Introduction to MS4SSA Robotics Modules

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23 May 2017

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."

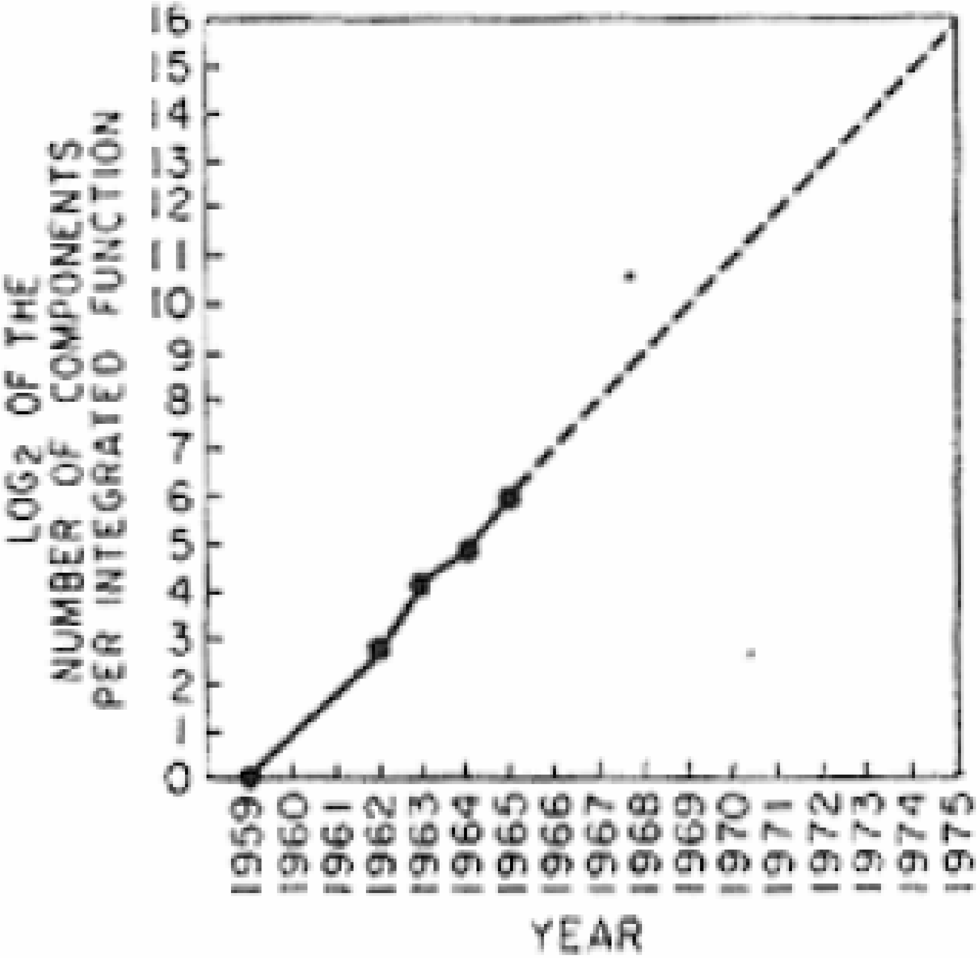
— Bill C … *hairman*

Driving Factors

Exponentials – x2 at regular intervals

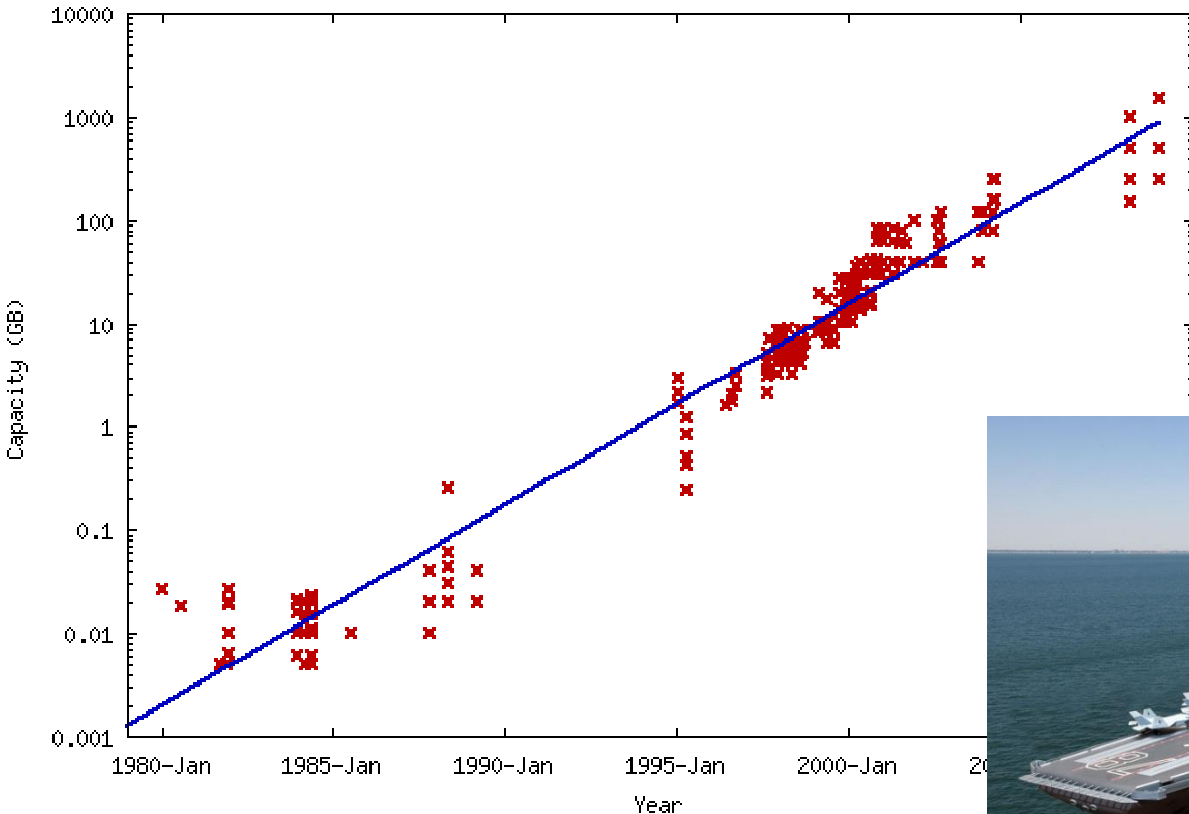
- Moore’s Law – Processors – 1.5 years
- Kryder’s Law – Storage – 1.5 years
- Butter’s Law – Network – 9 months

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



4 TB Hard Drive $109
newegg.com
4TB in punch cards = ?

US Library of Congress = 10 Tb

= 120,000 tons
= USS Gerald R. Ford

Butter's Law

"NEC and Corning achieve petabit optical transmission"

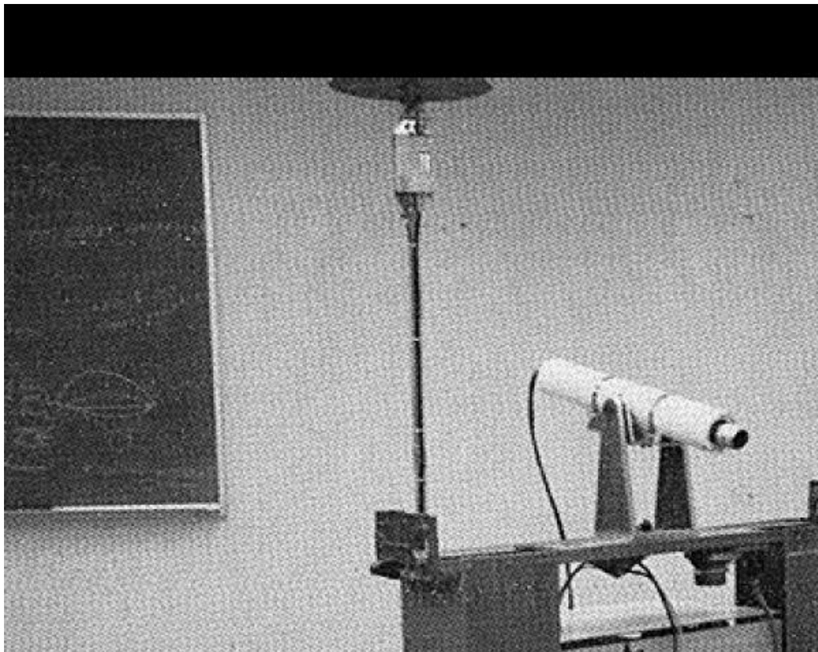
SPIE Optics.org, 22 Jan 2013

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

= Entire LoC in 0.01 s

Robotics Follows Exponentials

Stanford AI Lab Cart 1979, 3meters/hr

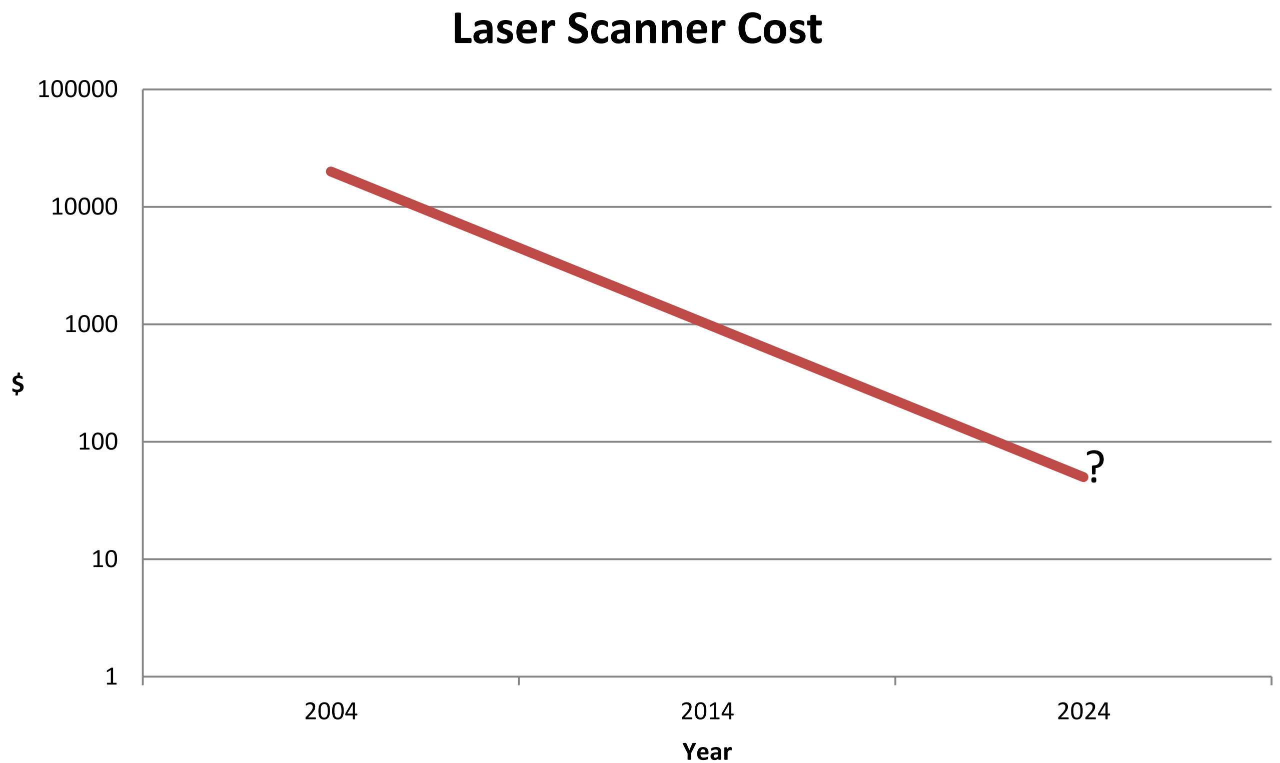


DARPA Grand Challenge 2005, 30Km/hr

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:



Yesterday's Robot

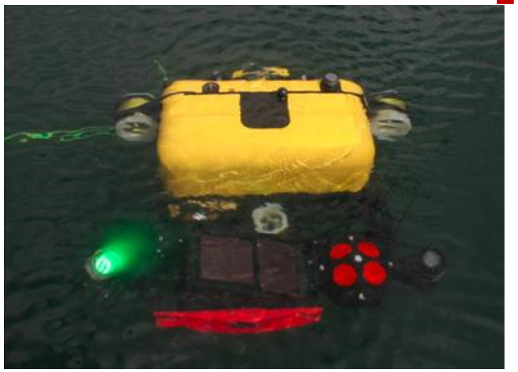


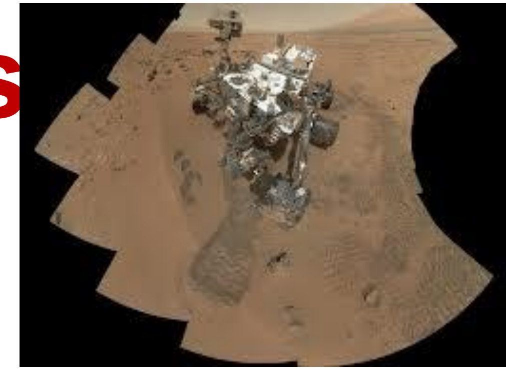






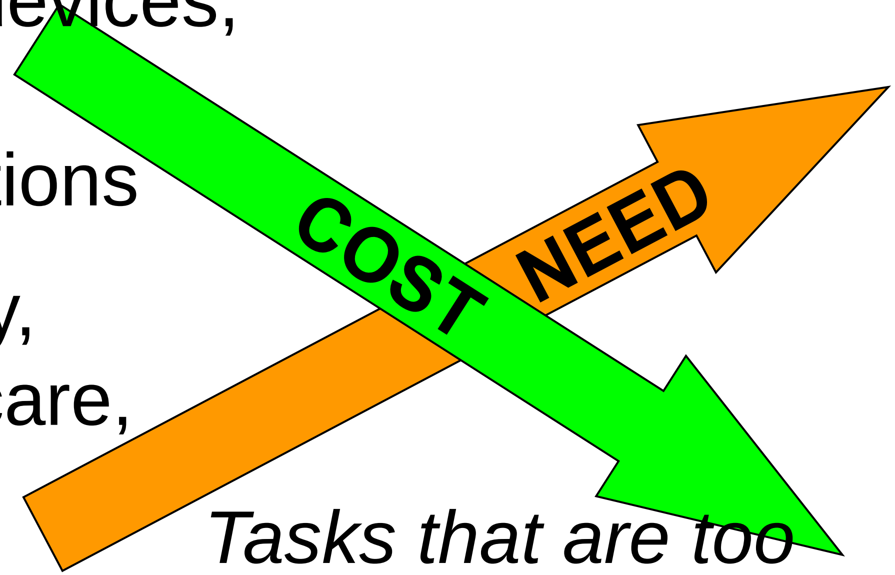
Today's Robots





The Robotics Equation

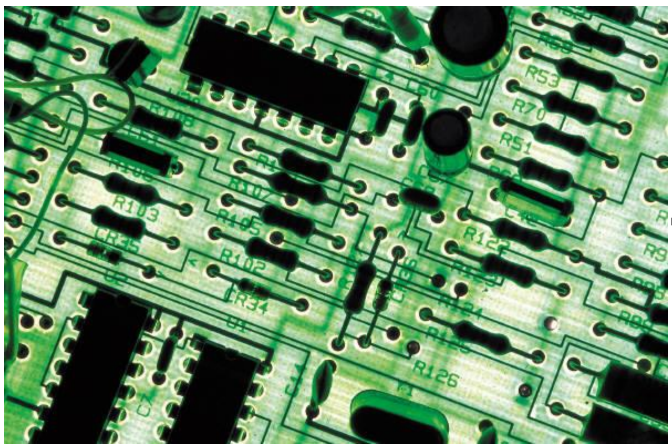
Sensors,
Computing devices,
Actuators,
Communications



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

Tasks that are too
-Dull
-Dangerous } *The 3 Ds*
-Dirty
for humans

Robotics Education



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Robotics Education Gap

Robotics Research

PhD @
rge Research
University

Robotics
Engineering

Industrial Robo
Technology

AA, AS @
Community College

“Making useful robots,
Making robots useful”

Motivation for Robotics Major

Growth in importance of Robotics

- Supply: Push of tech capability ↗ & cost ↘
- 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

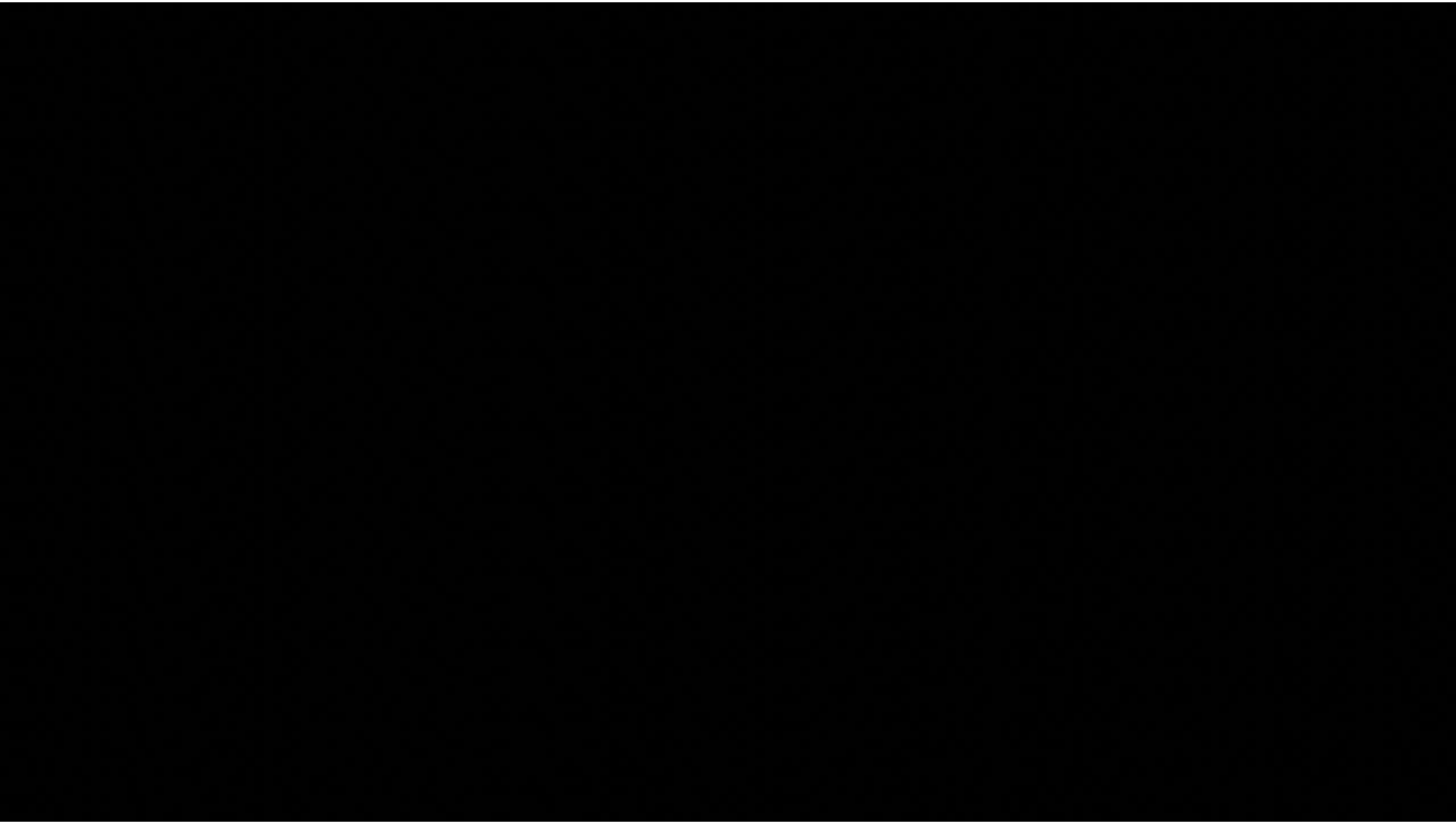
Eric Overström
Provost, Worcester Polytechnic Institute

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!”

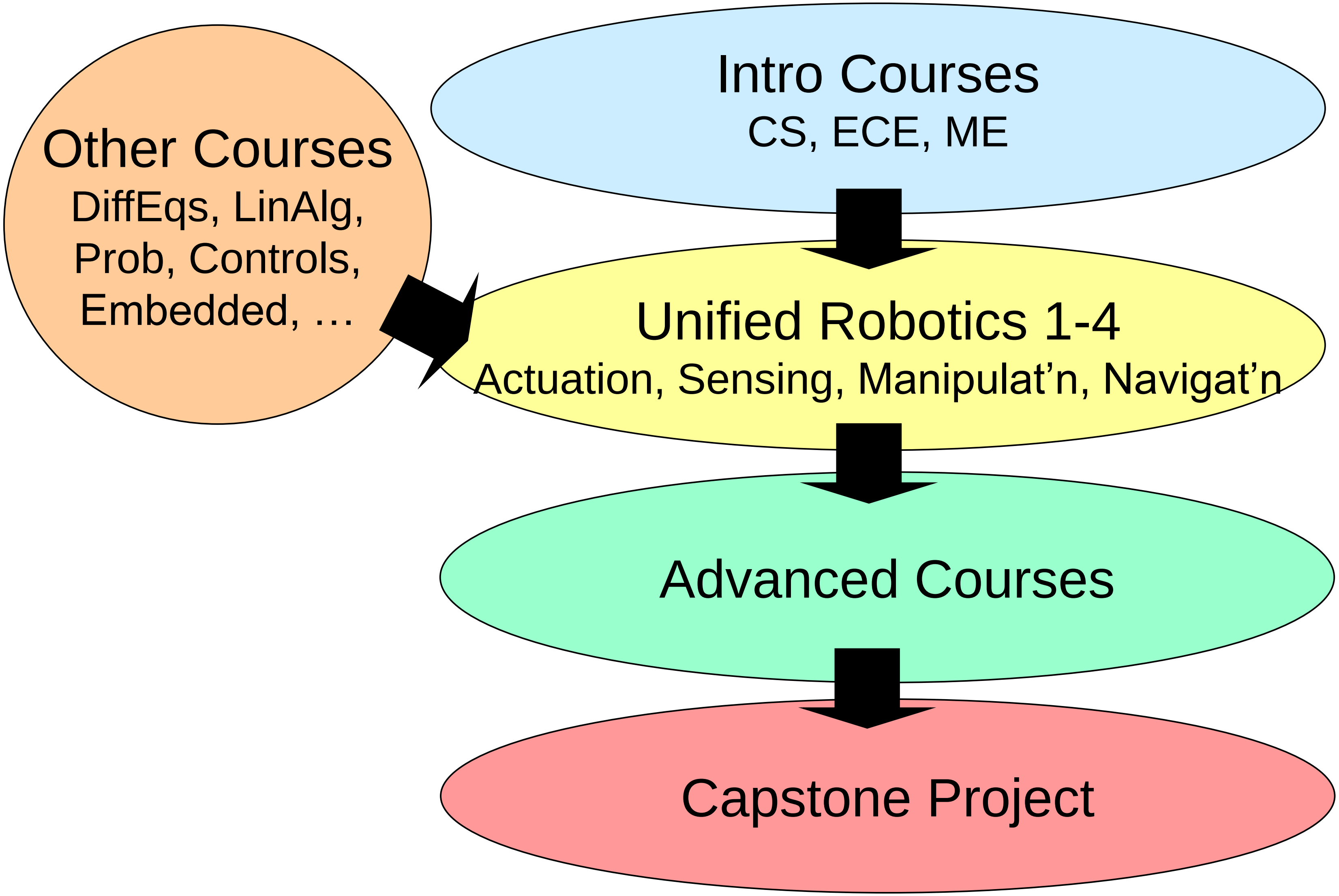
Curriculum 1.0

Black: Required General Education (12 courses)
Gr[illegible]red Basic Math and Science (9 co[illegible]
Purp[illegible]mended Basic Math and Scienc[illegible]ses)
Red: R[illegible]ngineering (13 courses)
Blue: Re[illegible]ed Engineering and Fre[illegible]s (9 courses)

Class	A Term	B Term	C Term	D Term
Freshman	MA 1021 PH 1110 HU	[illegible]1022 [illegible]01	MA 1023 PE HU	MA 1024 PH 1120 HU
Sophomore	CS 1101 RBE 1001 HU	C[illegible] M[illegible]	CS 2303 ECE 2011 SS	MA 2051 ECE 2022 SS
Junior	ECE 2801 ES 2501 IQP	[illegible]03 [illegible]223 [illegible]P	ME 3310 Project Preparation IQP	ECE 2311 CS 3733 Robotics Elective 1
Senior	CS 4341 ES 3011 MQP	Robotics Elect[illegible] Free Elective MQP	[illegible]obotics Elective 3 [illegible]ee Elective [illegible]	Free Elective

Where's the Robotics?

Curriculum Picture



Curriculum 2.0

Black: Required General Education (12 courses)
Green: Required Basic Math and Science (11 courses)
Red: Required Engineering (13 courses)
Blue: Recommended Engineering and Free Electives (9 courses)

Year	A Term	B Term	C Term	D Term
Freshman	Calculus 1 Physics 1 Great Problems	Calcul[illegible] Physic[illegible] Great [illegible]lems	Calculus 3 CS 1 HU&A	Calculus 4 Digital Logic Intro Robotics
Soph	Unified Robtcs 1 Embedded Sys Statics	Unifie[illegible]btcs 2 Diff Eq[illegible] HU&A	Controls Soc Sci HU&A	CS 2 Soc Sci HU&A Seminar
Junior	Unified Robtcs 3 Entrpreneur'p Junior Project	Unified[illegible]btcs 4 Probability Junior Project	Linear Algebra RBE Elective 1 Junior Project	Social Issues RBE Elective 2 Software Eng
Senior	Science RBE Elective 3 Capstone Project	Free E[illegible]e 1 Free E[illegible]e 2 Capstone Project	Free Elective 3 Free Elective 4 Capstone Project	Free Elective 5 Free Elective 6 Free Elective 7

Where's the Robotics?

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

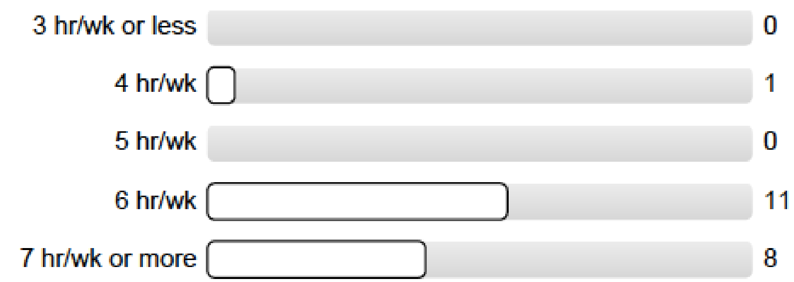
RBE500 Foundations
RBE501 Dynamics
RBE502 Robotic Control
RBE510 Multi-Robot Sys
RBE520 Biomechanics & Robotics
RBE526 Human-Robot Interaction
RBE549 Computer Vision
RBE550 Motion Planning
RBE580 Biomedical Robotics
RBE594 Capstone Proj Experience
RBE595 Special Topics

- 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

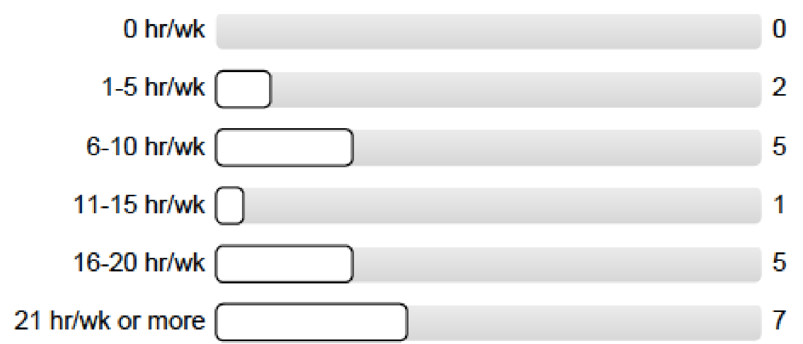
Hard-working Students

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

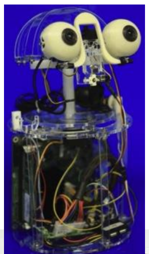
26A. On average, how many hours of the formally scheduled hours for lecture, conference, and labs did you ATTEND each week?

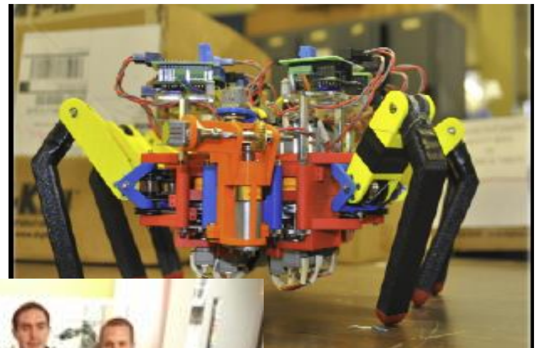


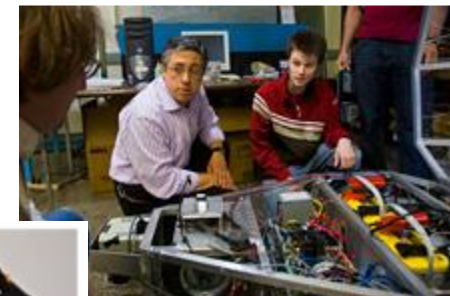
26B. On average, what were the total hours spent in each 7-day week OUTSIDE of formally scheduled class time in work related to course (including studying, reading, writing, homework, rehearsal, etc.)?



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

er

Select Project Sponsors

BOSTON ENGINEERING™

A123 Racing

SolidWorks

NATIONAL INSTRUMENTS™

AXIS® COMMUNICATIONS

QinetiQ North America

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

bobObots.com

GENERAL DYNAMICS
Strength On Your Side®

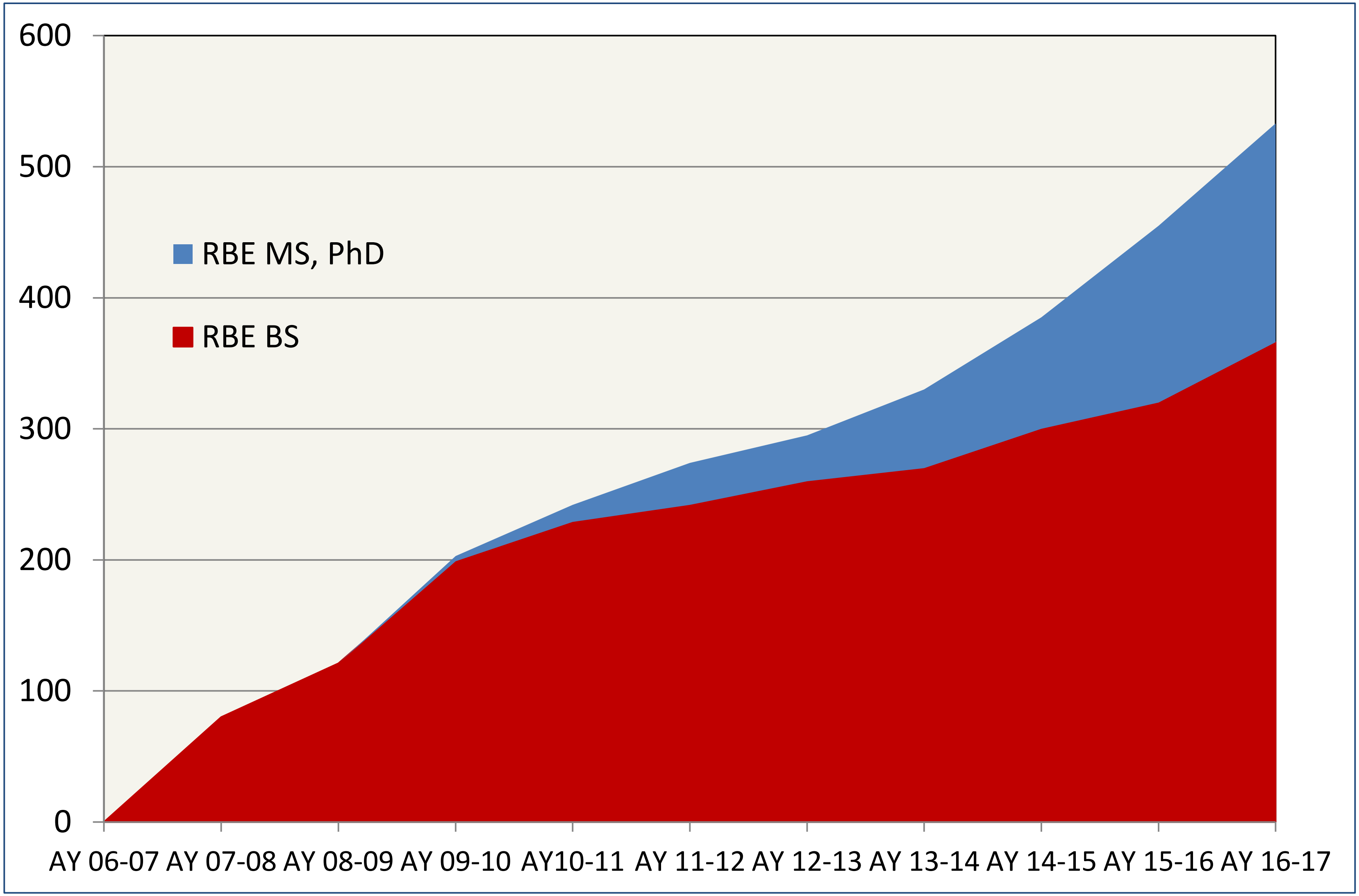
maxon motor
driven by precision

TRAVELERS

HC HYDRO-CUTTER
Precision Waterjet Cutting
www.Hydro-Cutter.com

MicroStrain®
Little Sensors. Big Ideas®

Enrollment


600
500
400
300
200
100
0
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

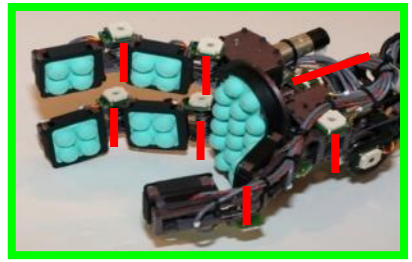
Jobs & Internships

amazon robotics
CATERPILLAR
BOSTON ENGINEERING
NATIONAL ROBOTICS NREC ENGINEERING CENTER
NetCracker
U.S. ARMY
Carnegie Robotics
Protonex
PHILIPS
QinetiQ
SEGWAY
ArcBotics Igniting Open Robotics
ARTAIC INNOVATIVE MOSAIC
DEKA
Raytheon
BAE SYSTEMS
ENERGID
symbotic
HONEYBEE ROBOTICS Spacecraft Mechanisms Corporation
Black-i Robotics
GENERAL DYNAMICS Strength On Your Side
SIEMENS
BLUEFIN ROBOTICS
INTERSYSTEMS
iRobot
TECHNOCOPIA WORCESTER, MA
UBER
BostonDynamics
LOCKHEED MARTIN
TELEDYNE TECHNOLOGIES INCORPORATED
BOSE Better sound through research
MITRE
rethink robotics
United Technologies
BOSSA NOVA ROBOTICS
MIT Lincoln Laboratory
myomo my own motion
UNITED STATES NAVY
ViaSat

Robotics Research

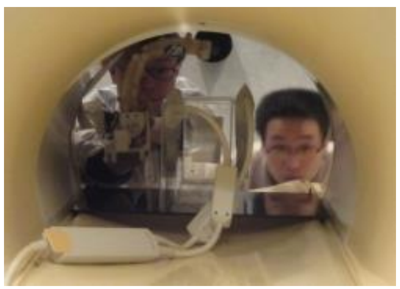
Sensing & Manipulation

Human-Robot Interaction



Autonomy & Navigation

Biomedical Robotics



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!

DRC Trials Video

Self-Driving Vehicles

SFGATE | Autos | Jobs | Real Estate | e-edition | Subscribe

San Francisco Chronicle — Biz & Tech

Self-driving shuttle loops around Santa Clara University campus

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

Photo: James Tensuan, Special To The Chronicle

SF Chronicle http://www.sfchronicle.com/business/article/Self-driving-shuttle-loops-around-Santa-Clara-10827588.php

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

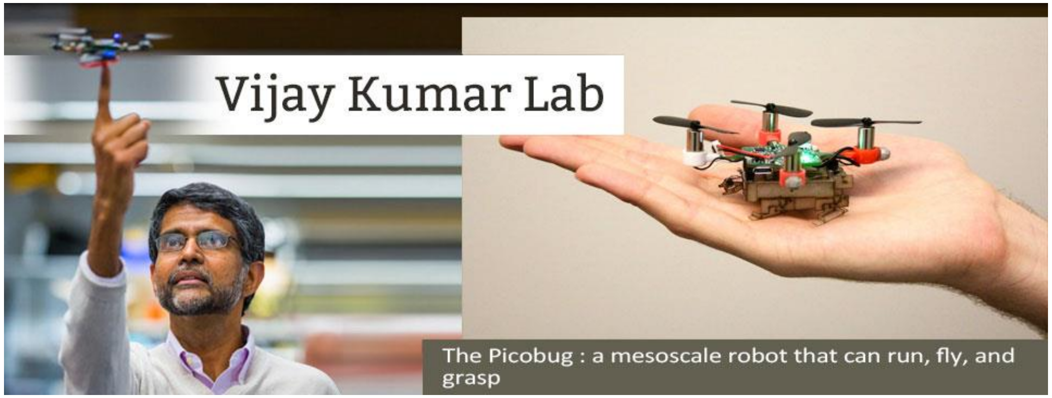
Residential Life

Ask TOH | Robotic Wall https://www.thisoldhouse.com/watch/ask-toh-robotic-wall-bench

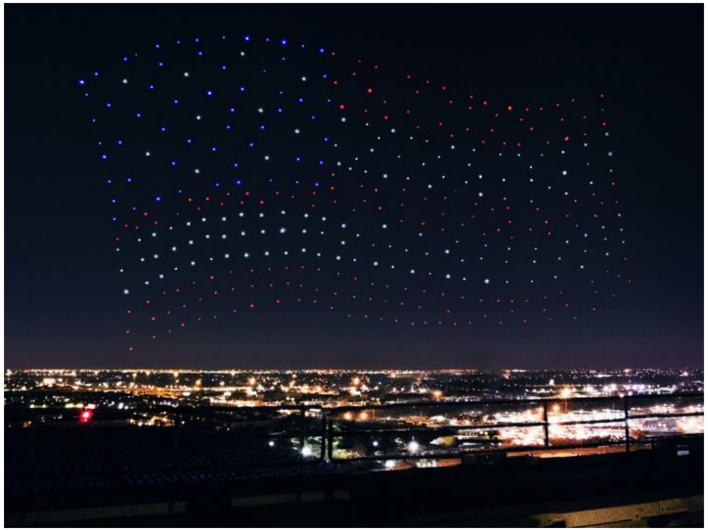
Dining Services & Food Prep

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

Drones



http://www.kumarrobotics.org/



https://assets.wired.com/photos/w_1440/wp-content/uploads/2017/02/American-Flag-ImageTA.jpg

Science http://www.sciencemag.org/news/2015/02/how-lawmakers-aim-protect-you-drone-invasion

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

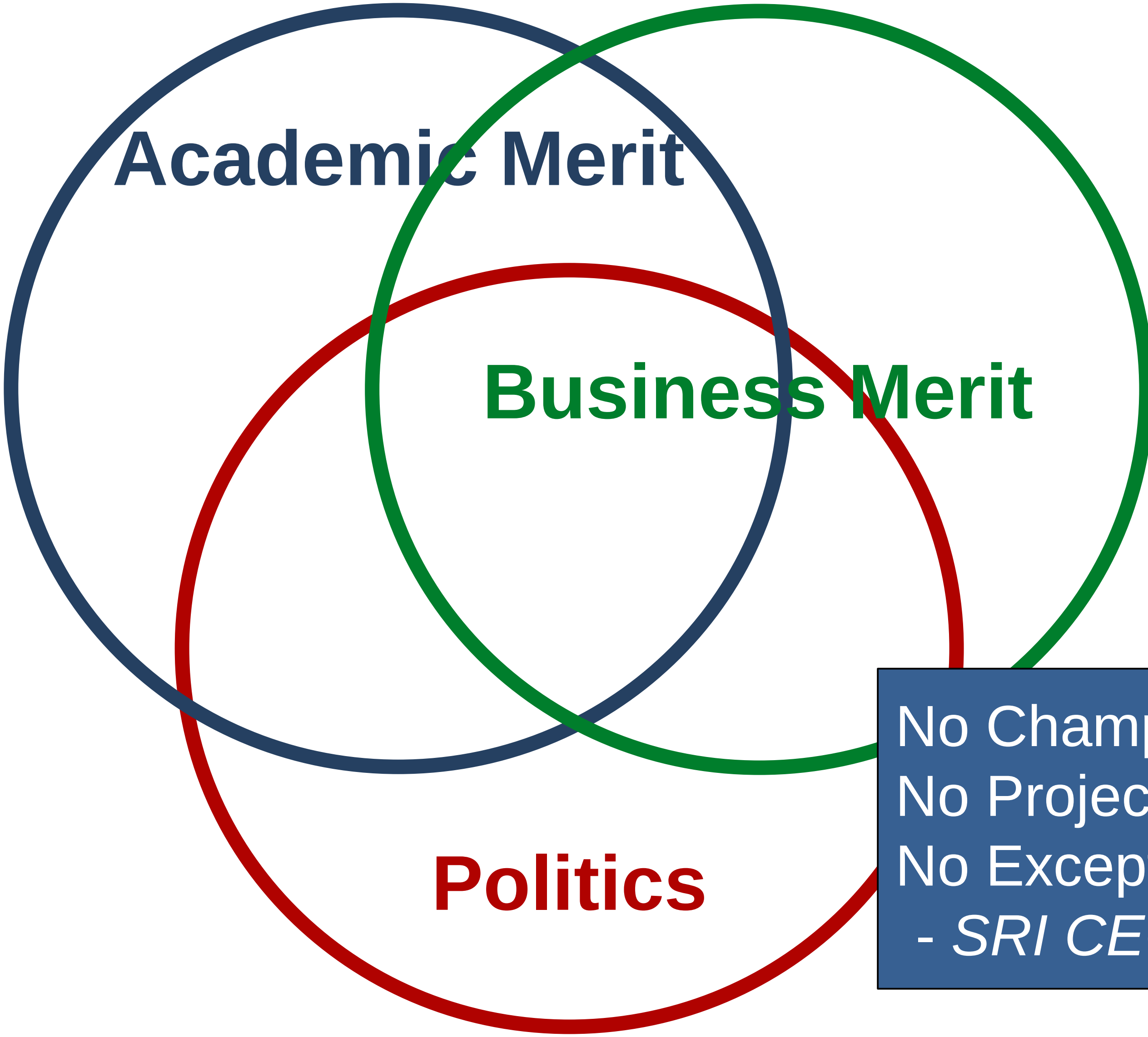
Lessons Learned

For faculty buy-in

- 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!**

For curriculum design

How to Win with Academics



No Champion,
No Project.
No Exceptions.
- *SRI CEO Curt Carlson*

Acknowledgements

- This work is sponsored in part by AFOSR, DARPA, GE, NIH, NSF, Toyota, WPI
- Equipment: ABB, Axis Communications, Maxon Motors, NVIDIA
- Many colleagues and contributors

Thank You!