A Robot in Every Home
Scientific American, January 2007

“I can envision a future in which robotic devices will become a nearly ubiquitous part of our day-to-day lives... to see, hear, touch and manipulate objects in places where we are not physically present.”

— Bill Gates, Microsoft Chairman
Driving Factors

Exponentials – x2 at regular intervals

- Moore’s Law – Processors – 1.5 years
- Kryder’s Law – Storage – 1.5 years
- Butter’s Law – Network – 9 months
Moore’s Law

- x2 every 1.5-2 years
- 58 years later…
  - 29-39 doubles
  - $2^{29} = 500\ M$, $2^{39} = 500\ B$
- ~30 B transistors on largest chips now
Kryder’s Law

US Library of Congress = 10 Tb

= 120,000 tons
= USS Gerald R. Ford

4 TB Hard Drive $109
newegg.com
4TB in punch cards = ?
Butter’s Law

“NEC and Corning achieve petabit optical transmission”

SPIE Optics.org, 22 Jan 2013

1 Pb/s = 10^{15} b/s

= Entire LoC in 0.01 s
Robotics Follows Exponentials

Stanford AI Lab Cart 1979, 3meters/hr

DARPA Grand Challenge 2005, 30Km/hr

10,000x in 26 years, 2x every 2 years
Tech Drivers

- Robotics *rode* Moore’s Law
- Robotics *will drive* future exponentials
- Laser range finder:
  - Past:
  - Present:
  - Future:

![Laser Scanner Cost Graph](image-url)
Yesterday’s Robots
Today’s Robots
The Robotics Equation

Sensors,
Computing devices,
Actuators,
Communications

Defense & Security,
Medicine & Elder care,
Consumer,
Manufacturing,
Nano-technology,
Entertainment

Tasks that are too
- Dull
- Dangerous
- Dirty
for humans

}
Robotics Education
Robotics Education Gap

Industrial Robotics Technology
AA, AS @ Community College

Robotics Engineering

Robotics Research
PhD @ Large Research University

“Making useful robots, Making robots useful”
Motivation for Robotics Major

Growth in importance of Robotics
• Supply: Push of tech capability $\uparrow$ & cost $\downarrow$
• Demand: Pull of needs & applications

K-12 interest in Robotics
• Offer students what they want

Great fit for WPI
• Strong CS, ECE, ME
• Project-based curricula
• FIRST Team 190 tradition

Leadership
TouchTomorrow

Eric Overström
Provost, Worcester Polytechnic Institute

Stephen Bowen
NASA Astronaut

Sam Ortega
NASA SRR Challenge Program Manager

Jascha Little
Team Leader, Survey
Middle School Robotics
Vision

• Exemplary, nationally recognized,
• Multidisciplinary center for
• Education, research, and innovation in
• Robotics
WPI Robotics Engineering

• BS
  – Goal: Educate engineers for 21st century
  – Grow robotics industry: Supply talent, Start companies

• MS
  – Goal: Technical Leadership
  – Expand robotics industry: Systems thinking

• PhD
  – Goal: Research Leadership
  – Advance robotics: Knowledge, Capabilities
Key Ideas

• Multidisciplinary: CS / ECE / ME
• Spiral Curriculum:
  – Intro to Robotics
  – Unified Robotics I-IV
    • Actuation, Sensing, Manipulation, Navigation
• Social Implications
• Entrepreneurship & the enterprising eng’r
• Project-based

It’s never “Not my job!”
## Curriculum 1.0

Black: Required General Education (12 courses)
Green: Required Basic Math and Science (9 courses)
Purple: Recommended Basic Math and Science (3 courses)
Red: Required Engineering (13 courses)
Blue: Recommended Engineering and Free Electives (9 courses)

<table>
<thead>
<tr>
<th>Class</th>
<th>A Term</th>
<th>B Term</th>
<th>C Term</th>
<th>D Term</th>
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<tbody>
<tr>
<td>Freshman</td>
<td>MA 1021</td>
<td>MA 1022</td>
<td>MA 1023</td>
<td>MA 1024</td>
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<td>PH 1110</td>
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<tr>
<td>Sophomore</td>
<td>CS 1101</td>
<td>CS 2303</td>
<td>ES 3011</td>
<td>ECE 2311</td>
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<td></td>
<td>RBE 1001</td>
<td>ECE 2011</td>
<td>CS 2223</td>
<td>CS 3733</td>
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<tr>
<td></td>
<td>HU</td>
<td>SS</td>
<td>IQP</td>
<td>Robotics Elective 1</td>
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<tr>
<td>Junior</td>
<td>ECE 2801</td>
<td>ME 3310</td>
<td>ECE 2801</td>
<td>ECE 2801</td>
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<tr>
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<td>ES 2501</td>
<td>Project Preparation</td>
<td>ES 2501</td>
<td>CS 3733</td>
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<td></td>
<td>IQP</td>
<td>IQP</td>
<td>ES 2503</td>
<td>Robotics Elective 1</td>
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<td></td>
<td></td>
<td></td>
<td>Robotics Elective 2</td>
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<tr>
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<td>CS 4341</td>
<td>Robotics Elective 3</td>
<td>Free Elective</td>
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<td>ES 3011</td>
<td>Free Elective</td>
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<td></td>
<td>MQP</td>
<td></td>
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</table>

Where’s the Robotics?
Curriculum Picture

- Intro Courses
  - CS, ECE, ME

- Unified Robotics 1-4
  - Actuation, Sensing, Manipulat’n, Navigat’n

- Advanced Courses

- Capstone Project

- Other Courses
  - DiffEqs, LinAlg, Prob, Controls, Embedded, …
Curriculum 2.0

Where’s the Robotics?

<table>
<thead>
<tr>
<th>Year</th>
<th>A Term</th>
<th>B Term</th>
<th>C Term</th>
<th>D Term</th>
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</thead>
<tbody>
<tr>
<td>Freshman</td>
<td><strong>Calculus 1</strong>&lt;br&gt;Physics 1&lt;br&gt;Great Problems</td>
<td><strong>Calculus 2</strong>&lt;br&gt;Physics 2&lt;br&gt;Great Problems</td>
<td><strong>Calculus 3</strong>&lt;br&gt;CS 1&lt;br&gt;HU&amp;A</td>
<td><strong>Calculus 4</strong>&lt;br&gt;Digital Logic&lt;br&gt;Intro Robotics</td>
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<tr>
<td>Soph</td>
<td><strong>Unified Robtcs 1</strong>&lt;br&gt;Embedded Sys&lt;br&gt;Statics</td>
<td><strong>Unified Robtcs 2</strong>&lt;br&gt;Diff Eq&lt;br&gt;HU&amp;A</td>
<td><strong>Controls</strong>&lt;br&gt;Soc Sci&lt;br&gt;HU&amp;A</td>
<td><strong>CS 2</strong>&lt;br&gt;Soc Sci&lt;br&gt;HU&amp;A Seminar</td>
</tr>
<tr>
<td>Junior</td>
<td><strong>Unified Robtcs 3</strong>&lt;br&gt;Entrepreneur’p&lt;br&gt;Junior Project</td>
<td><strong>Unified Robtcs 4</strong>&lt;br&gt;Probability&lt;br&gt;Junior Project</td>
<td><strong>Linear Algebra</strong>&lt;br&gt;RBE Elective 1&lt;br&gt;Junior Project</td>
<td><strong>Social Issues</strong>&lt;br&gt;RBE Elective 2&lt;br&gt;Software Eng</td>
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<tr>
<td>Senior</td>
<td><strong>Science</strong>&lt;br&gt;RBE Elective 3&lt;br&gt;Capstone Project</td>
<td><strong>Free Elective 1</strong>&lt;br&gt;Free Elective 2&lt;br&gt;Capstone Project</td>
<td><strong>Free Elective 3</strong>&lt;br&gt;Free Elective 4&lt;br&gt;Capstone Project</td>
<td><strong>Free Elective 5</strong>&lt;br&gt;Free Elective 6&lt;br&gt;Free Elective 7</td>
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</tbody>
</table>
Courses

Undergraduate
RBE1001 Intro to Robotics
RBE2001 Unified 1: Actuation
RBE2002 Unified 2: Sensing
RBE3001 Unified 3: Manipulation
RBE3002 Unified 4: Navigation
RBE4322 Mechatronics
RBE4815 Industrial Automation

Graduate
RBE500 Foundations
RBE501 Dynamics
RBE502 Robotic Control
RBE510 Multi-Robot Sys
RBE520 Biomechanics & Robotics
RBE526 Human-Robot Interaction
RBE549 Computer Vision
RBE550 Motion Planning
RBE580 Biomedical Robotics
RBE594 Capstone Proj Experience
RBE595 Special Topics
  Adv. Robot Navigation
  Adv. Robotic Parallel & Walking Mechanisms
  Deep Learning for Adv. Robotic Perception
  Formal Methods in Robotics
  Smart Materials & Actuation
  Soft Robotics
  Space & Planetary Robotics
Hard-working Students

RBE 1001 Intro to Robotics Student Course Evaluations C Term 2013:

26A. On average, how many hours of the formally scheduled hours for lecture, conference, and labs did you ATTEND each week?

<table>
<thead>
<tr>
<th>Hours</th>
<th>Count</th>
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<tbody>
<tr>
<td>3 hr/wk or less</td>
<td>0</td>
</tr>
<tr>
<td>4 hr/wk</td>
<td>1</td>
</tr>
<tr>
<td>5 hr/wk</td>
<td>0</td>
</tr>
<tr>
<td>6 hr/wk</td>
<td>11</td>
</tr>
<tr>
<td>7 hr/wk or more</td>
<td>8</td>
</tr>
</tbody>
</table>

26B. On average, what were the total hours spent in each 7-day week OUTSIDE of formally scheduled class time in work related to this course (including studying, reading, writing, homework, rehearsal, etc.)?

<table>
<thead>
<tr>
<th>Hours</th>
<th>Count</th>
</tr>
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<tbody>
<tr>
<td>0 hr/wk</td>
<td>0</td>
</tr>
<tr>
<td>1-5 hr/wk</td>
<td>2</td>
</tr>
<tr>
<td>6-10 hr/wk</td>
<td>5</td>
</tr>
<tr>
<td>11-15 hr/wk</td>
<td>1</td>
</tr>
<tr>
<td>16-20 hr/wk</td>
<td>5</td>
</tr>
<tr>
<td>21 hr/wk or more</td>
<td>7</td>
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Capstone Projects
WPI
ROBOTICS ENGINEERING

IPASS
AN INTELLIGENT PORTABLE AERIAL SURVEILLANCE SYSTEM

PROJECT TEAM:
ADAM BLUMENAU – ALEC ISHAK – BRETT LIMONE
ZACHARY MINTZ – COREY RUSSELL – ADRIAN SUDOL

ADVISORS:
TASKIN PADIR – LIFENG LAI
Select Project Sponsors

- BOSTON ENGINEERING™
- A123 Racing
- DS SolidWorks
- NATIONAL INSTRUMENTS™
- AXIS Communications
- QinetiQ North America
- LINCOLN LABORATORY Massachusetts Institute of Technology
- GENERAL DYNAMICS Strength On Your Side®
- maxon motor driven by precision
- TRAVELERS
- HC HYDRO-CUTTER Precision Waterjet Cutting
- MicroStrain® Little Sensors. Big Ideas®
Enrollment

![Enrollment Graph]

- **RBE MS, PhD**
- **RBE BS**

AY 06-07  AY 07-08  AY 08-09  AY 09-10  AY10-11  AY 11-12  AY 12-13  AY 13-14  AY 14-15  AY 15-16  AY 16-17

RBE MS, PhD and RBE BS enrolments are shown over the years from AY 06-07 to AY 16-17. The enrolment trend indicates a significant increase over the years.
Jobs & Internships
Robotics Research

Human-Robot Interaction

Biomedical Robotics

Sensing & Manipulation

Autonomy & Navigation

Assistive Robotics

Manufacturing

Odometry & Mapping

Soft Robotics
DARPA Robotics Challenge

Fukushima Disaster

Too dangerous for humans ...

... send a robot

Too bad robots can’t ...

- Traverse rubble
- Attach hoses
- Close valves
- Open doors
- Climb ladders
- Use tools
- Remove debris
- Drive vehicle

... YET!
Self-Driving Vehicles

Self-driving shuttle loops around Santa Clara University campus

By Carolyn Said | December 31, 2016 | Updated: December 31, 2016 5:00pm
Construction

Semi-Autonomous Mason (SAM) https://www.youtube.com/watch?v=MVWayhNpHr0
Human Augmentation

Lockheed-Martin FORTIS https://www.youtube.com/watch?v=x34mySH1jYc
Logistics

Garbage Trucks: On Route, In Action! https://www.youtube.com/watch?v=LTUjiLxzDQs
Residential Life

Ask TOH | Robotic Wall https://www.thisoldhouse.com/watch/ask-toh-robotic-wall-bench
Dining Services & Food Prep

Moley Robotics http://www.moley.com/
Drones

- Ubiquitous
- Cheap
- Hazards / threats
- FAA Regs
  - Fun vs. Work
  - Restrictions
  - Registration

http://www.kumarrobotics.org/


Lessons Learned

• Need vision & passion… & a business plan
• Bottom-up approach better than top-down
• Top-down approach better than bottom-up
• Stick to one’s principles
• Be open to compromise on anything else
• Communicate & cooperate
• Be bold!
How to Win with Academics

Academic Merit

Business Merit

Politics

No Champion, No Project. No Exceptions.

- SRI CEO Curt Carlson
Acknowledgements

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• Many colleagues and contributors
Thank You!