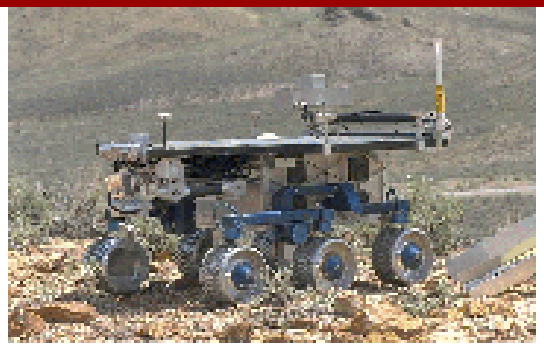
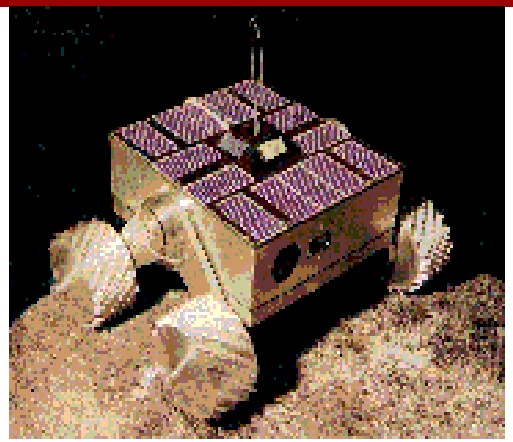
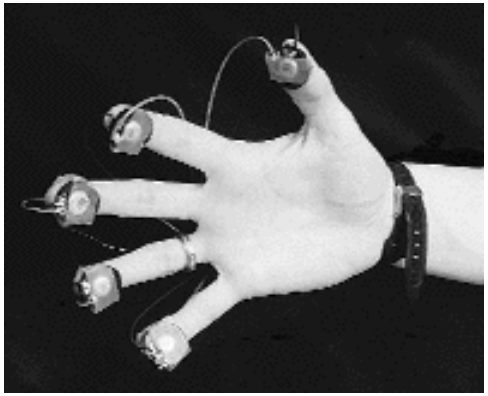
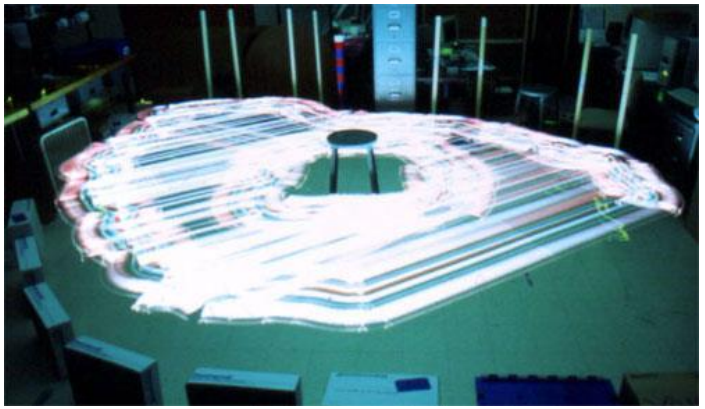





# Introduction to ROBOTICS

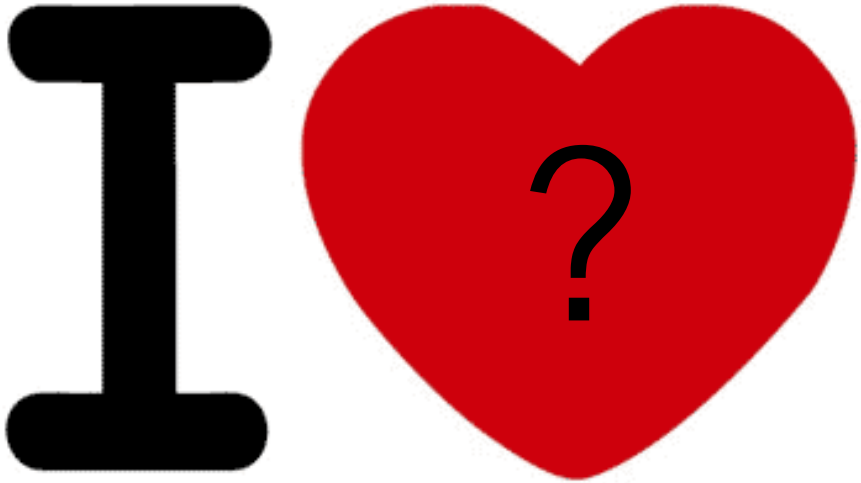
*Howie Choset*



# Are robots a good?

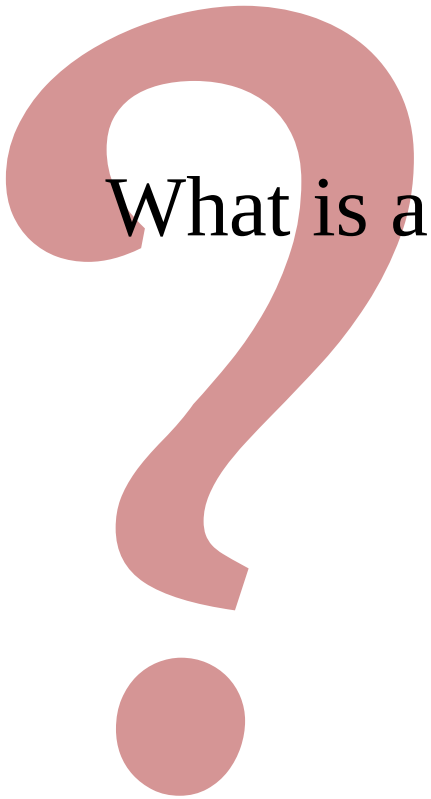
- 322 BC – Aristotle, a Greek philosopher, wrote “If every tool, when ordered, or even of its own accord, could do the work that befits it... then there would be no need either of apprentices for the master workers or of slaves for the lords.”




# ROBOTS

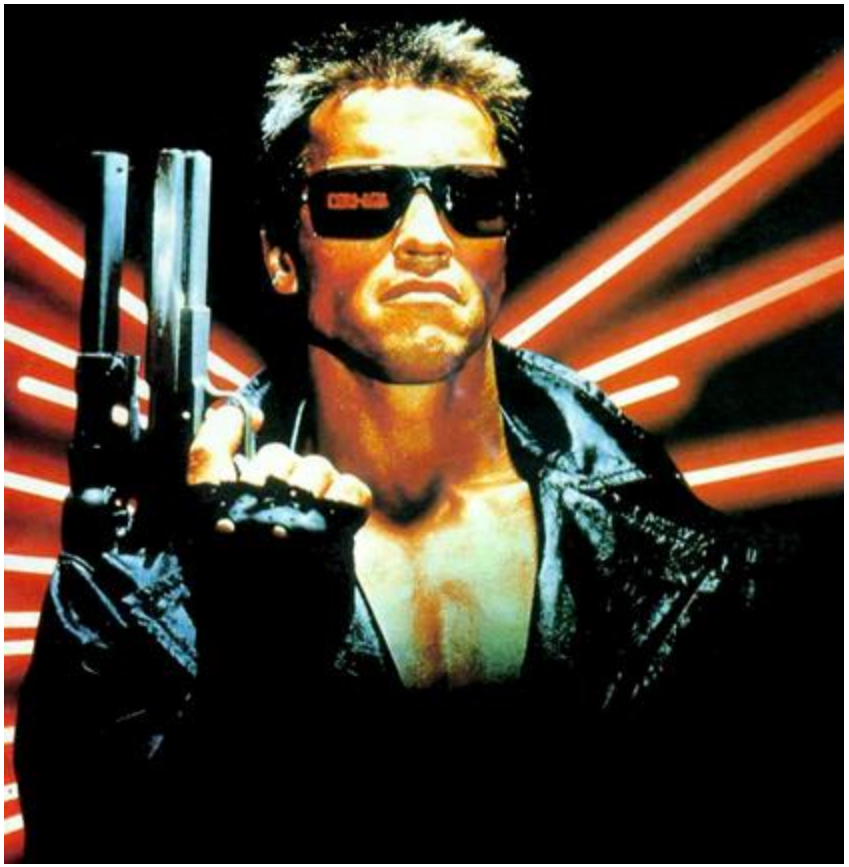
# robot: (*noun*) …

Insert image here

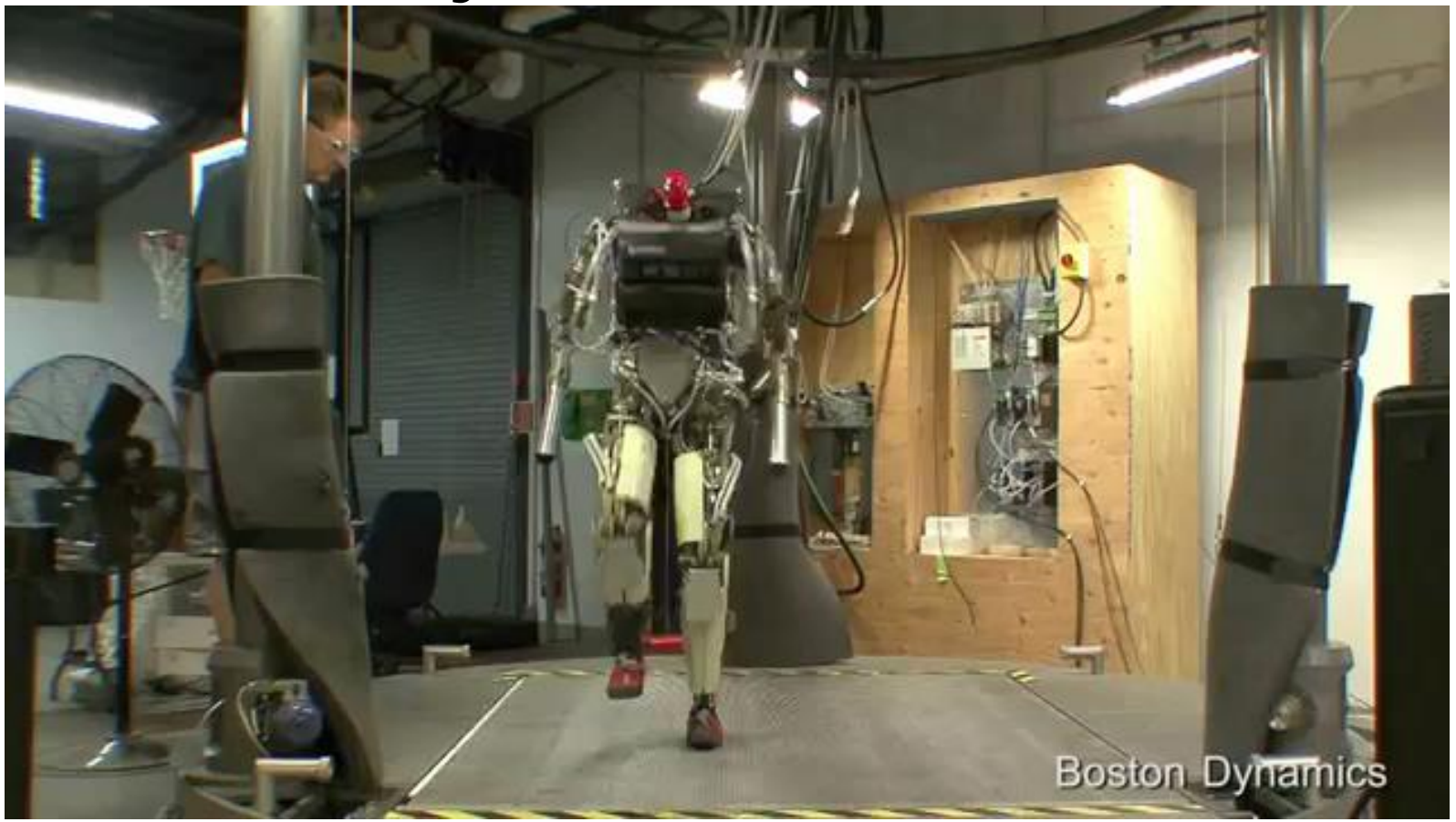


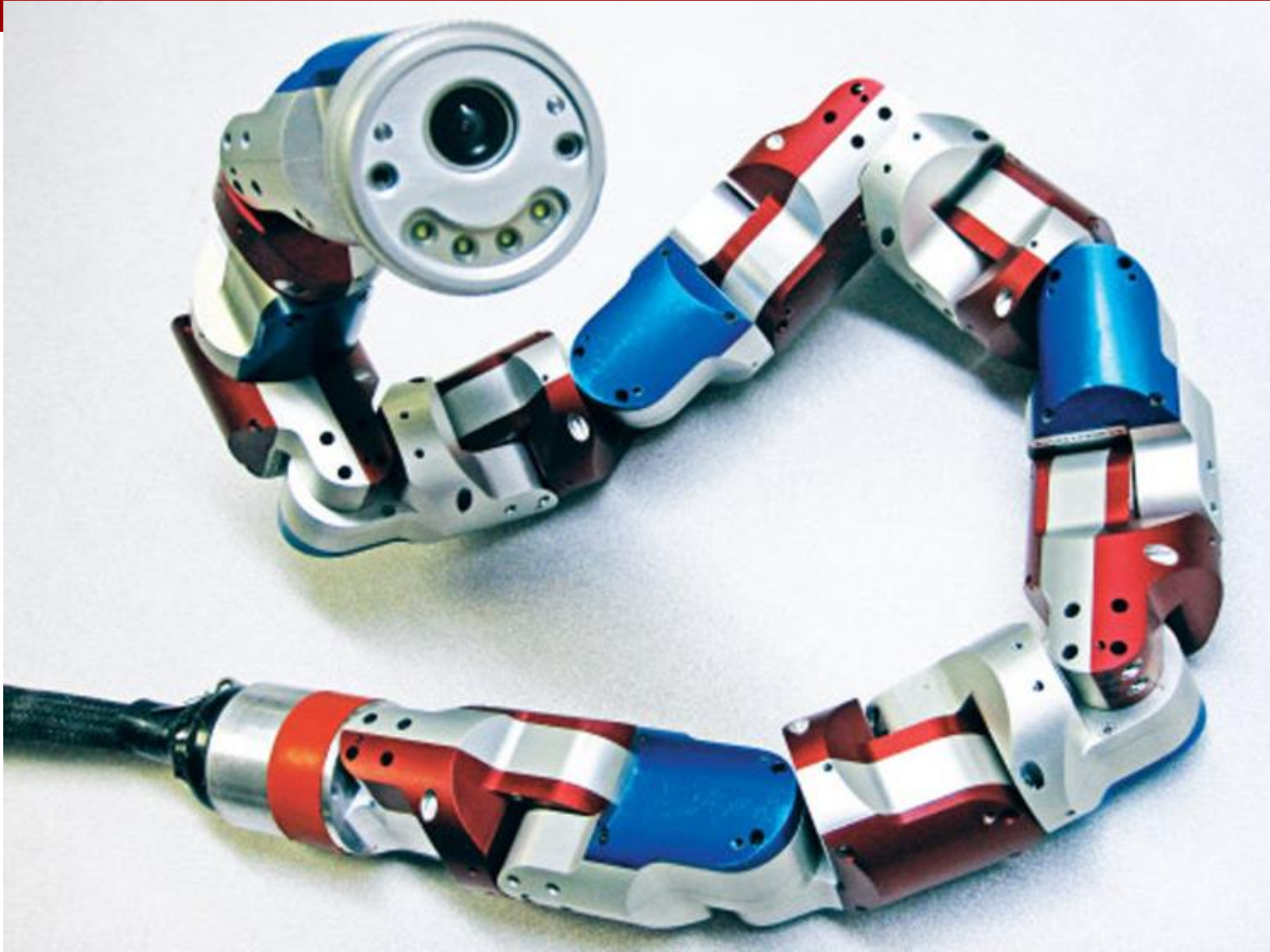
What is a robot?

# Humanoid Form



# Boston Dynamics Petman/Atlas



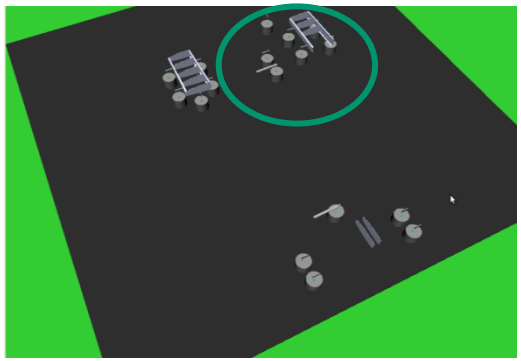


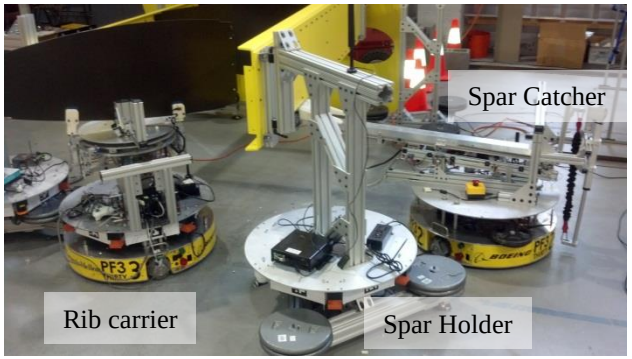
# Archeology (Bard, Fattovich, El-Maguid,Hawass)

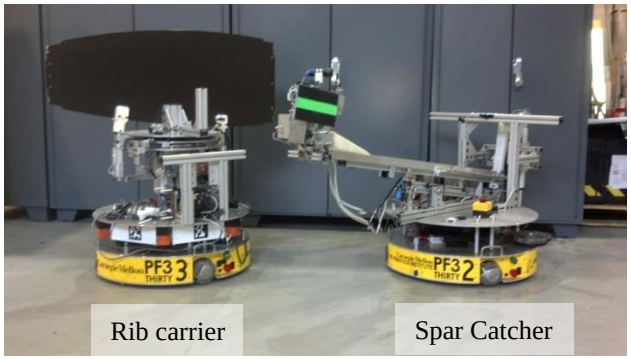


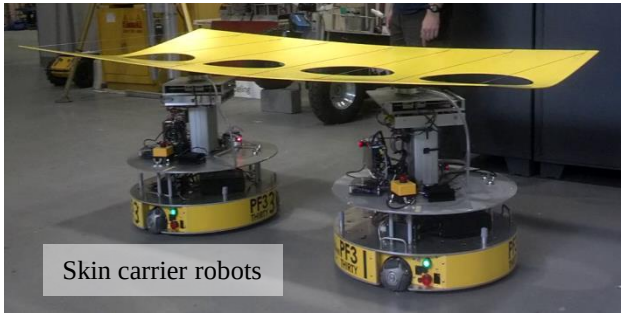
# Remove the Monuments

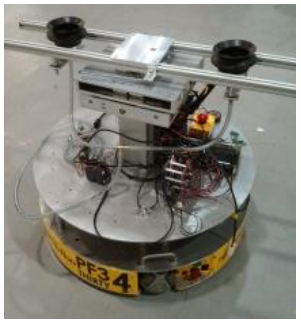
# UNIVERSITY RESPONSE

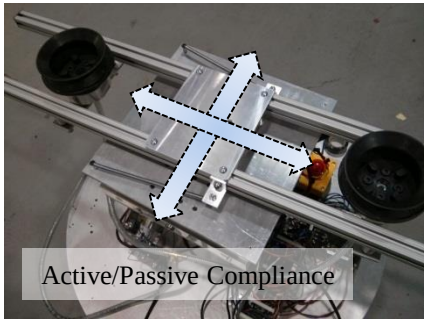


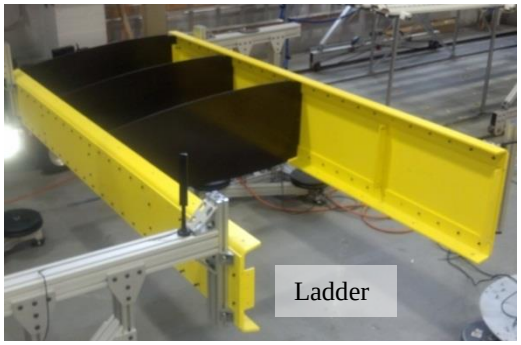


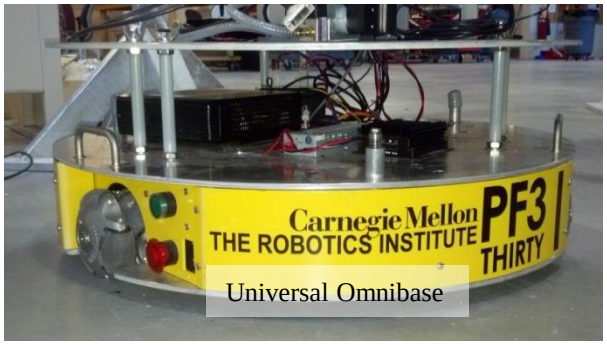





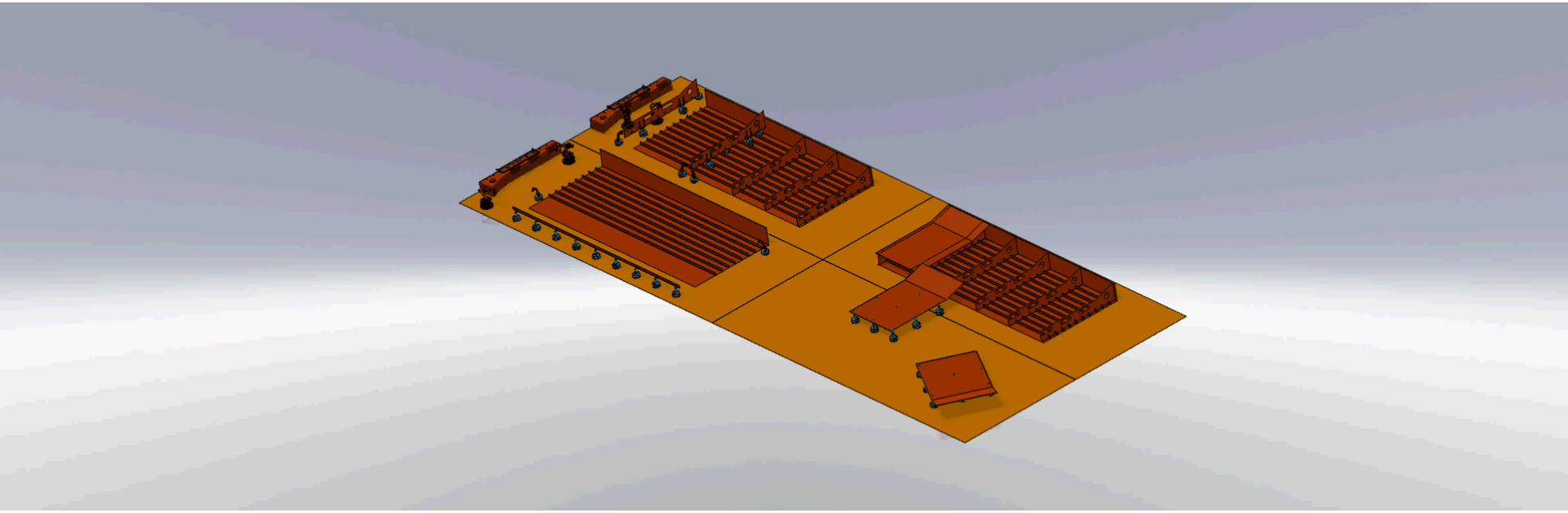



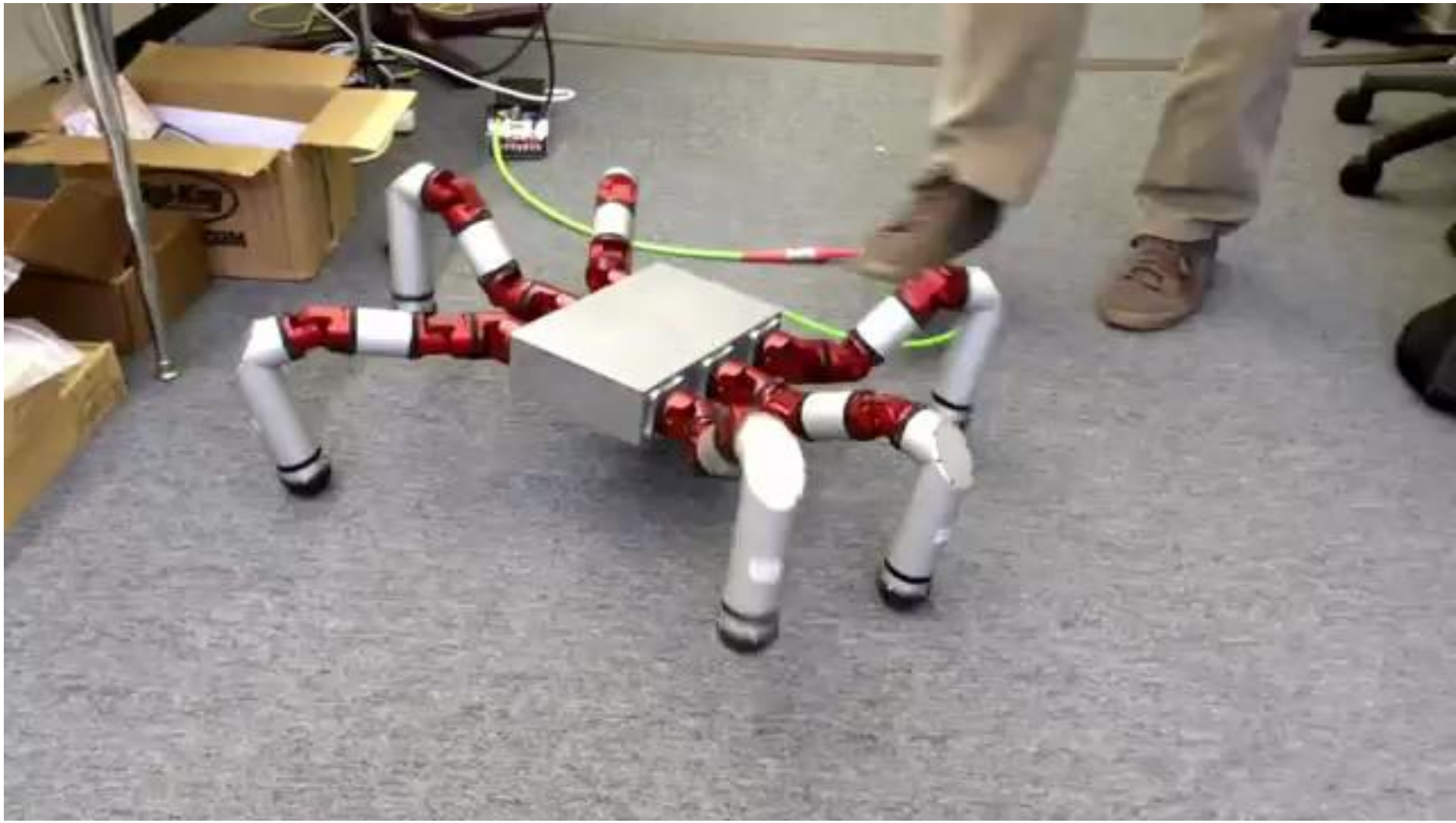




THE ROBOTICS INSTITUTE

# Proof of Concept Idea



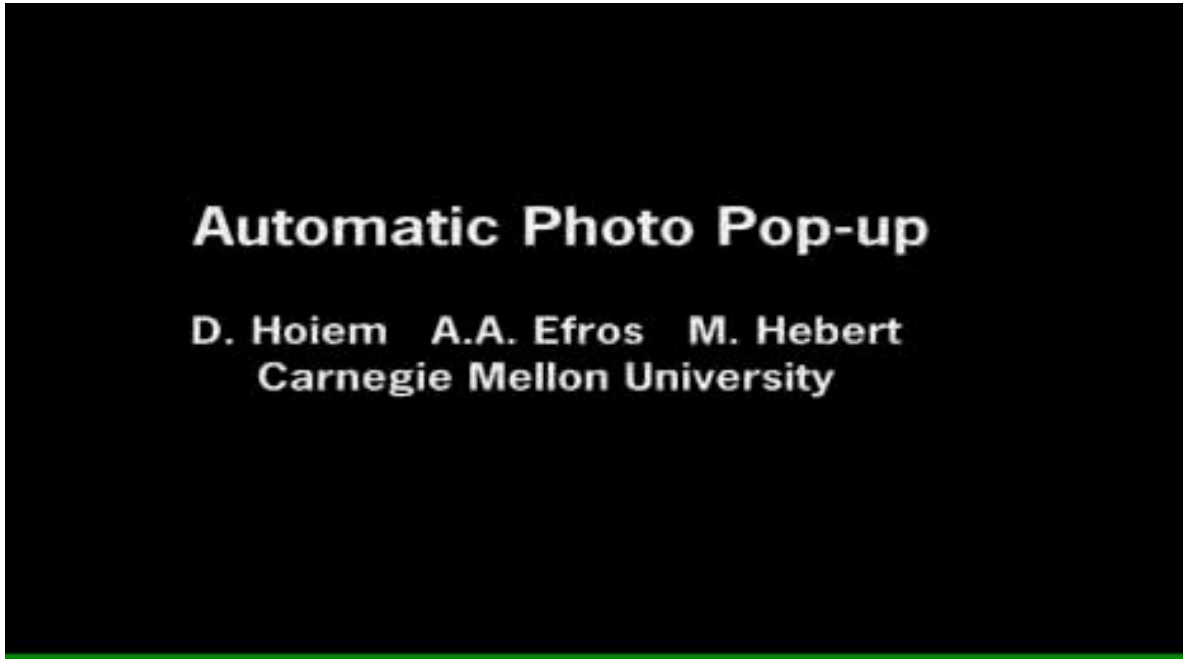


# Apples and Oranges

- USDA Specialty Crop Research Initiative
- First round (Fall 2008)  $28M awarded
- Two Robotics Institute-led efforts won $10M total
  - Comprehensive Automation for Specialty Crops
    - Sanjiv Singh, PI
    - $6M / 4 years
    - Apples and horticultural stock
  - Integrated Automation for Sustainable Specialty Crop Farming Project
    - Tony Stentz and Herman Herman, PIs
    - $4M / 3 years
    - Oranges

# Vision

Hoiem, Efros, and Hebert
"Automatic Photo Pop-up"
ACM SIGGRAPH 2005.




Finds coarse 3D shape from a *single image*!

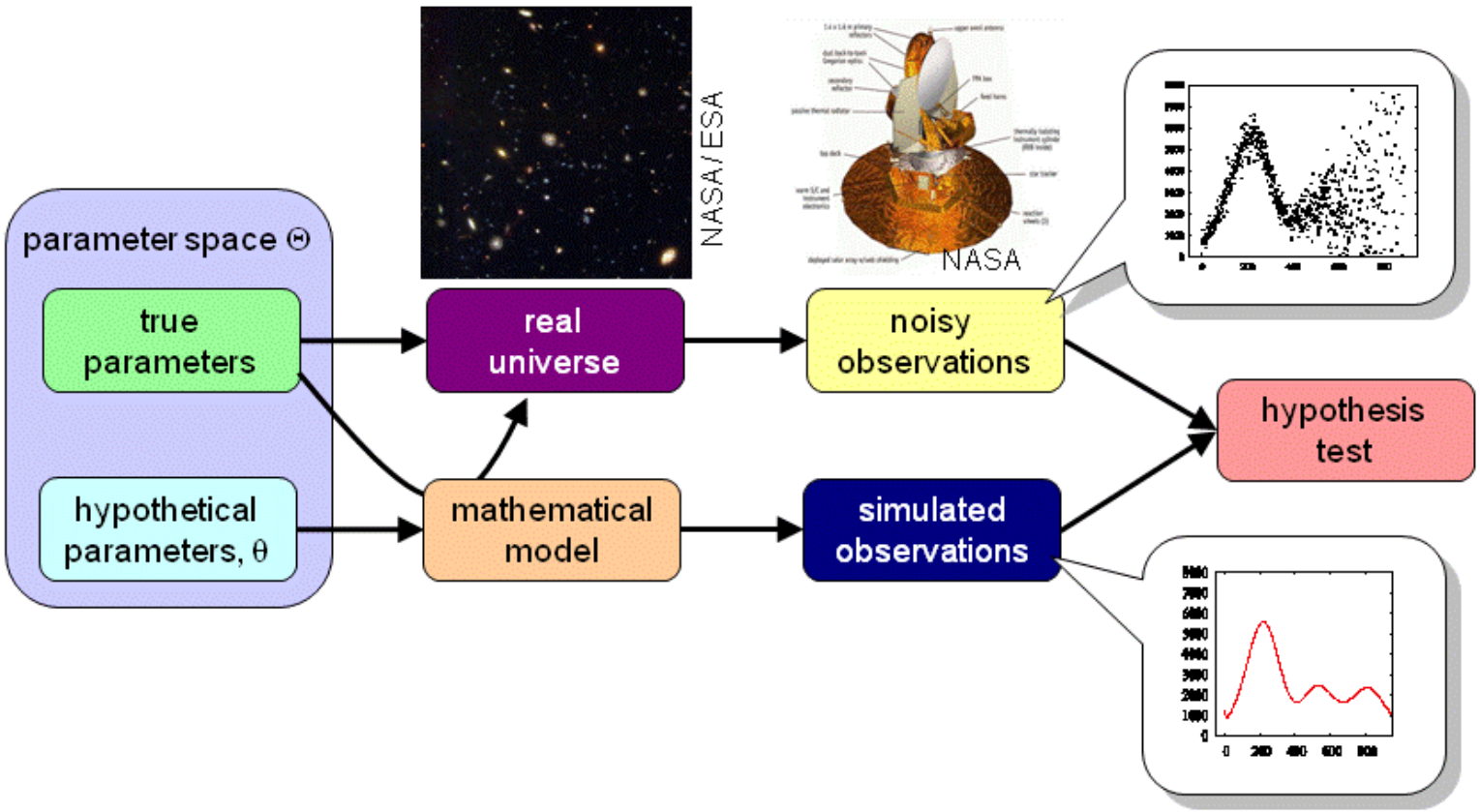
# Dynamic Seethroughs

Kanade, Sheikh

# Drug Discovery


Schneider

# Cosmology



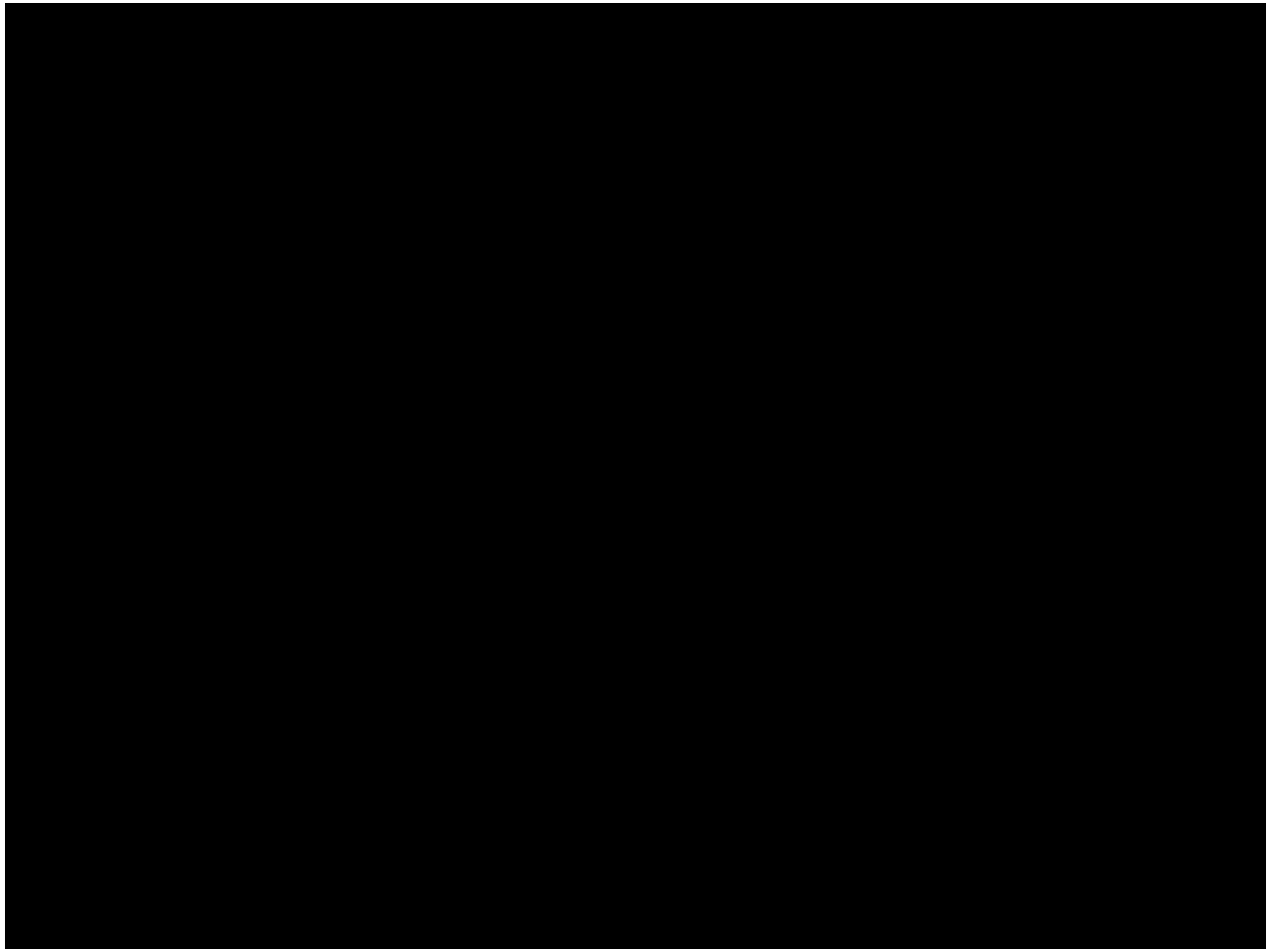

Schneider

There is no widely accepted definition of what a robot is.

# Is this a robot?

# Are we there yet?

# Urban Challenge




DARPA
URBAN CHALLENGE
FINISH
URBAN
DARPA
URBAN CHALLENGE
November 3, 2007
Boss
$ 2,000,000
Two Million Dollars
First Place
Tony Tether
19
CAT

# Self-driving Google Car

# DARPA Rescue Challenge

# DARPA Rescue Challenge

# DARPA Rescue Challenge

DARPA Atlas

SCHAFT

BostonDynamics

Carnegie Mellon University

# Google

Google


Google

Carnegie Mellon University

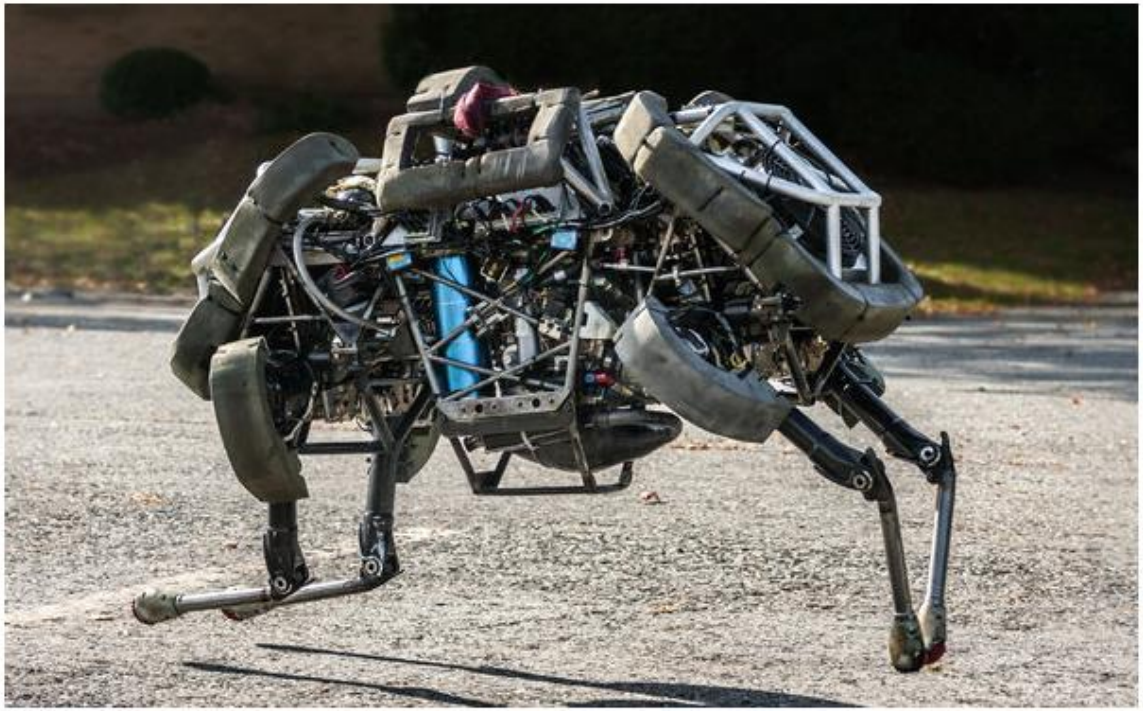
# Google

The New York Times

Business Day
Technology

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINION

## Google Adds to Its Menagerie of Robots



Boston Dynamics

Boston Dynamics' four-legged robot named WildCat can gallop at high speeds.

- Boston Dynamics
- Bot and Dolly
- Autofus
- Holonomi
- Meka Robotics
- Redwood Robotics
- Industrial Perception
- Schaft

# Humanoids will Take Over

Inspirations:

Robots
Animals

Elements:

Perception
Intelligenc
Action

Technologies:

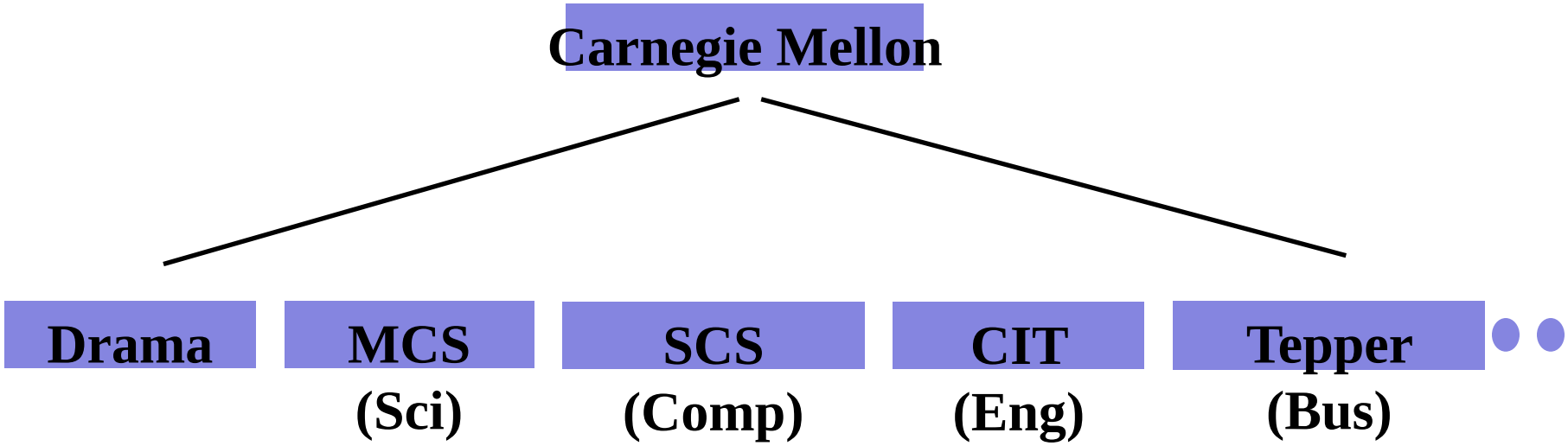
Vision
Speech recog'n
Motion planning
Localization
Navigation
Dynamic balance
Gait recognition
Face recognition
Behavior recog'r
...

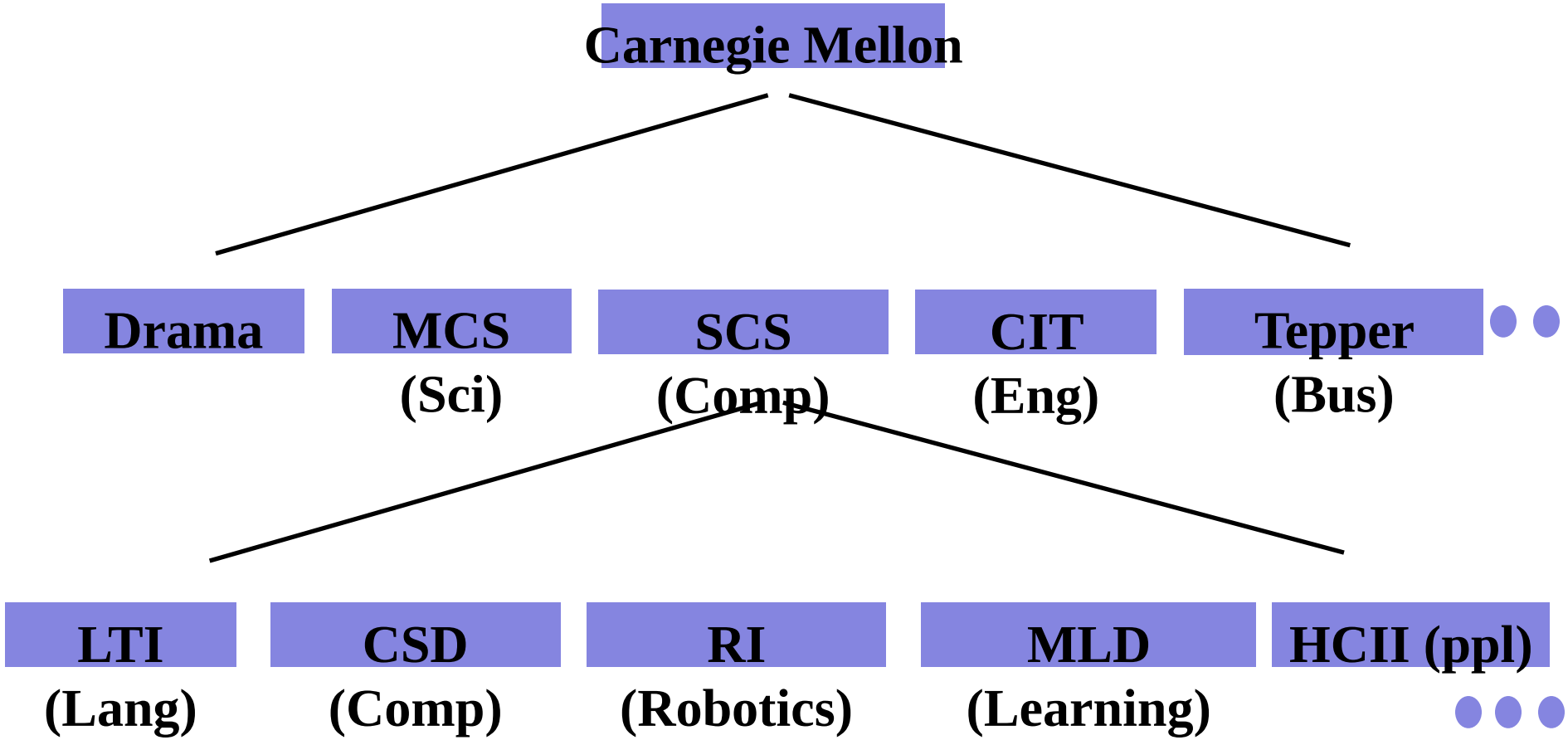
Applications:

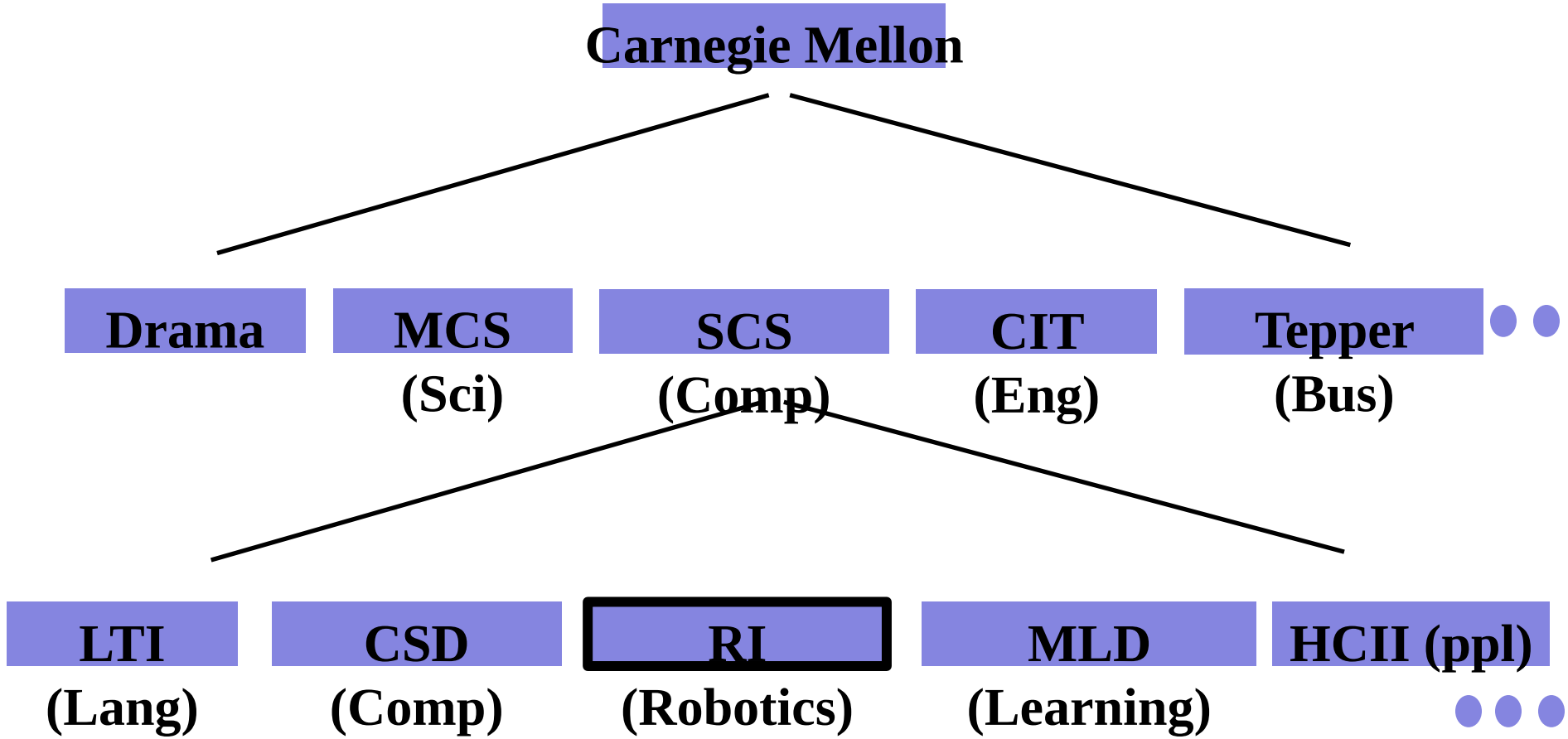
Search image databases
Public health early warning
Astronomical survey
Watch mice
Tutor beginning readers
Museum guide
Watch for customers
Video games
Movie and TV animation
Model protein structure
Surgery
Vacuuming
...

# Carnegie Mellon

- 10,000 students
- $320M sponsored research
- History of leadership in Management, Computer Science, Statistics, Psychology, Engineering, Drama, Art, ... and Robotics!
- Of top 25, the youngest, almost smallest.
- Values:
  - We work.
  - We build.
  - We test.
  - We collaborate.





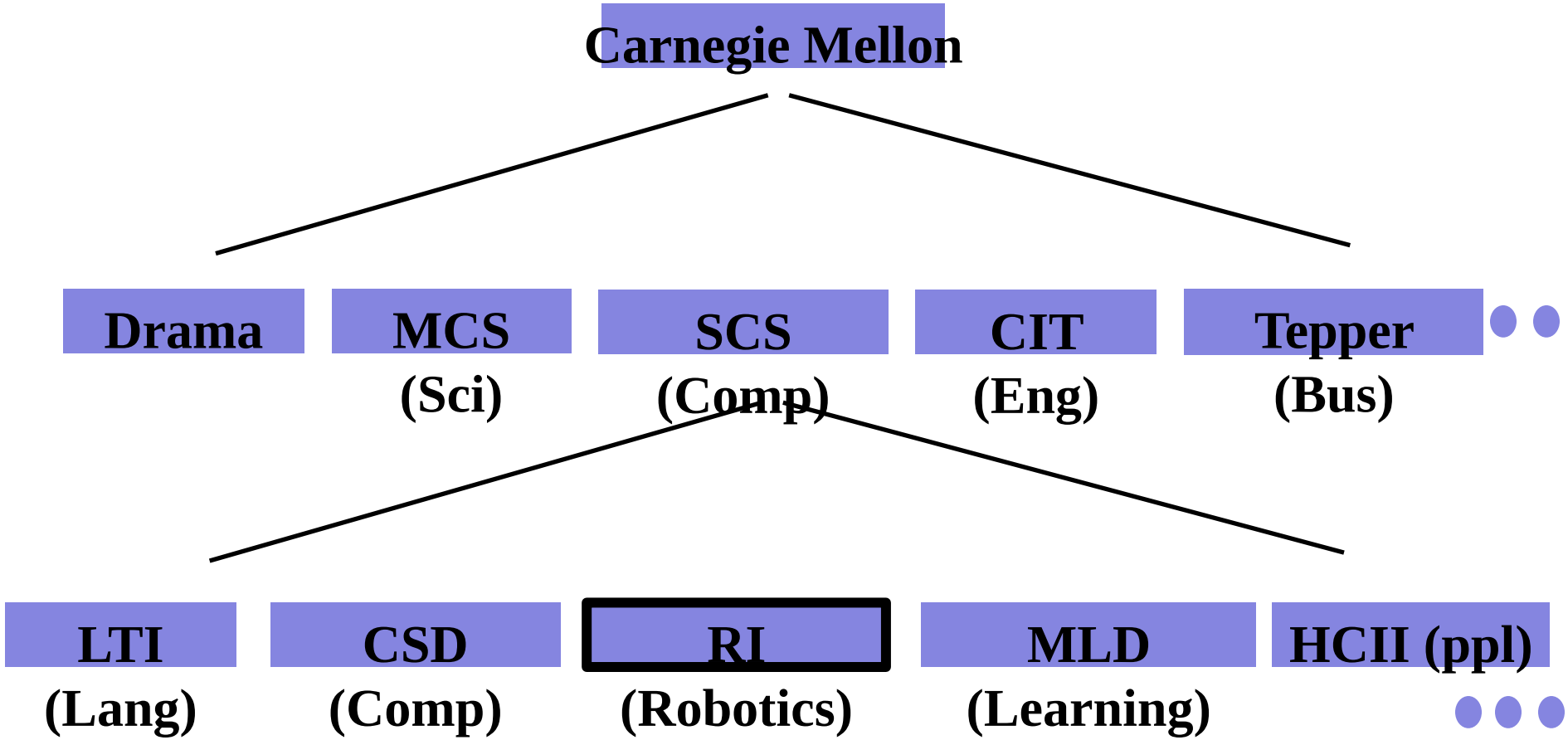



Founded 35 years ago as a research institute.

The first Robotics Department, for 30 years.

- Still more of a research institute
- PhD, MS, MRSD, BS2, Minor, FIRST, K-12, pre-K,

"The unquestioned worldwide leader in robotics research and education." Advisory Board

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"The unquestioned worldwide leader in robotics research and education" Advisory Board

About 700 researchers

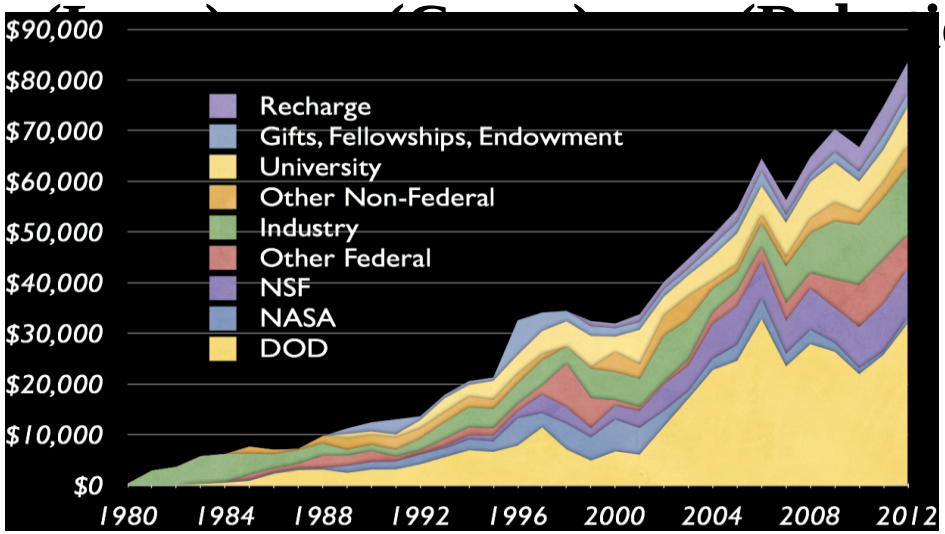
15% faculty (2/3 on soft $)
25% graduate students,
45% technical staff,
15% visiting faculty/postdocs.

Sponsored research budget:
~$100MM (2X7.25 years in real$)

# Carnegie Mellon

Drama | MCS (Sci) | SCS (Comp) | CIT (Eng) | Tepper (Bus)

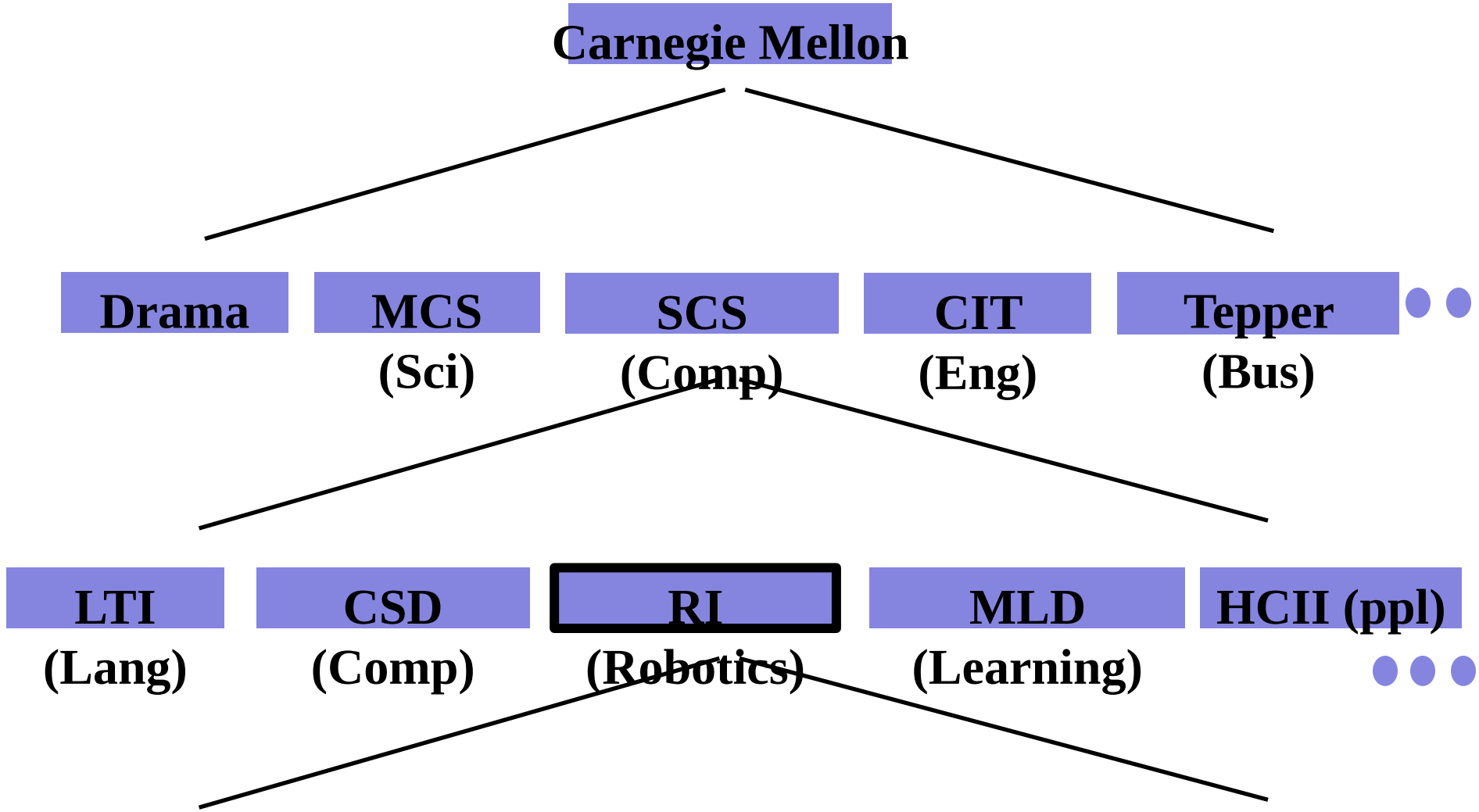
LTI | CSD | RI | MLD (Learning) | HCII (ppl)



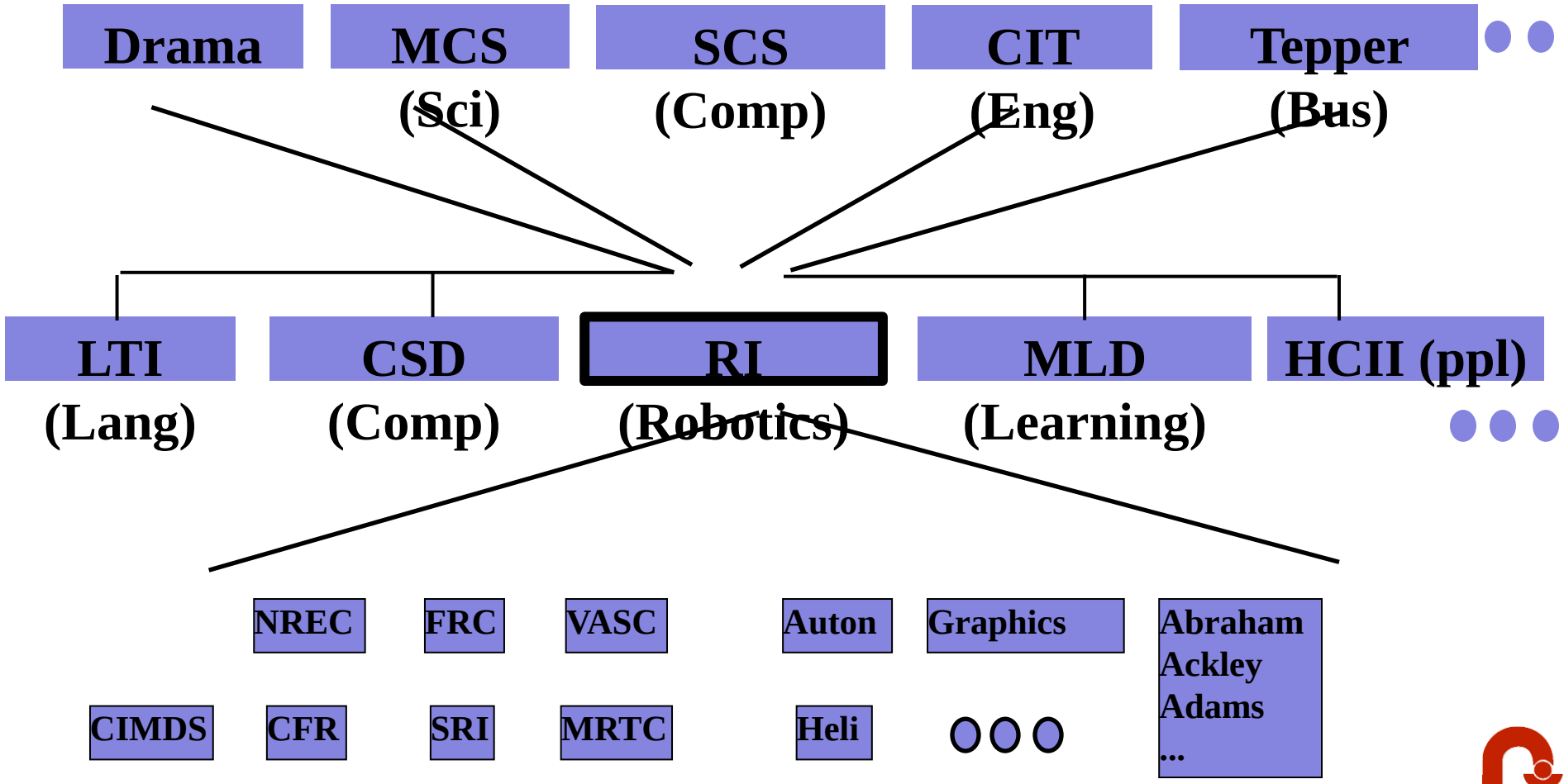

About 700 researchers

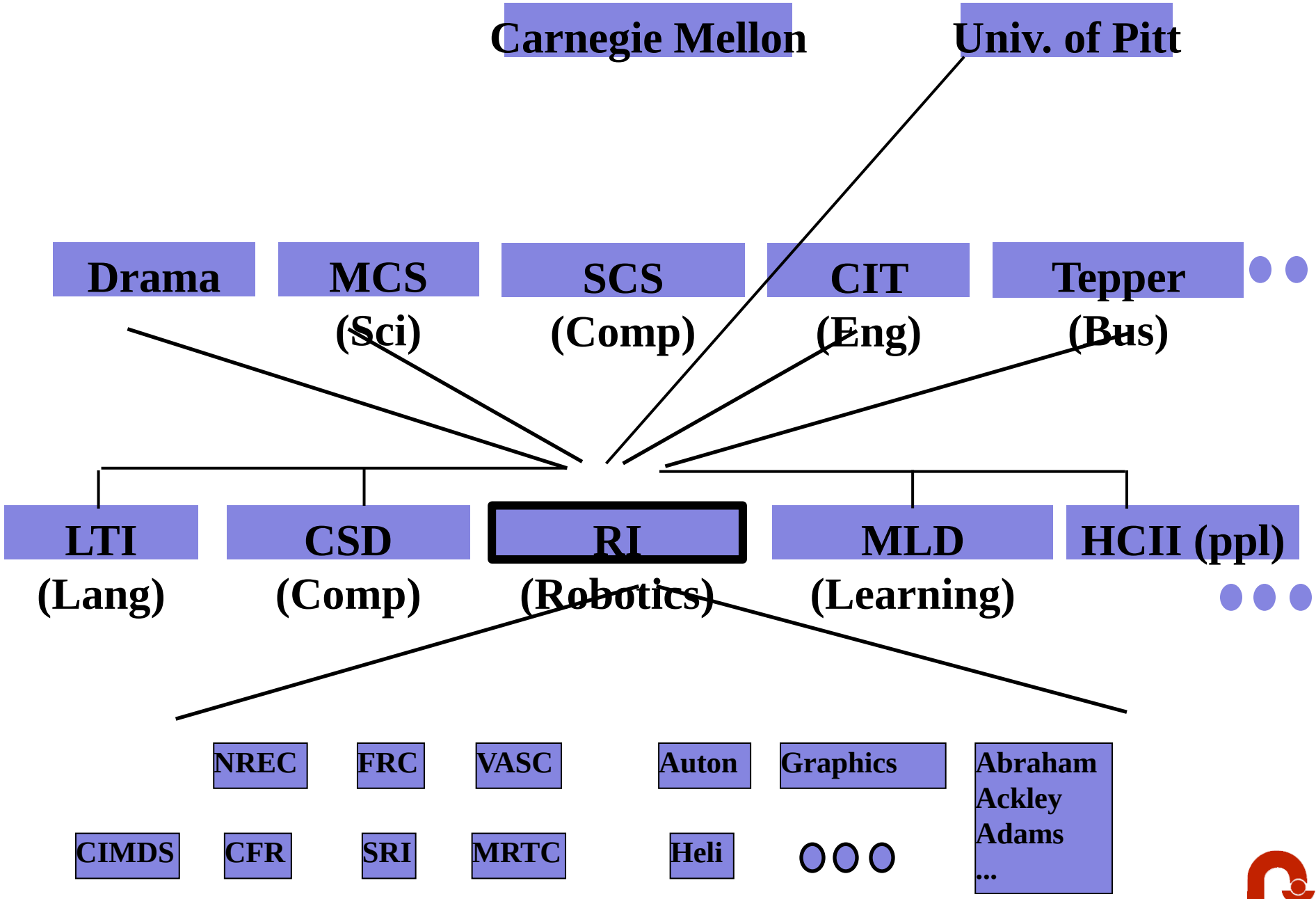
- 15% faculty (2/3 on soft $)
- 25% graduate students,
- 45% technical staff,
- 15% visiting faculty/postdocs.

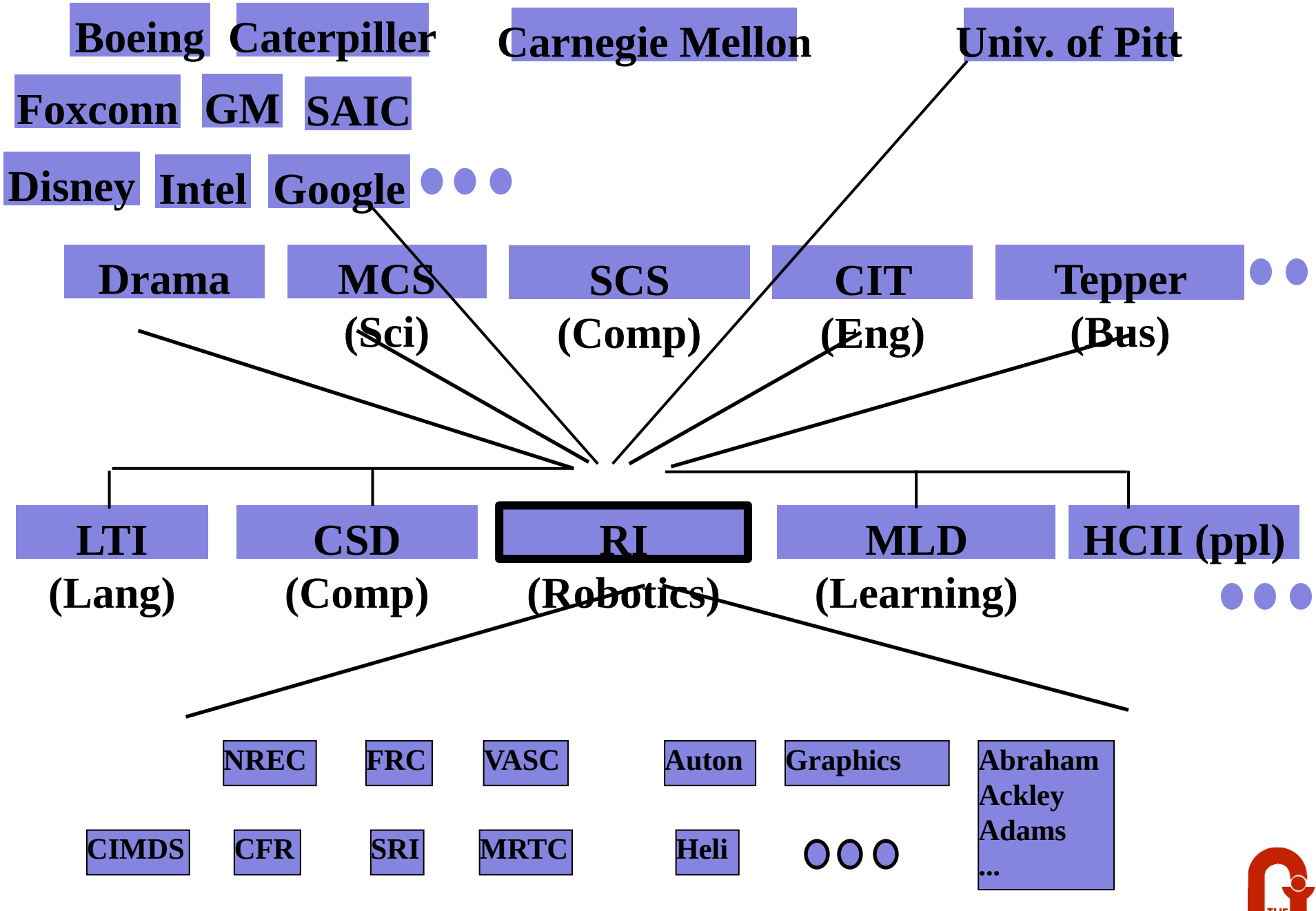
Sponsored research budget:
~$100MM (2X7.25 years in real $)



# Carnegie Mellon

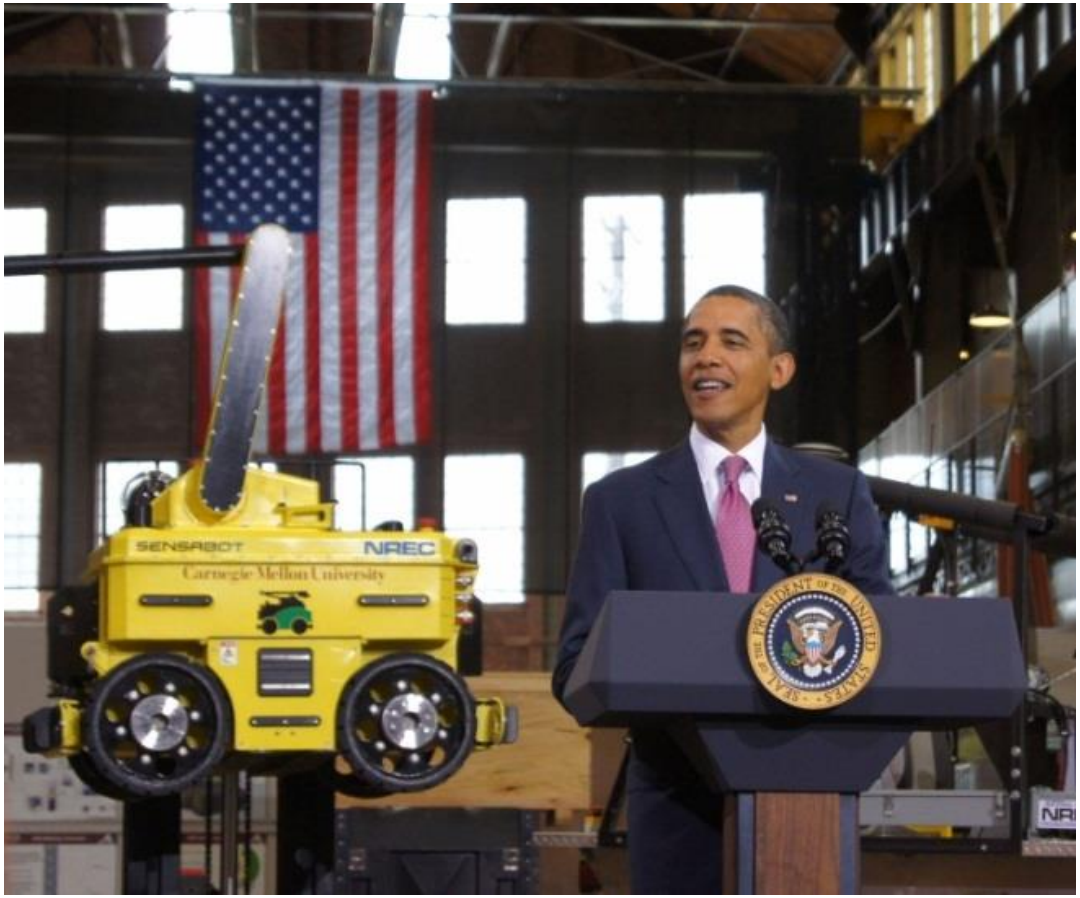






# Martial Hebert

# Large Robotics Activity



# RI research foci

- Manufacturing
  - Planning, layout, scheduling, safety, monitoring, ...
- Field Robotics
  - Space, Security, Vehicles, Mining, Agriculture, Nuclear, ...
- Vision, perception in general
  - Faces, outdoor terrain, scene understanding, ...
- Manipulation and Motion Planning
- Machine Learning
- Mapping
- Aerial Robotics
- Medical
- Graphics, computer generated animation
  - Fluids, soft tissues, motion capture, hands, ...
- Human robot interaction
  - Education, behavior recognition, dancing, ...
- Novel mechanisms
- and more ... haptics, snakes, humanoids, logistics ...

# Robotics Institute Graduate Activities

- Courses
- PhD
- MS in Robotics
- MS in Vision
- MRSD
- RoboORG

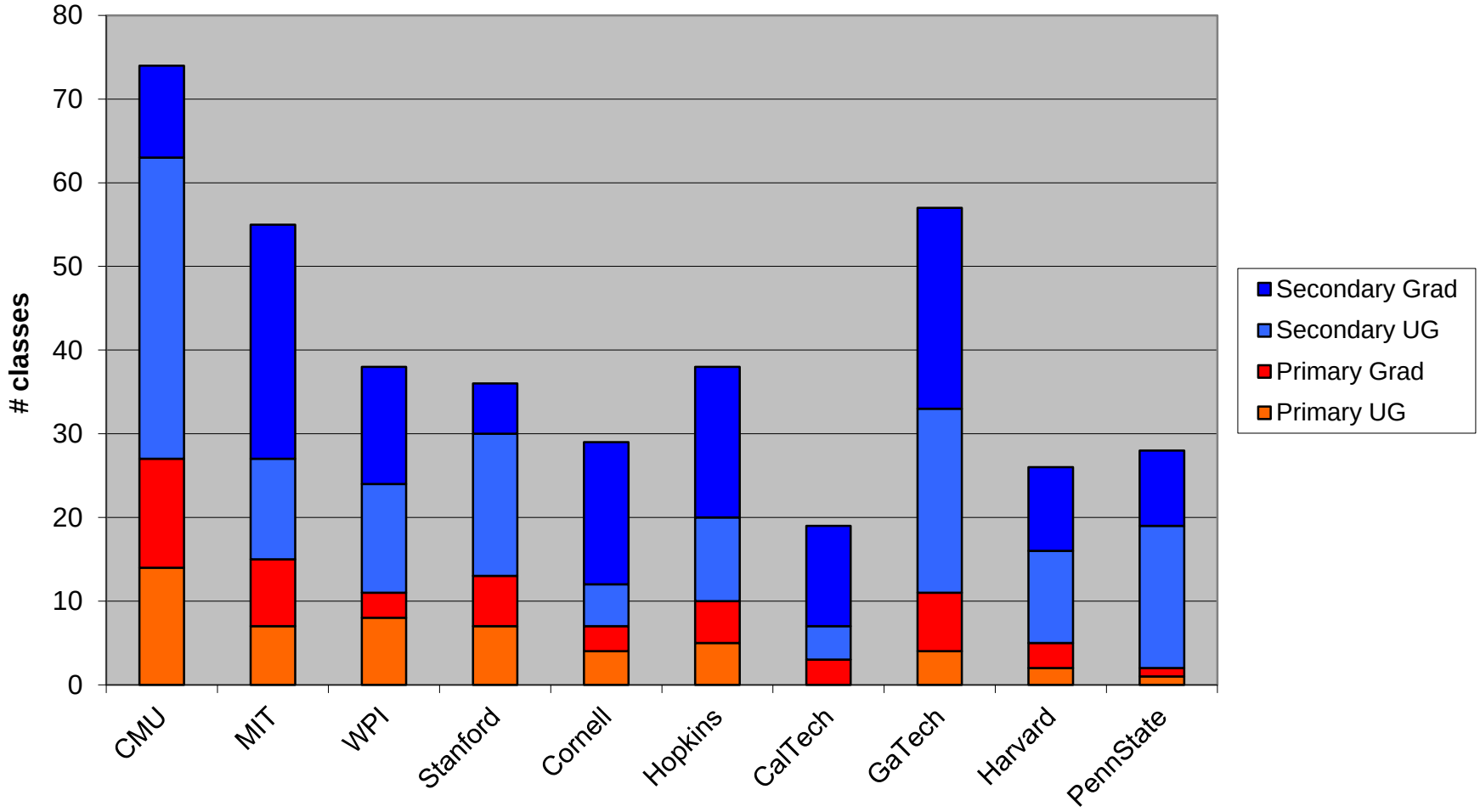
# Robotics Institute Undergraduate Activities

- Courses
- Robotics Major
- Robotics Minor
- Fifth Year MS Program
- Robotics Club
- On-campus competitions: Mobot!

# Fill out File Card

- Name
- Email
- Major
- Acting Major (Green – CS/ Yellow ECE/ Orange ME)
- Enrolled/Waitlist
- Favorite robot movie
- Why are you taking this class
- Draw a robot (on back)

# Robotics and Related Courses



# Robotics Minor

| Requirements | Choose among |
|---|---|
| **Overview/Introductory Course** | 16-311 Introduction to Robotics |
| **Controls** | 18-370 Fundamentals of Control,<br>24-451 Feedback Control Systems<br>16-299 Introduction to Feedback Control Systems |
| **Manipulation** | 15-384 Manipulation<br>24-355 Kinematics and Dynamics of Mechanisms (not offered regularly) |
| **Two electives** | Long list, see a subset below<br>An upper-level RI course<br>Up to one independent study |

We have a very liberal view toward electives. Web site has descriptions. List is constantly changing because classes are offered and cancelled.

- 10-601: Machine Learning
- 11-344: Machine Learning in Practice
- 15-491: CMRoboBits:
- 15-494: Cognitive Robotics
- 15-385: Computer Vision
- 15-462: Computer Graphics
- 15-862: Computational Photography
- 16-362 / 16-862: Introduction to Mobile Robot Programming
- 16-421: Vision Sensors
- 16-861: Mobile Robot Design
- 16-865: Advanced Mobile Robot Development
- 18-342: Fundamentals of Embedded Systems *
- 18-348: Embedded System Engineering *
- 18-349: Embedded Real-Time Systems *
- 18-578: Mechatronic Design
- 24-491 / 24-492: Departmental Research Honors
- 24-673: Special Topics in Soft Robots - Mechanics,

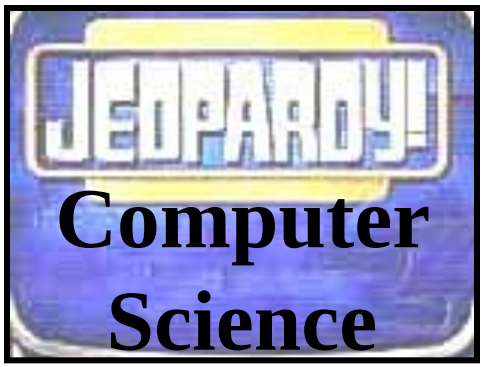
24-675: Micro/Nano Robotics

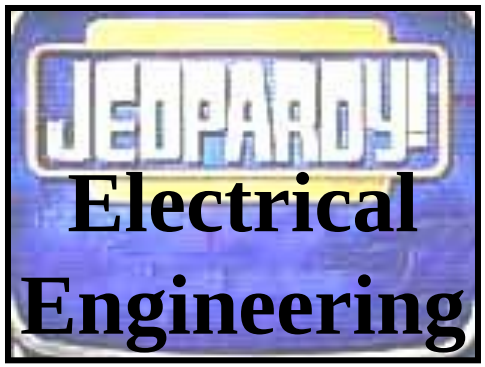
- 48-787: Architectural Robotics
- 85-370: Perception
- 85-382: Consciousness and Cognition
- 85-395: Applications of Cognitive Scienc
- 85-412: Cognitive Modeling
- 85-419: Introduction to Parallel Distributed Processing
- 85-420: Perception and Perceptual Development

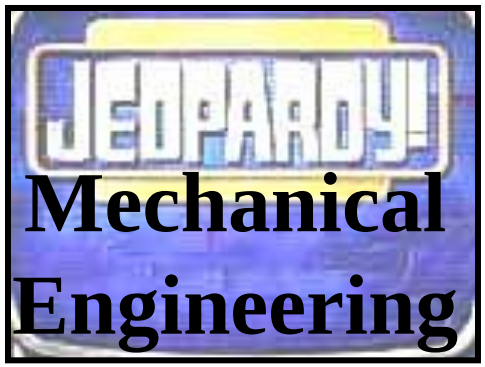
| Requirements (10 classes) | Choose among |
|---|---|
| Overview/Introductory Course | 16-311 Introduction to Robotics |
| Controls | 18-370 Fundamentals of Control,<br>24-451 Feedback Control Systems<br>16-299 Introduction to Feedback Control Systems |
| Kinematics | 15-384 Manipulation (possibly rename to Kinematics and Dynamics of Motion and give it a 16 number)<br>24-355 Kinematics and Dynamics of Mechanisms (not offered regularly) |
| Machine Perception | 15-385: Computer Vision<br>16-421: Vision Sensors<br>85-370: Perception |
| Cognition and Reasoning | 10-601: Undergraduate Machine Learning<br>15-381: Artificial Intelligence<br>15-494: Cognitive Robotics<br>Upper-level RI planning course with instructor permission |
| “Hands-on Course” | 15-491: CMRobotBits: Creating Intelligent Robots<br>16-362: Mobile Robot Programming Lab<br>18-578: Mechatronics<br>Upper-level RI project course like 16-861 or 16-865<br>Independent study with instructor permission |
| Two Electives | See list with minor or any upper level RI course. Any of these can be independent study but only one independent study is allowed. A student can also take additional courses from the core; e.g., a student who takes 15-385 as a core can take 16-421 as an elective |
| Systems Engineering | To be developed |
| Capstone Course | To be developed |

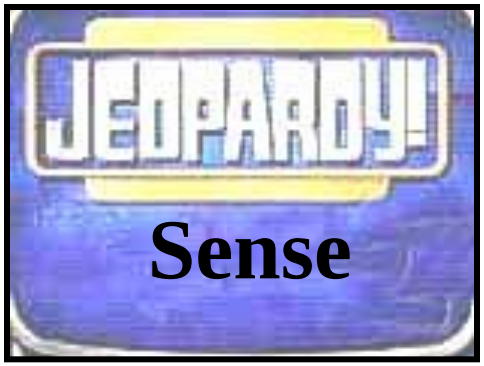
# Introduction to Robotics

# The Categories Are…..








This semester we will study many aspects of robotics.

**Vision**

**Controls**

**Motion Planning**

**Sensors and Sensor Planning**

**Mobile Robot Platforms**

**Forward Kinematics**

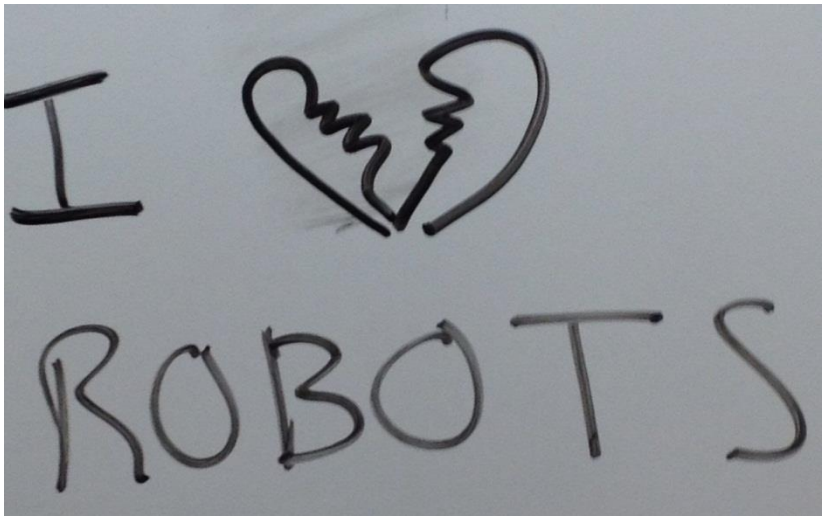
**Inverse Kinematics**

**Non-Holonomic constraints**

**http://generalrobotics.org**

# High Workload

- Lots of homework
- First HW assignment handed out today
- Second HW assignment handed out Wed
- Work responsibly
- Time consuming design experience
- If you cannot make a demo, must demo before due date
- Lots of work assigned around Carnival times
- Another design experience
- No superbowl/Stanley Cup/etc excuses
- Programming
- Exams



# HW 1

- See web site
- **Due at beginning of class Tuesday, January 21rd ← fix date on web site**
- Create a webpage containing your text answers (and any pictures) in HTML format.
- Find a picture of a robot, not from Carnegie Mellon, on the web and display it. Comment on its application in terms of sense, plan, and act. As a student of Carnegie Mellon you get free webspace, click here to find out how to use it.
- **Program:** *Matrix-Vector Evaluator*
  Write a program that runs under unix to perform 3x1 vector and 3x3 matrix arithmetic.

- The program should take from *standard input* one line at a time a sequence of expressions, described below.

- A line with nothing on it should do nothing. The command END should terminate the program.

- The following are the commands to be defined:
  - Vector and Matrix instantiation.
- For vectors, a lower case letter followed by an ``=" sign, and then followed by three numbers sets the value for the vector. For matrices, an upper case letter, followed by an ``=" sign, and then followed by nine numbers sets the value for a matrix. To make things easier, assume there could only be 26 vectors and 26 matrices. Hint: there is a nice relationship between chars and ints in C.
  - Printing.
- A vector or matrix on a line by itself followed by return should print the vector or matrix in their appropriate forms.
  - Addition.
- c = a + b ------ store the sum of a and b into c.

- C = A + B ------ store the sum of A and B into C.

  - Multiplication
- c = a.b ----- should compute the dot product of a and b and store in it in the first component of c. (Set the other components of c to zero)

- c = a*b ----- store the cross product of a and b in c

- C = A*B ----- perform matrix multiplication of A and B

- v = M*x ----- perform the matrix-vector multiplication.

# Some strict rules

- Attendance not mandatory, punctuality is, texting is forbidden
- No late HW assignments accepted, your printer or dog eating your HW is not an excuse…
- Demos start on-time (early), your responsibility to make it work (memory stick, etc)
- Absence from a demo receives a zero
- Lowest HW grade dropped, if you get all the HW's in at the end of semester, except HW 1 and 2
- Exams: 8.5 x 11 sheet of paper, both sides, in your hand
- Cannot take this class if it overlaps with another
- Miscommunications must be cleared up before demo day
- Three strikes on mess
  - Strike 1: you lose your ability to drop the lowest HW score
  - Strike 2: your team gets 0's
  - Strike 3: you are out of the class

# Tuesdays/Thursdays

- Tuesdays are a must
- Thursdays “backup” day?

# Meet the TA's

# Waitlist people

- Motivated students usually get in

# What to Expect