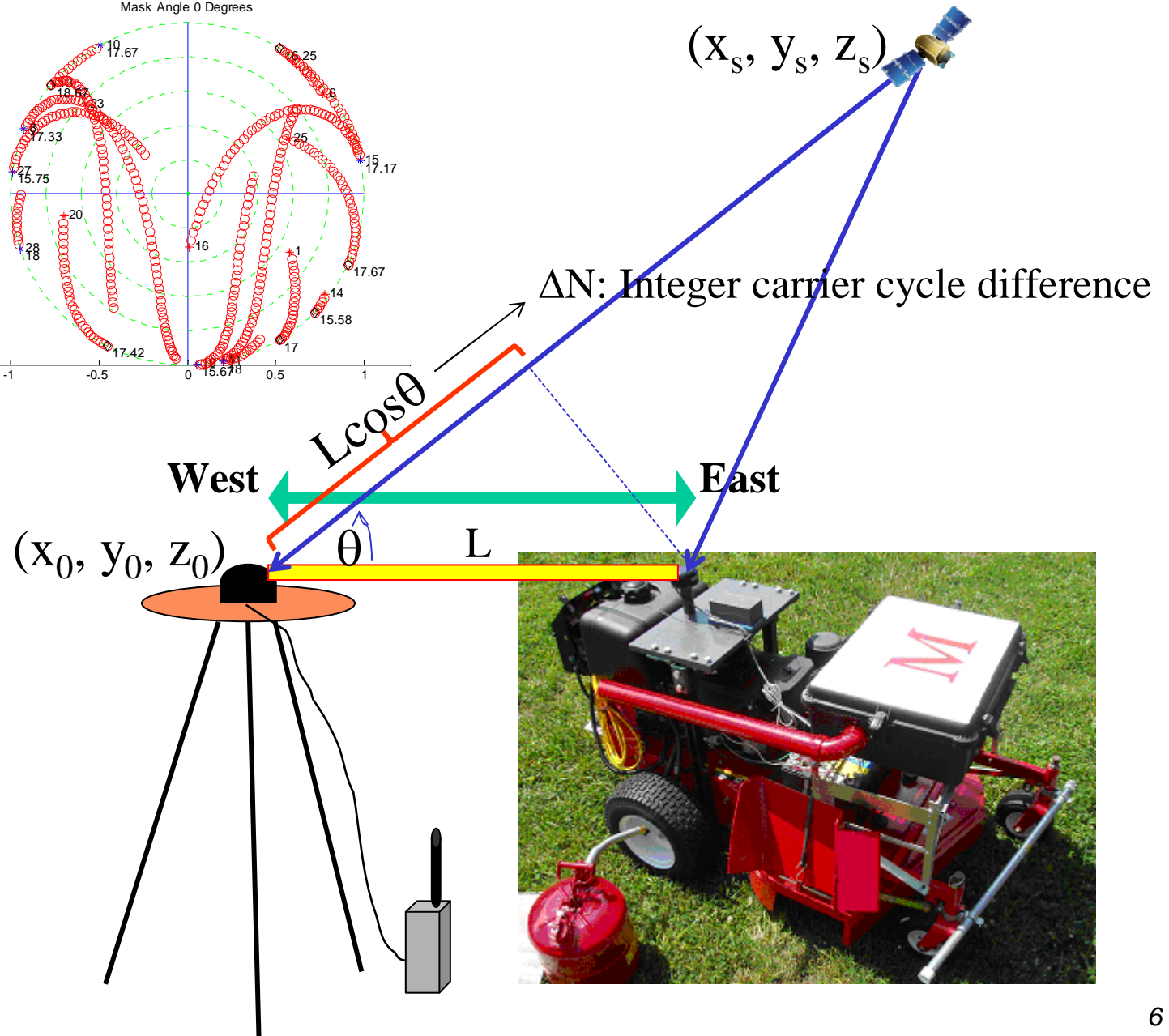
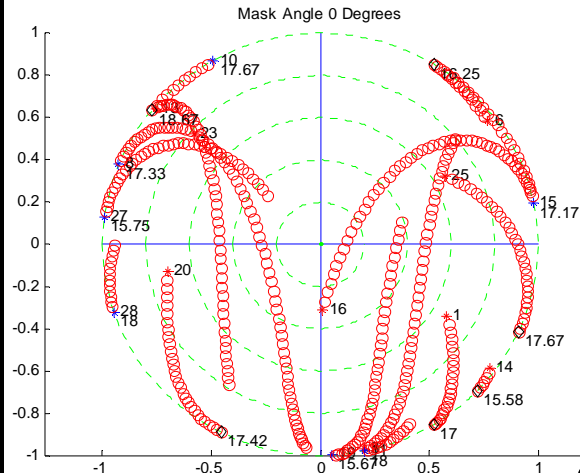




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# RedBlade I: Custom DGPS





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# RedBlade I: Custom DGPS

Carrier phase measurement:  $\phi = r - I + T + c(\delta t_u - \delta t^s) + N\lambda + \varepsilon$

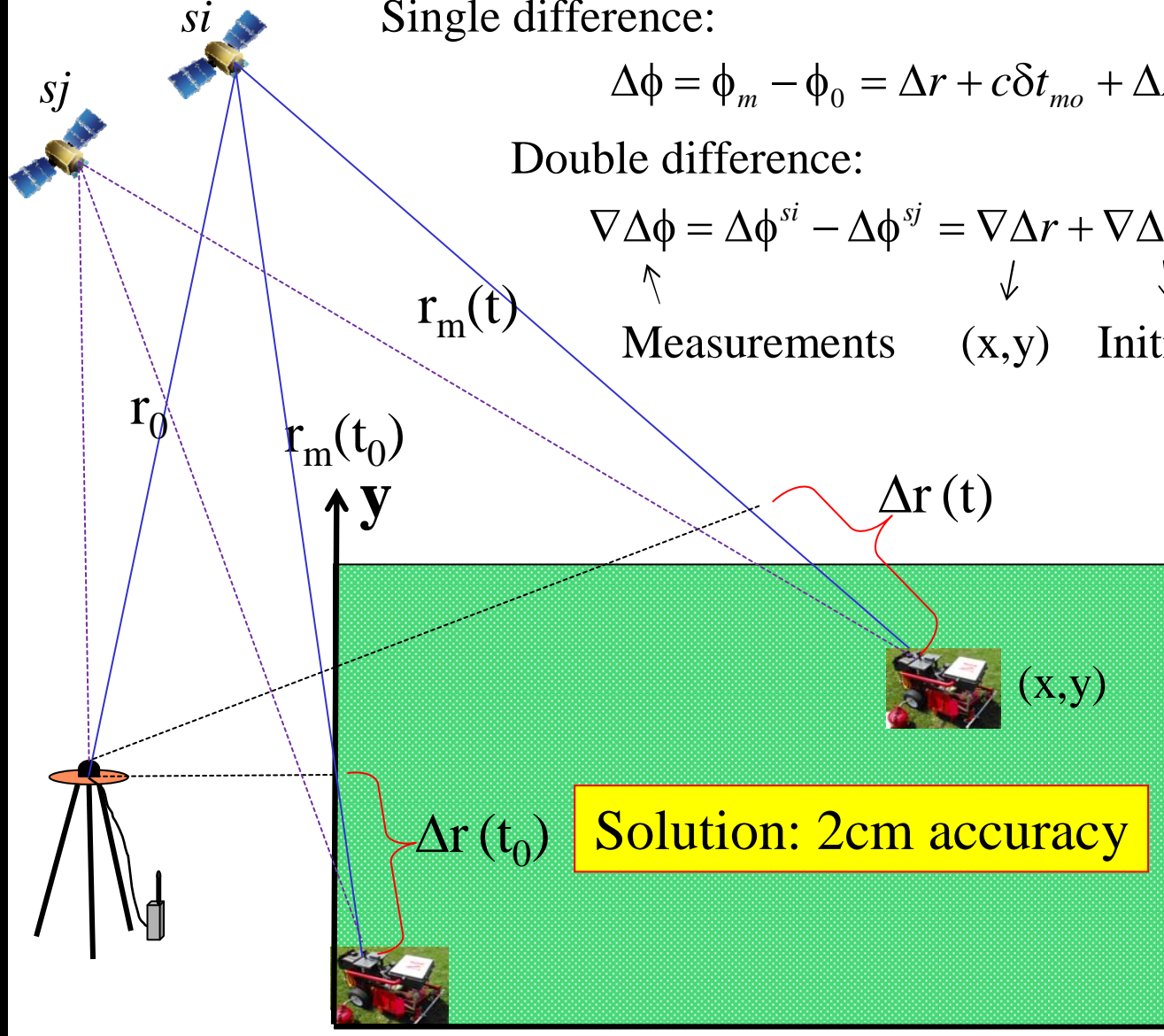
Single difference:

$$\Delta\phi = \phi_m - \phi_0 = \Delta r + c\delta t_{m0} + \Delta N\lambda + \varepsilon_{m0}$$

Double difference:

$$\nabla\Delta\phi = \Delta\phi^{si} - \Delta\phi^{sj} = \nabla\Delta r + \nabla\Delta N\lambda + \nabla\varepsilon_{m0}$$

$\uparrow$  Measurements       $\downarrow$  (x,y)       $\downarrow$  Initialization

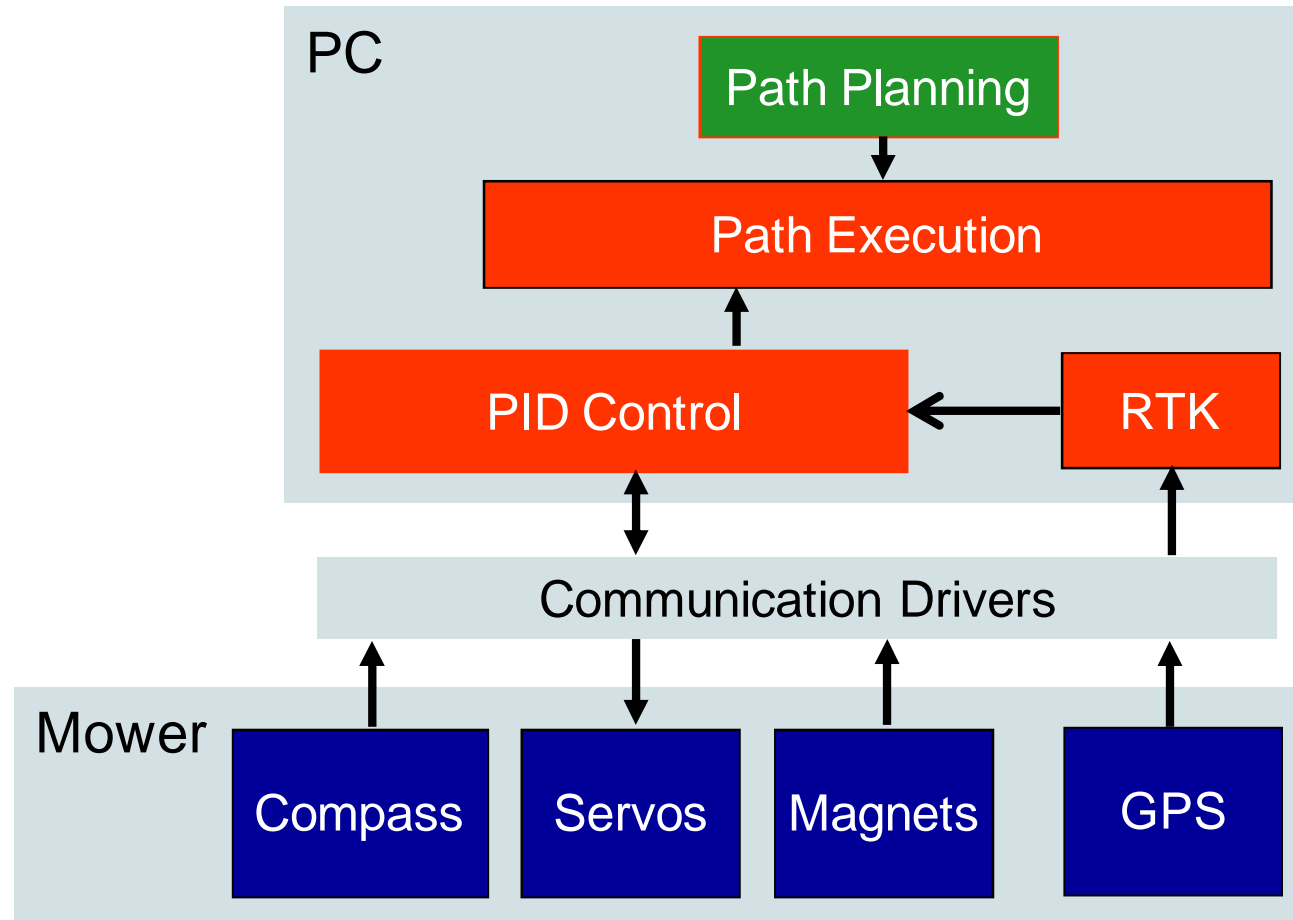




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# Control Architecture

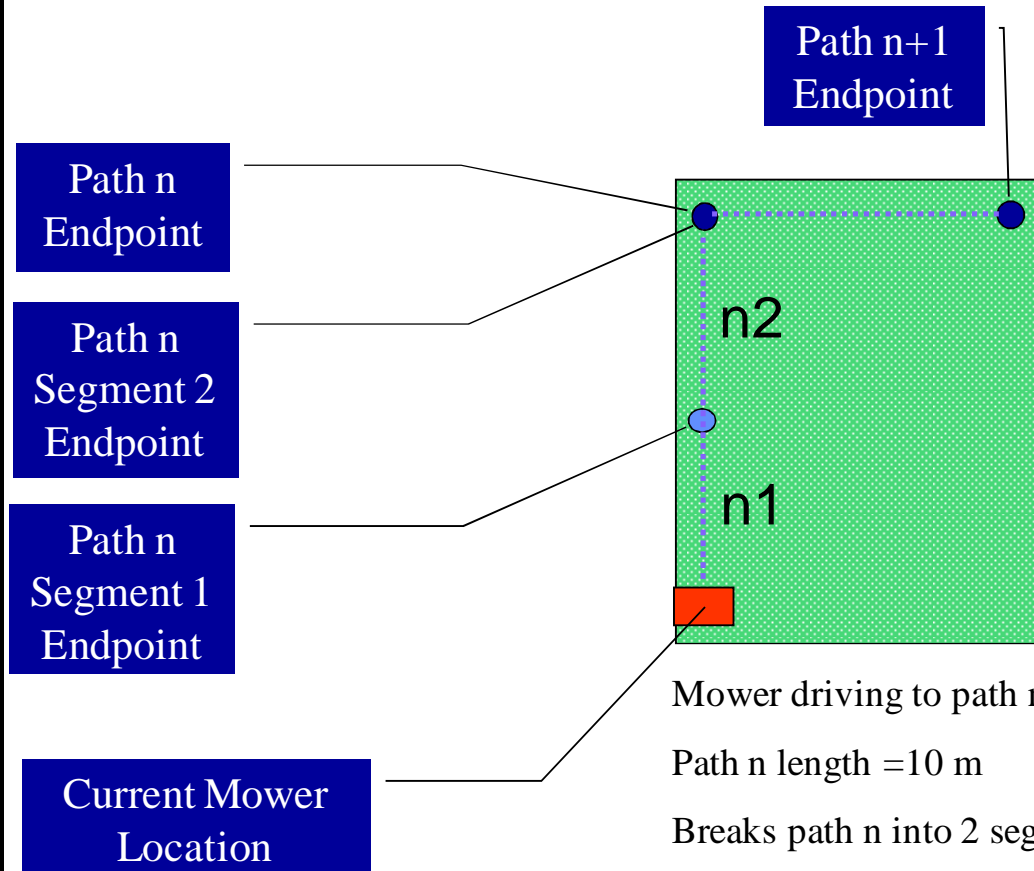






# Control Algorithm

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Mower driving to path n endpoint.

Path n length = 10 m

Breaks path n into 2 segments: n1, n2

Given current GPS location, drive 5 meter North, stop,  
Take new GPS reading and continues to n2 goal goal.



# PID Control

- Introductions

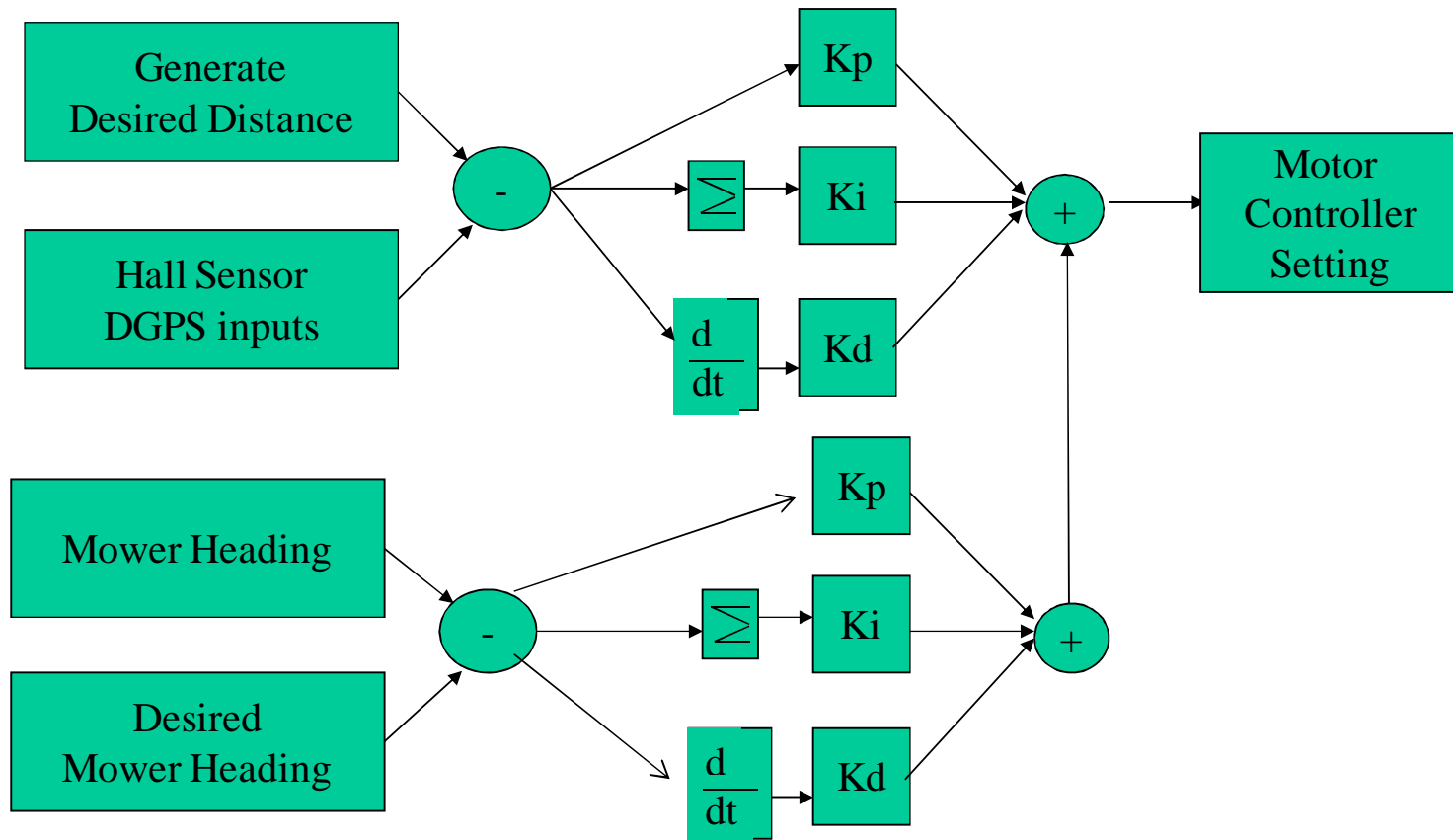
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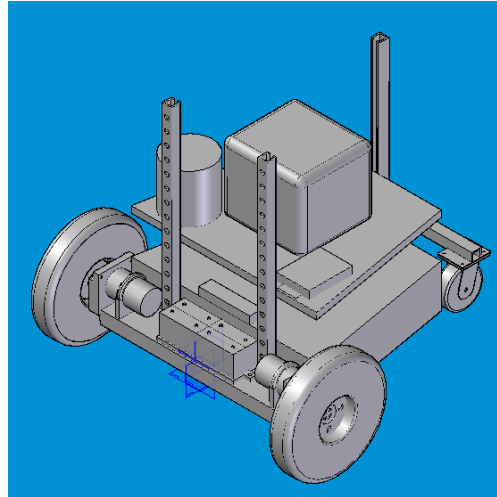


# RedBlade II: Platform Re-design

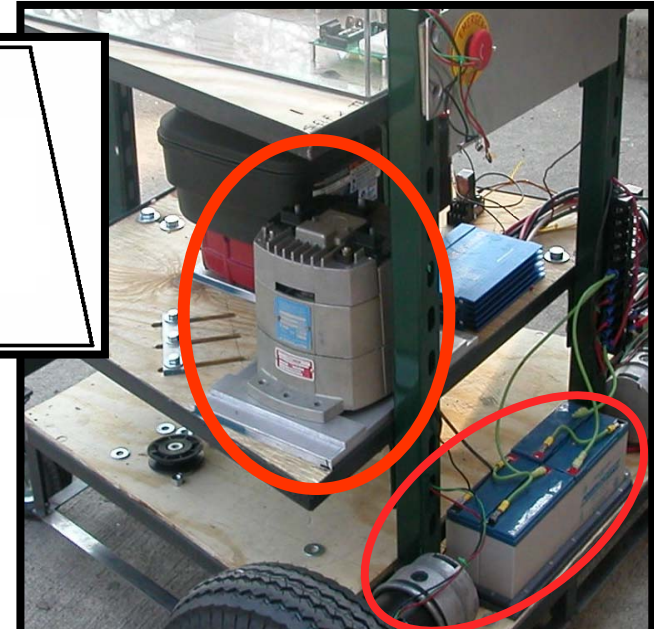
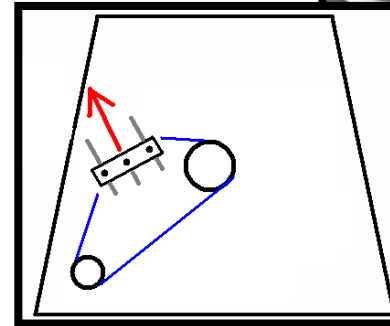
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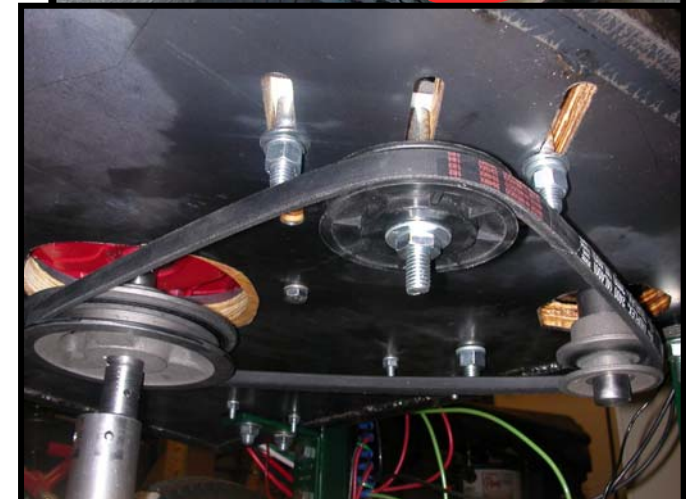
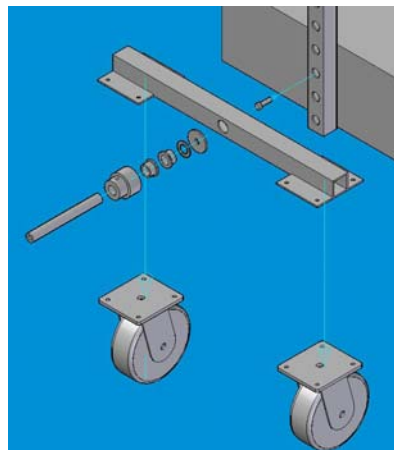
## New base design



## Hybrid battery/gas power generation system



## Multi-layered shelves Electric motors





# RedBlade II: Platform Re-design

## New base design

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# RedBlade II: New Electronics

- 2 on-board NovAtel Superstar II RX: mower heading
- Optical encoder
- Roboteq motor controller
- Systronix Saje Processor
- Programmed in Java
  - Multi-threaded execution, dynamic class loader





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# RedBlade III: Obstacle Avoidance

Sonar  
(Parallax)



Range < 3m

Scanning Laser  
(Sick)



Stereo Vision  
(Unibrain)



Over a range of 12m,  
the ranging error <5%.



# RedBlade II: Dynamic Path Planning

• Introductions

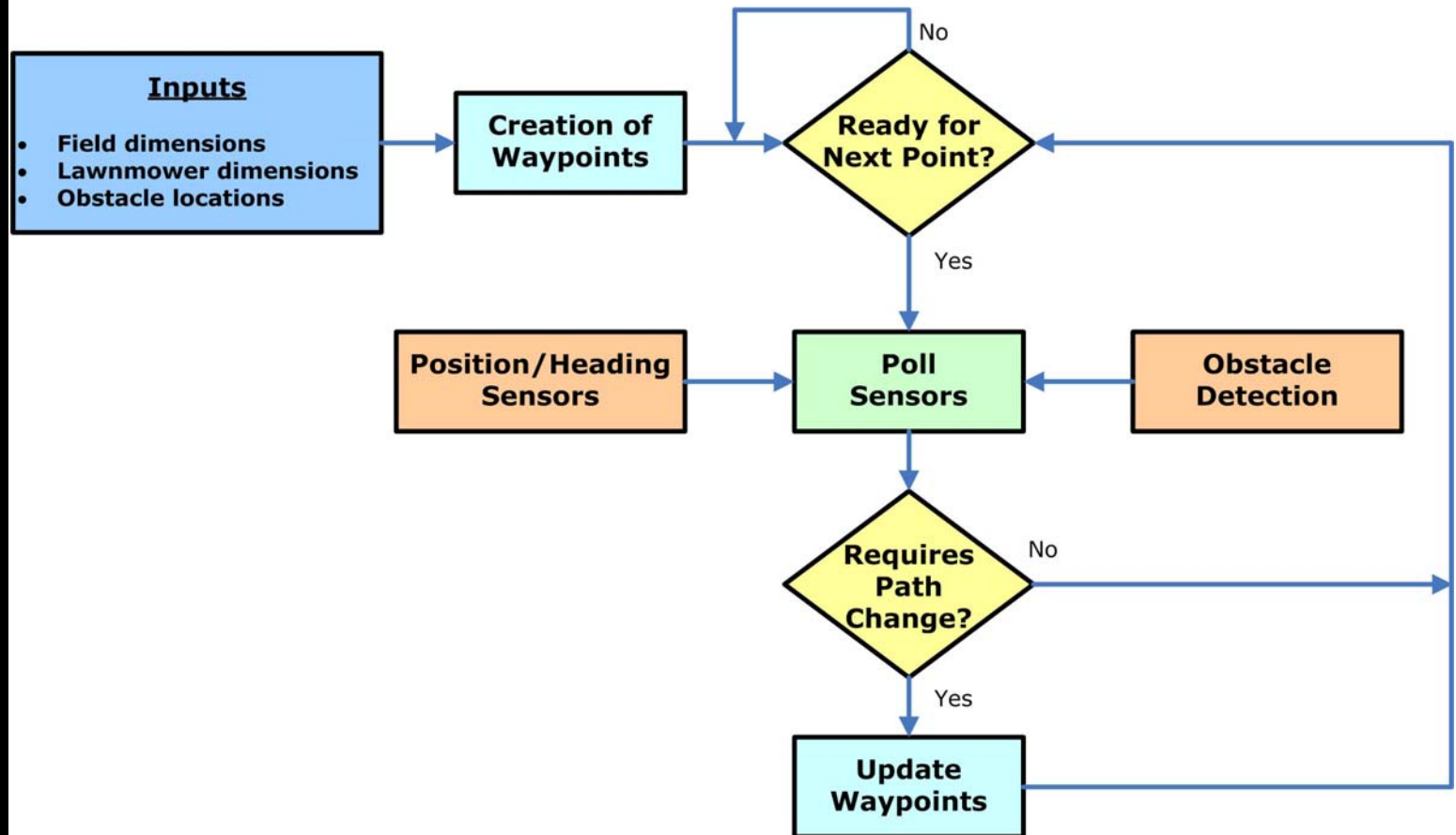
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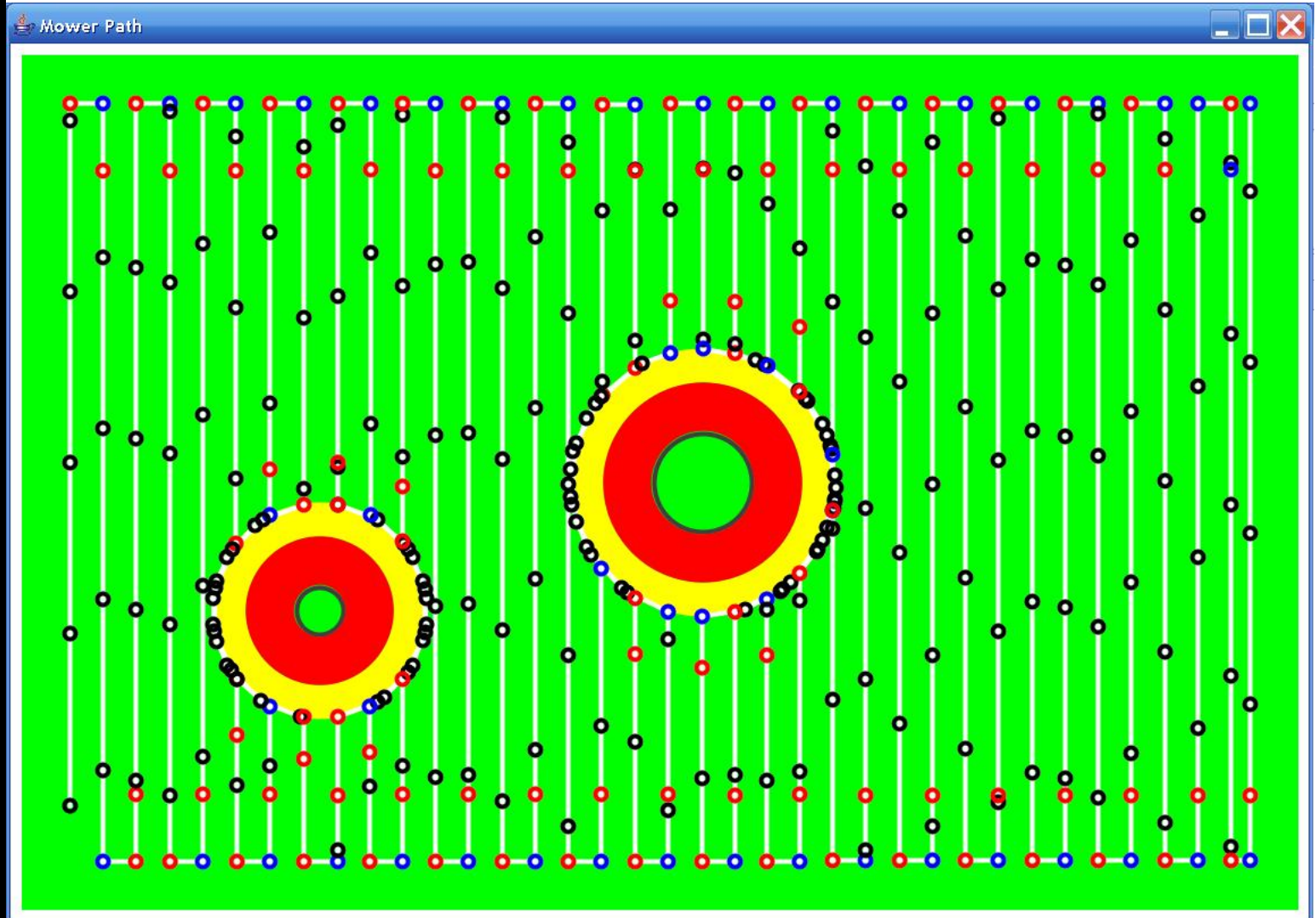
• **Lego® Mindstorms Challenge**





# RedBlade III: An Example Path Layout

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# Final Two Days



← We left campus in this shape

....

**Mechanical support problem**

**Laser problem**

**IMU problem**

.....

Two days later.... →

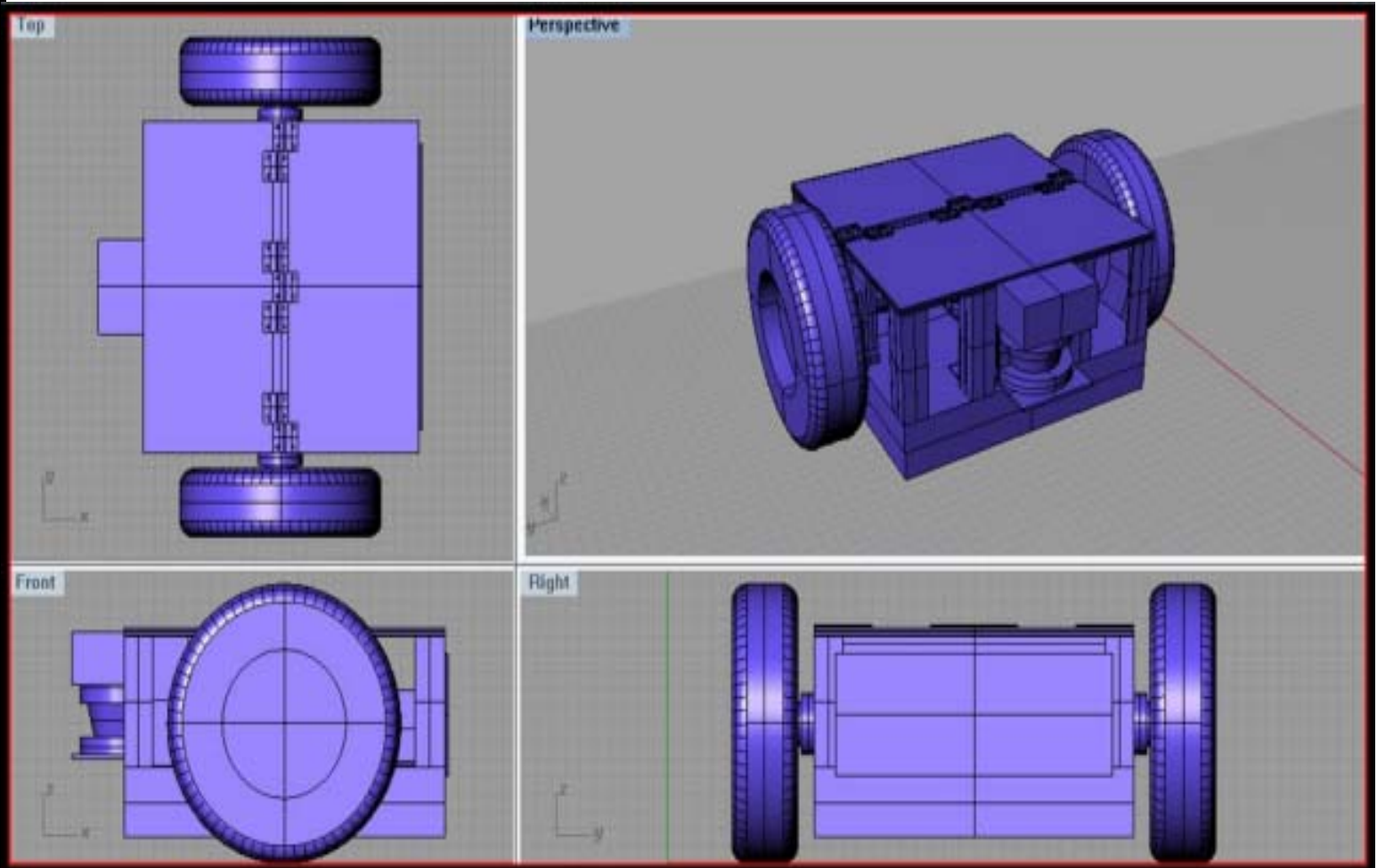




# RedBlade IV: Everything All Over Again...

## New Platform

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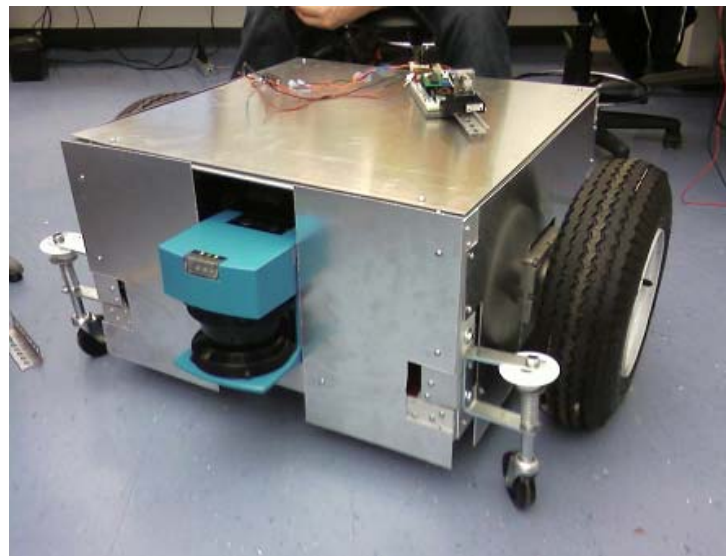




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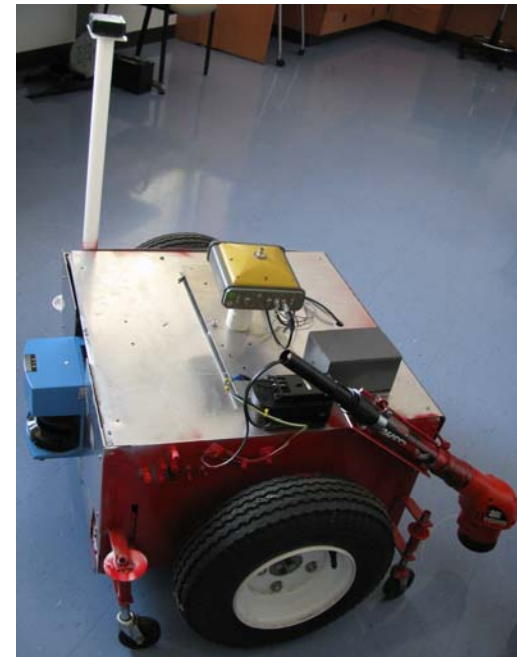
# RedBlade IV: New Gadgets



## Topcon Hiper Lite+



IMU



Edge Trimmer



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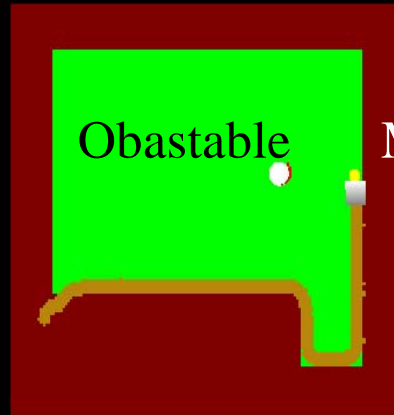
- Lego® Mindstorms Challenge



# RedBlade IV: Control Simulator

REDBLADE SIMULATION

x: 16.704  
y: 9.191



Mower

x: 16.670  
y: 9.177

REDBLADE SIMULATION

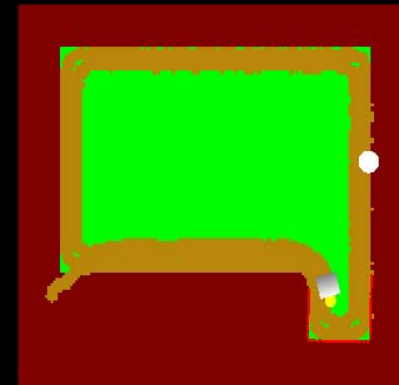
x: 7.994  
y: 5.759



x: 7.962  
y: 5.743

REDBLADE SIMULATION

x: 14.963  
y: 4.492



x: 14.949  
y: 4.542

## Variables:

- Field layout
- Obstacle control
- Sensor error model
- Sensor update rates
- Mower response time

It is raining, lightening, and thundering, but we are not ready yet....



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# Sample Designs from Competition

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CWRU



Cedarville



Ohio University



Florida State



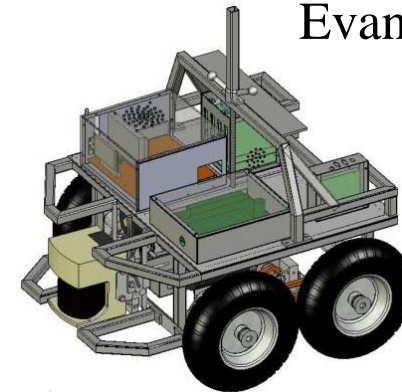
University  
Evansville



University  
of Waterloo



Wright State  
University



École de technologie  
supérieure

