The New Robotics Ecosystem for Defense & Security

Prof. Michael A. Gennert
Robotics Engineering Program Director

May 2014

Talk Roadmap

Technology Context

Current State of Robotics

Robots as Co-X

Future Robotic Ecosystem

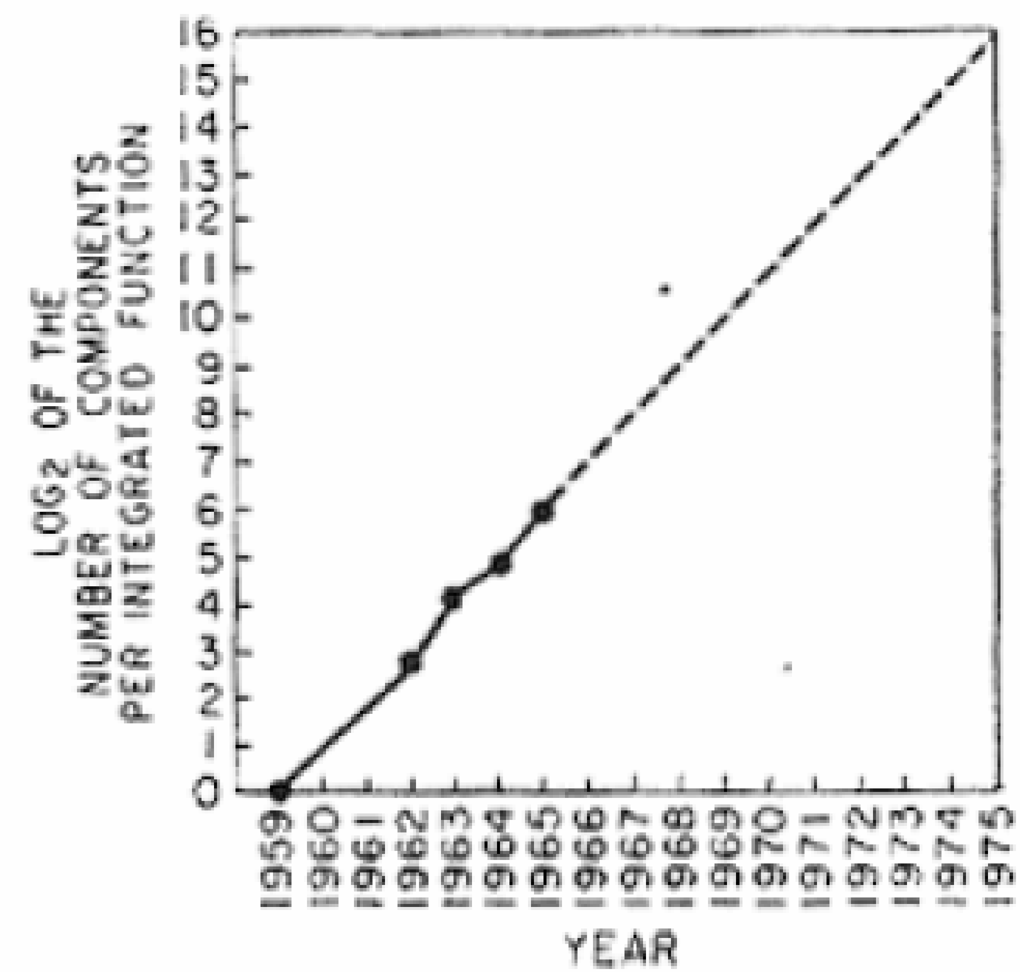
Popular Electronics, Dec 1958

Driving Factors

Exponentials – x2 at regular intervals

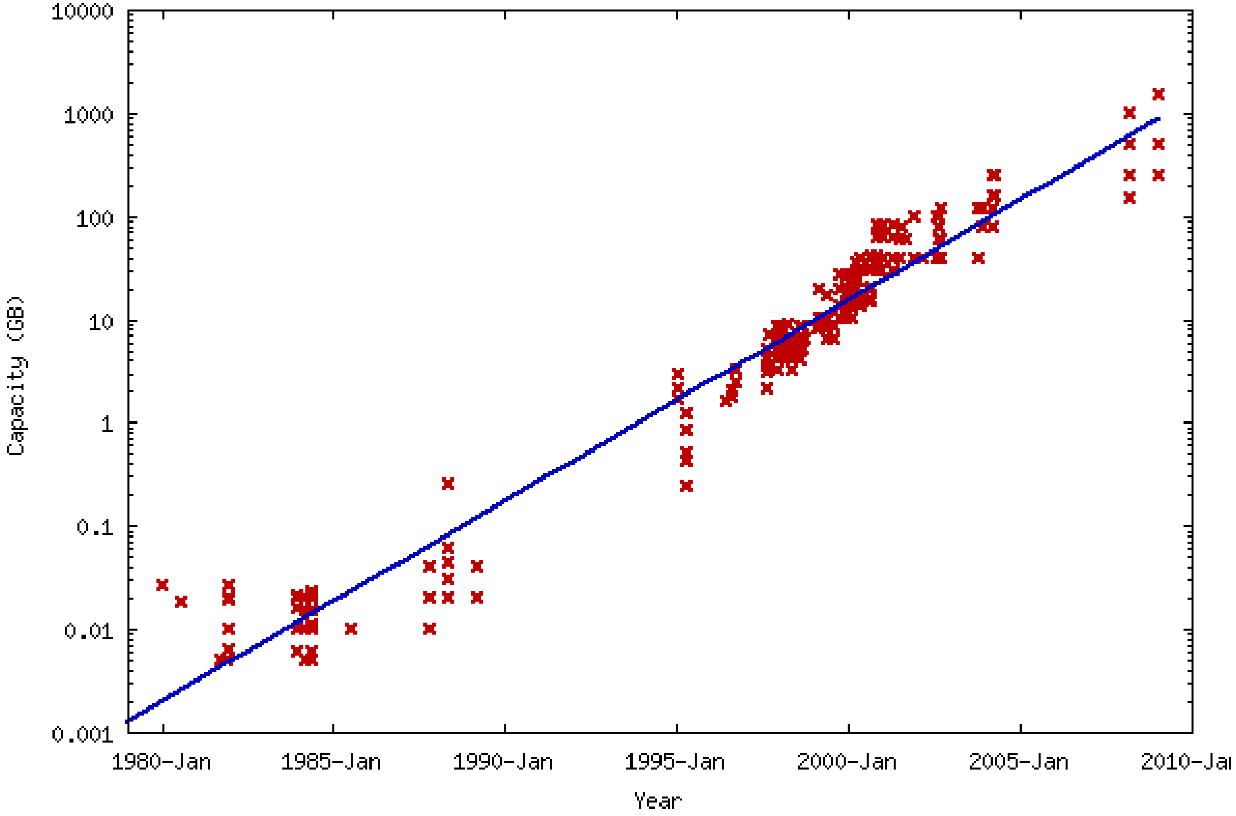
- Moore’s Law – Processors – 1.5 years
- Kryder’s Law – Storage – 1.5 years
- Butter’s Law – Network – 9 months

Moore's Law



- x2 every 1.5-2 years
- 54 years later…
  - 27-36 doubles
  - 2^{27} = 128 M, 2^{36} = 64 B
- ~7 B transistors on largest chips now

Kryder's Law



US Library of Congress = 10 Tb

2 TB Hard Drive $89.99
newegg.com
2TB in punch cards = ?

= 60,000 tons = USS JFK

= 650 B-52s (out of 744)

Butter's Law

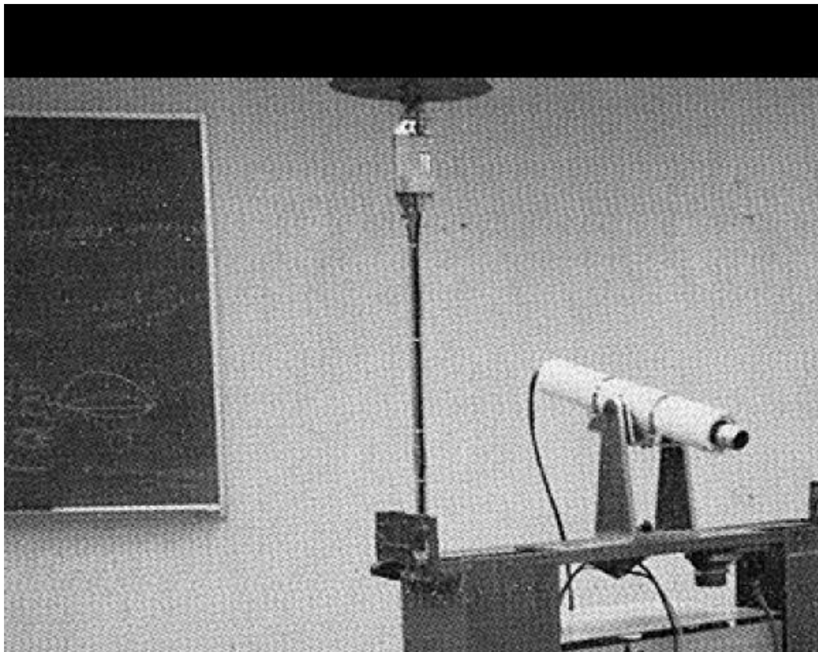
"NEC and Corning achieve petabit optical transmission"

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

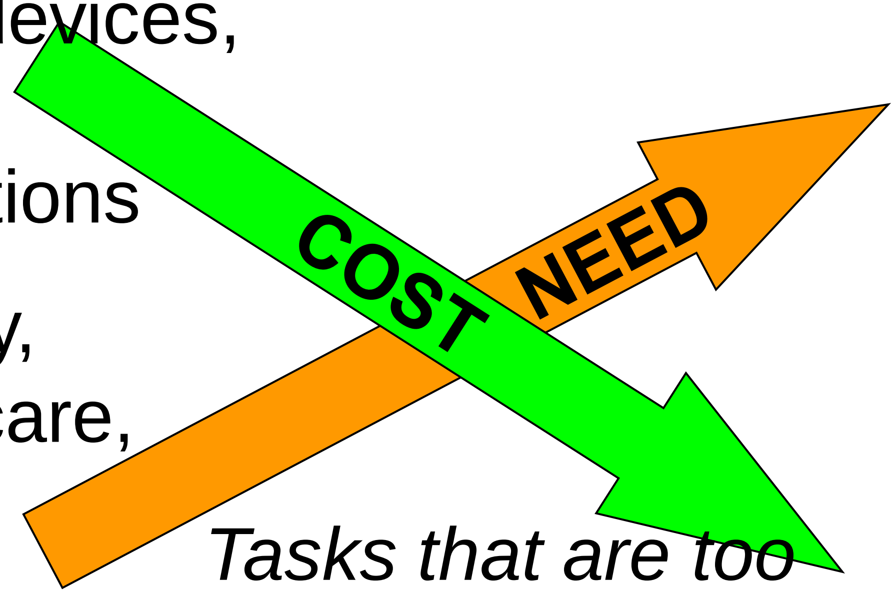


DARPA Grand Challenge 2005, 30Km/hr

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

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

Talk Roadmap

Technology Context

Current State of Robotics

Robots as Co-X

Future Robotic Ecosystem

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

Yesterday’s Robot

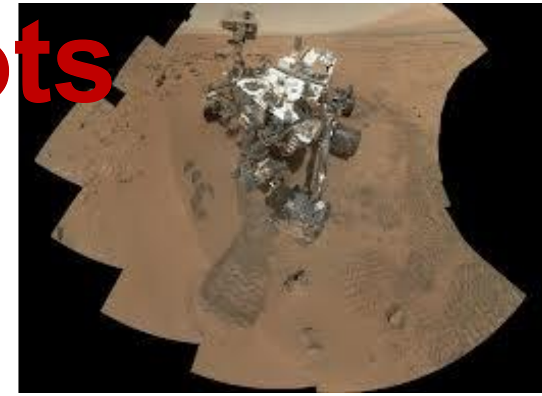


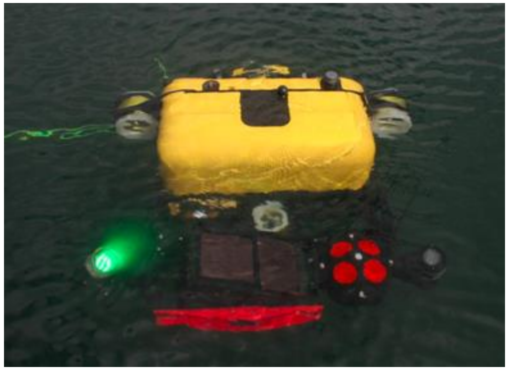






Today’s Robots





WPI

ROBOTICS ENGINEERING

IPASS

AN INTELLIGENT PORTABLE AERIAL SURVEILLANCE SYSTEM

PROJECT TEAM:

ADAM BLUMENAU – ALEC ISHAK – BRETT LIMONE

ZACHARY MINTZ – COREY RUSSELL – ADRIAN SUDOL

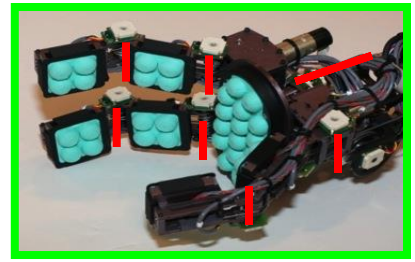
ADVISORS:

TASKIN PADIR – LIFENG LAI

Robotics Research

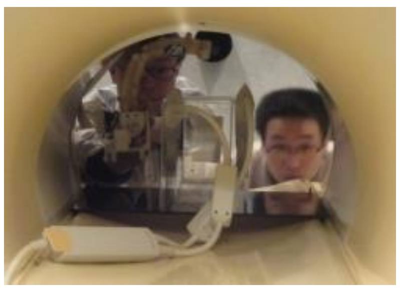
Human-Robot Interaction

Sensing & Manipulation



Autonomy & Navigation

Biomedical Robotics



Assistive Robotics

Manufacturing

Odometry & Mapping

Soft Robotics

Tree-Climbing Robot

Invasive insect detection

C^4I?

Drones over desert ✔

Drones over jungle ✖

Talk Roadmap

Technology Context

Current State of Robotics

Robots as Co-X

- **DARPA Robotics Challenge**

Future Robotic Ecosystem

DARPA Robotics Challenge

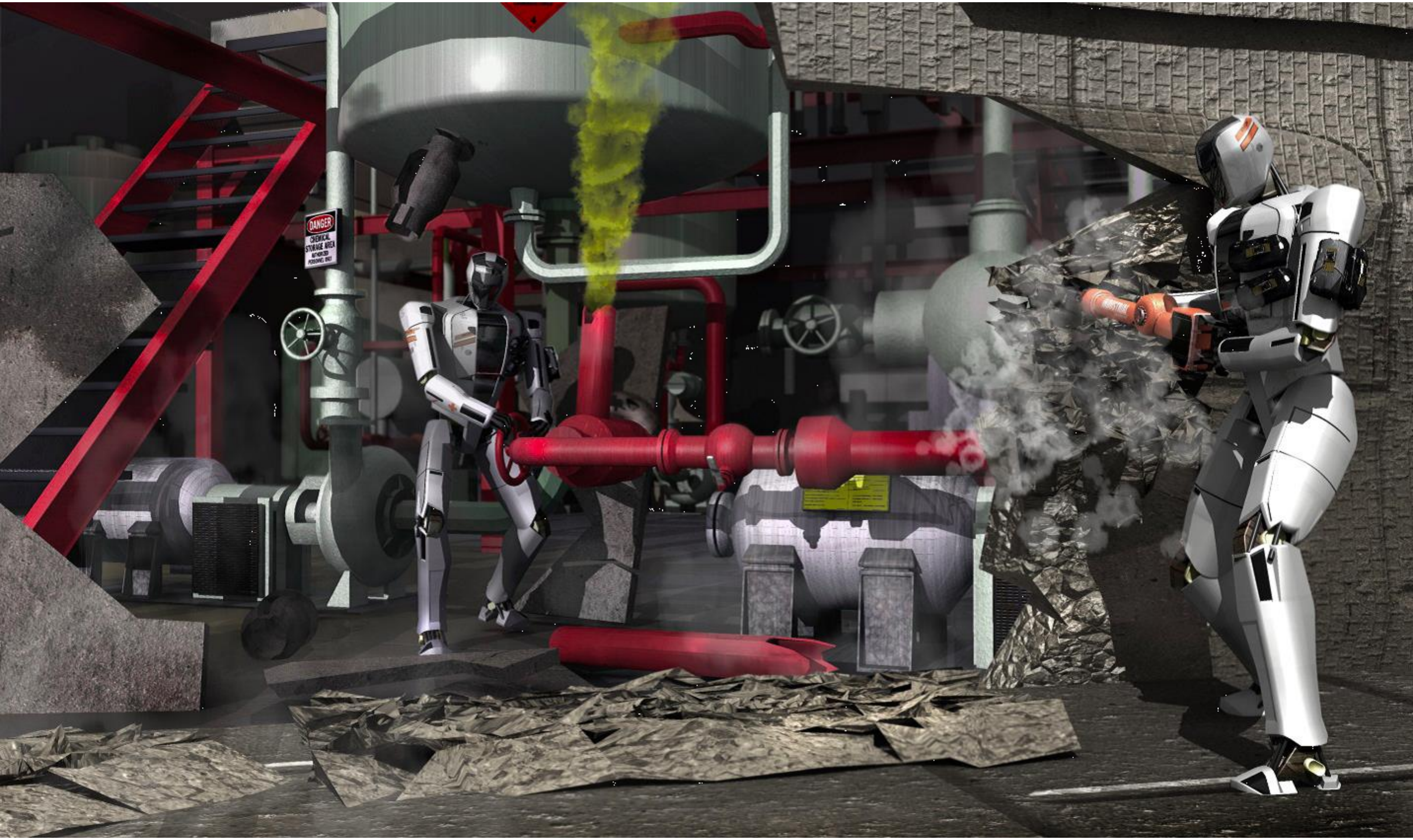
Fukushima Disaster

Too dangerous for humans …

… send a robot

Too bad robots can't …

- Traverse rubble
- Attach hose
- Close valves
- Open doors
- Climb ladders
- Use tools
- Remove debris
- Drive vehicle …*YET!*


DANGER
CHEMICAL STORAGE AREA

Other Disasters

Hurricane Katrina

Deepwater Horizon

Oso Mudslide

Soma Mine

Capabilities Gap

- Supervised Autonomy
  - Not tele-op
- Mobility
  - Go where needed
- Manipulation
  - Operate in human environment
- Perception

All hard – integrating harder still

DARPA Robotics Challenge

1. Virtual Robotics Challenge – Simulation SW

   Best teams have 5 months for SW → HW

   $2M Atlas Robot + $750K Funding

2. DRC Trials – Select winners

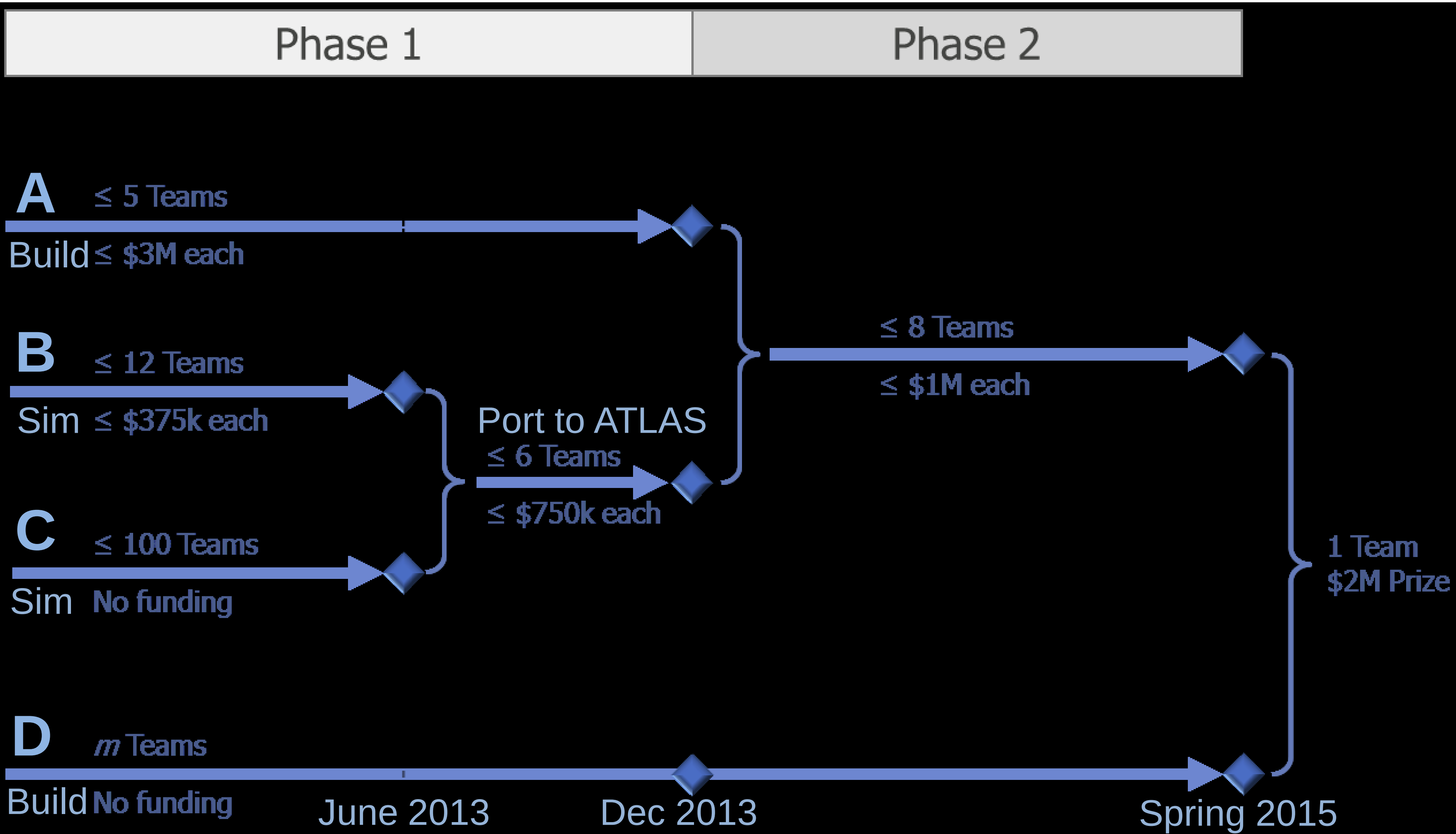
   Best teams have 12+ months

   $1M Funding

3. DRC Final – Select winner

   $2M Prize

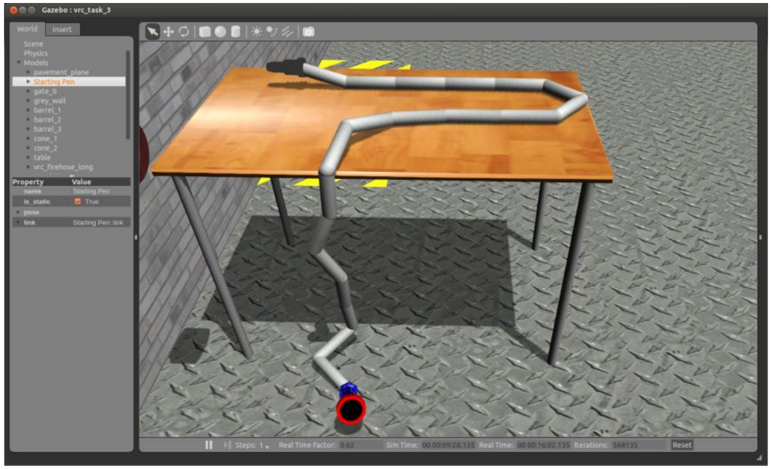
DARPA Robotics Challenge

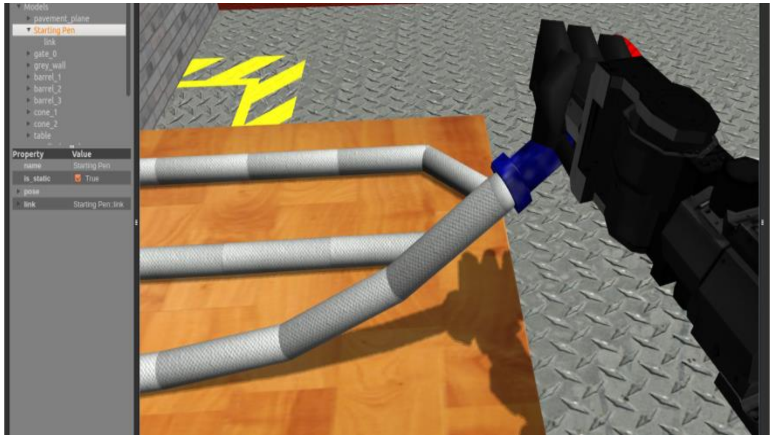


Virtual Robotics Challenge

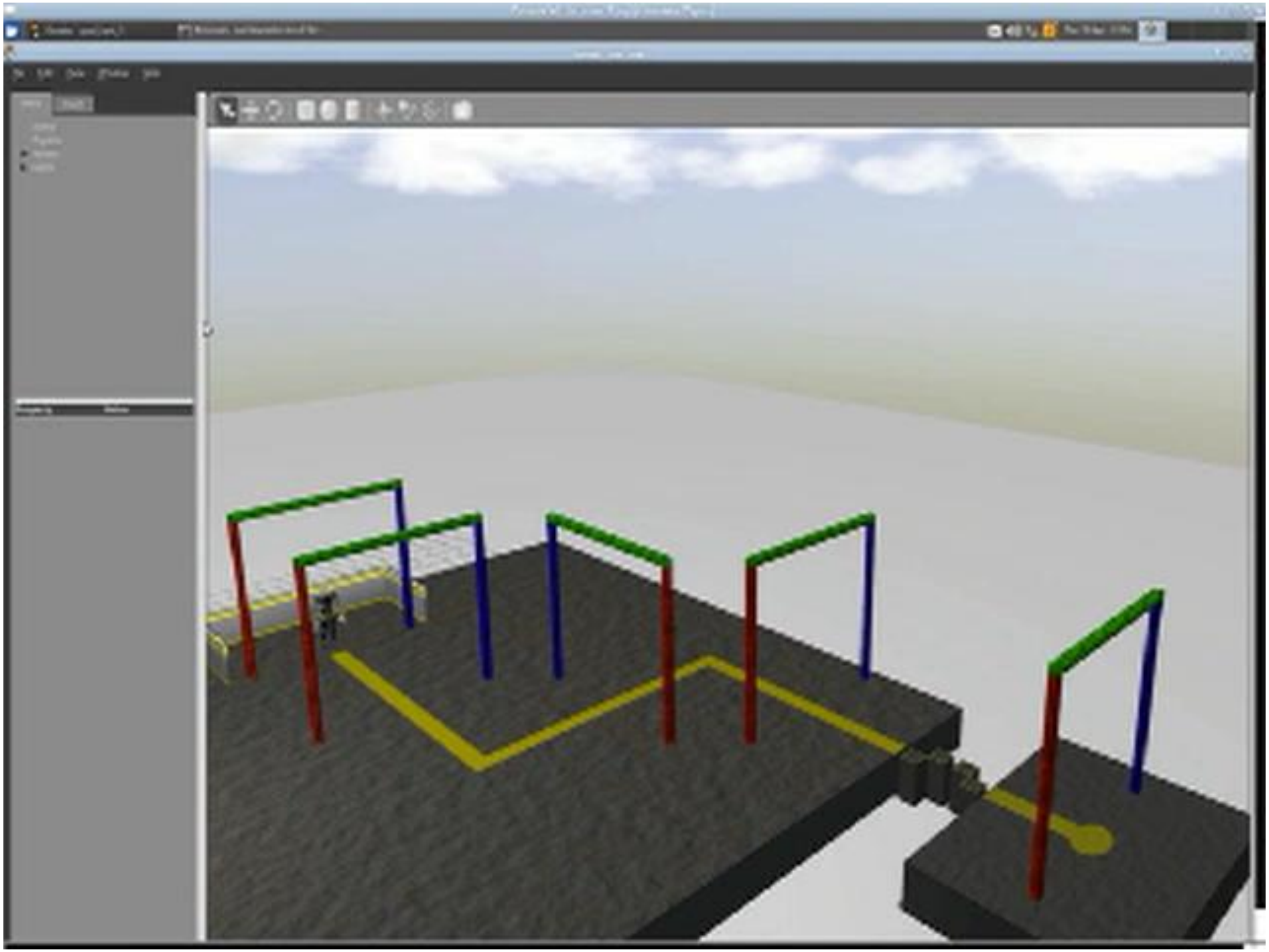
- Perform subset of tasks …
- … in simulation … *How hard can this be?*
- … port to robot later. *How hard can this be?*
- Using
  - ROS
  - Gazebo simulator
  - Rviz visualization
  - Some Boston Dynamics, Inc. software

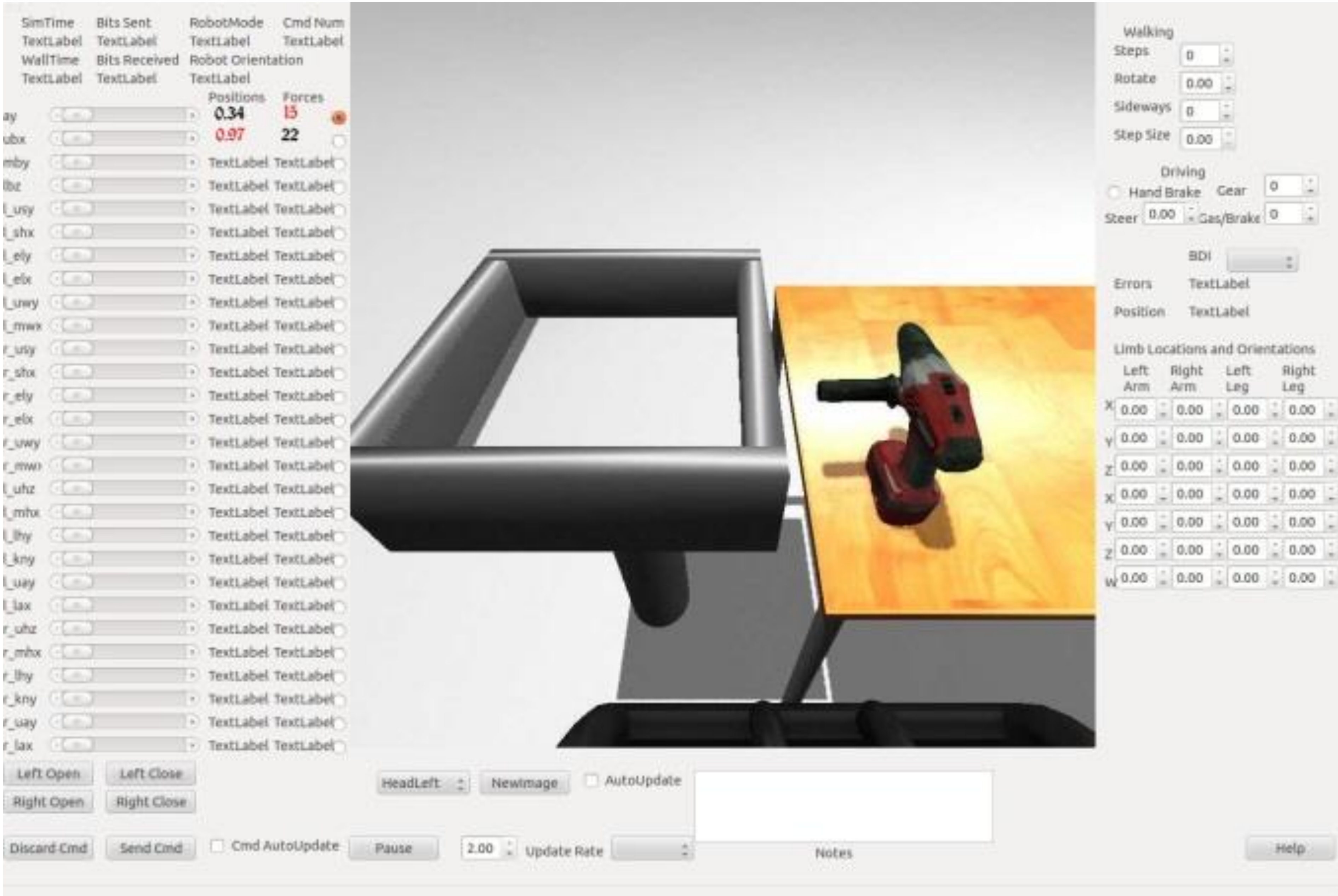
Manipulation



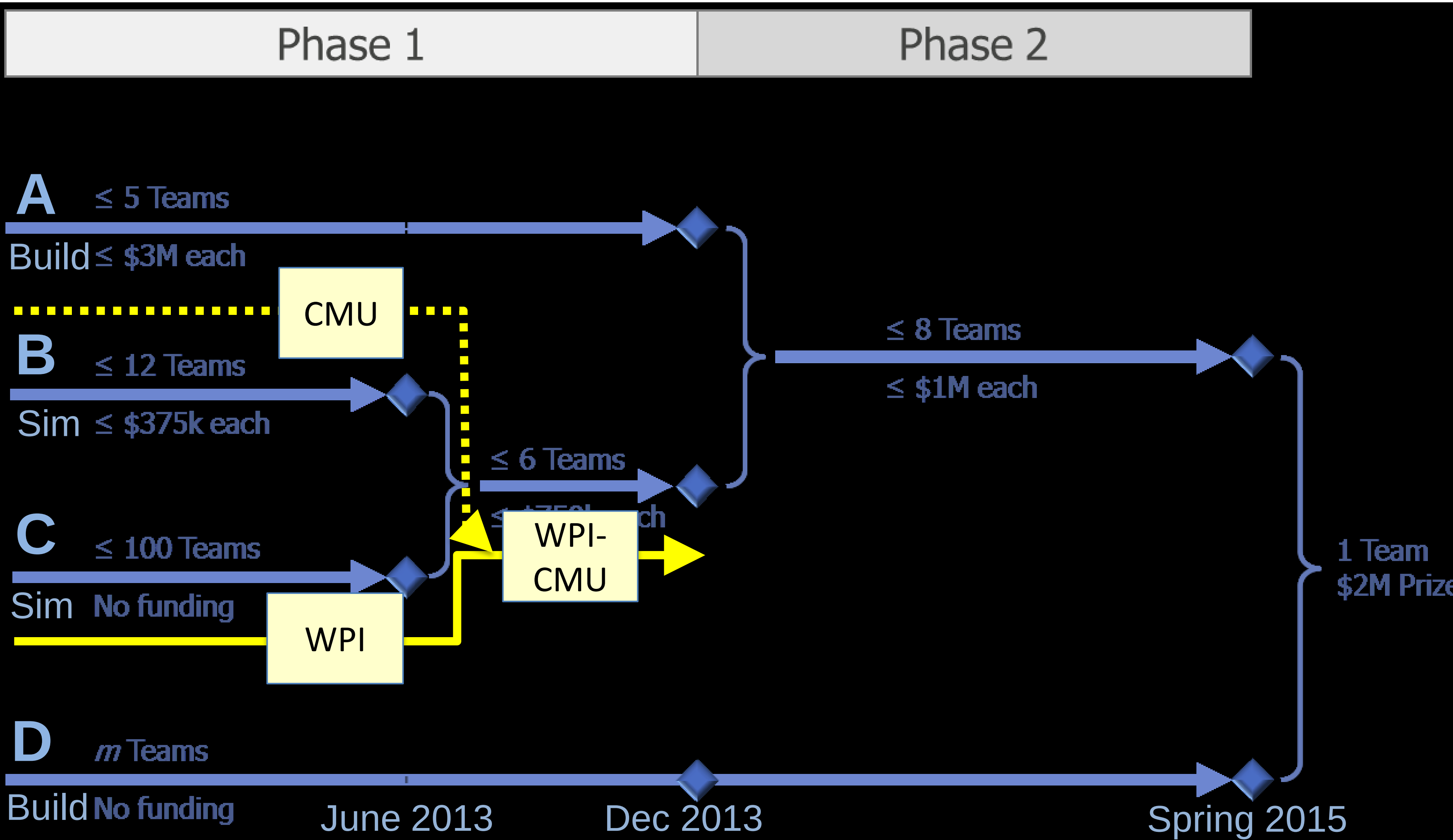


Walking




SimTime
Bits Sent
RobotMode
Cmd Num
WallTime
Bits Received
Robot Orientation
Positions
Forces
Walking
Steps
Rotate
Sideways
Step Size
Driving
Hand Brake
Gear
Steer
Gas/Brake
BDI
Errors
Position
Limb Locations and Orientations
Left Arm
Right Arm
Left Leg
Right Leg
Left Open
Left Close
Right Open
Right Close
HeadLeft
NewImage
AutoUpdate
Discard Cmd
Send Cmd
Cmd AutoUpdate
Pause
Update Rate
Notes
Help

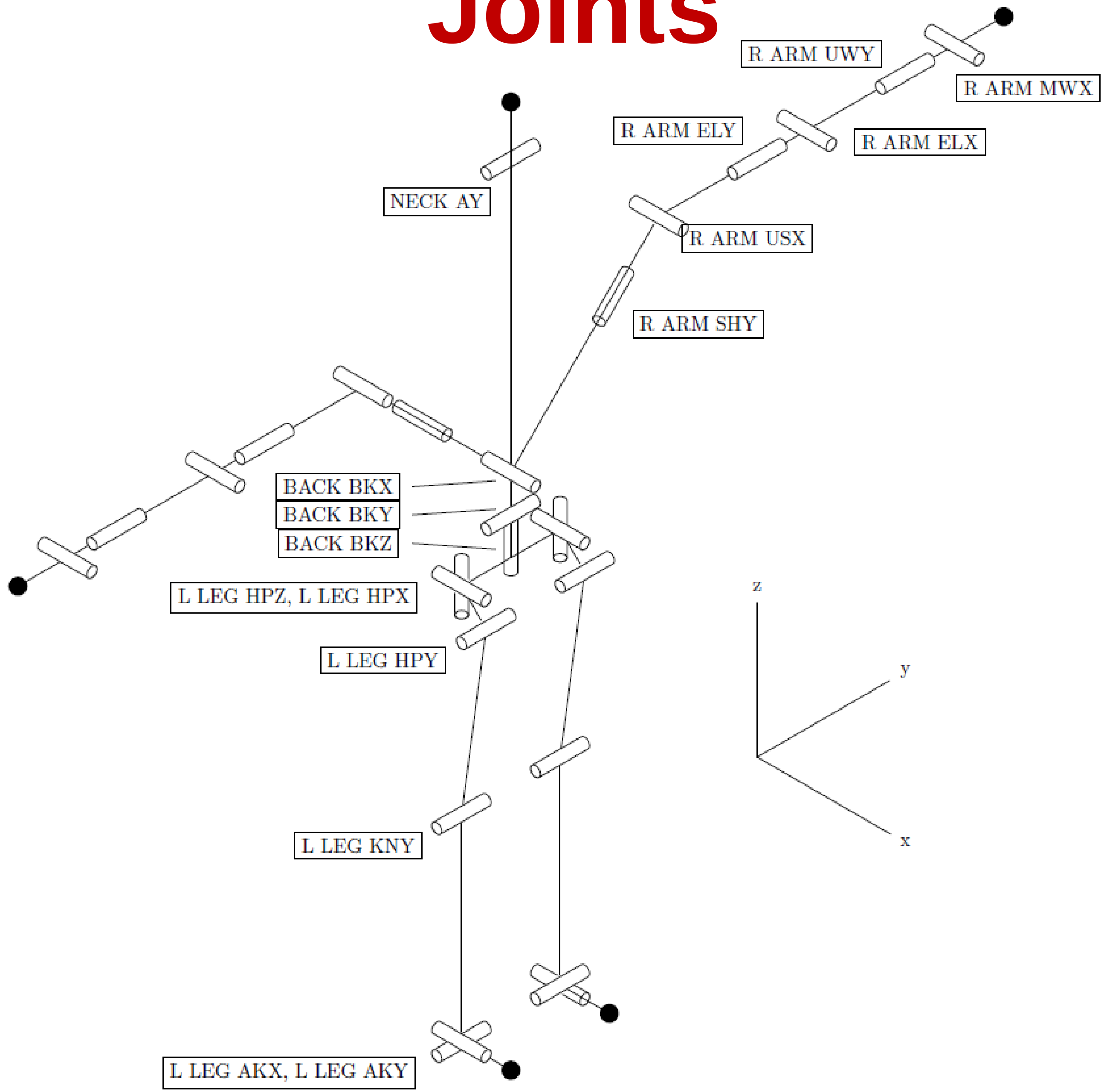
DARPA Robotics Challenge



Boston Dynamics Inc. ATLAS

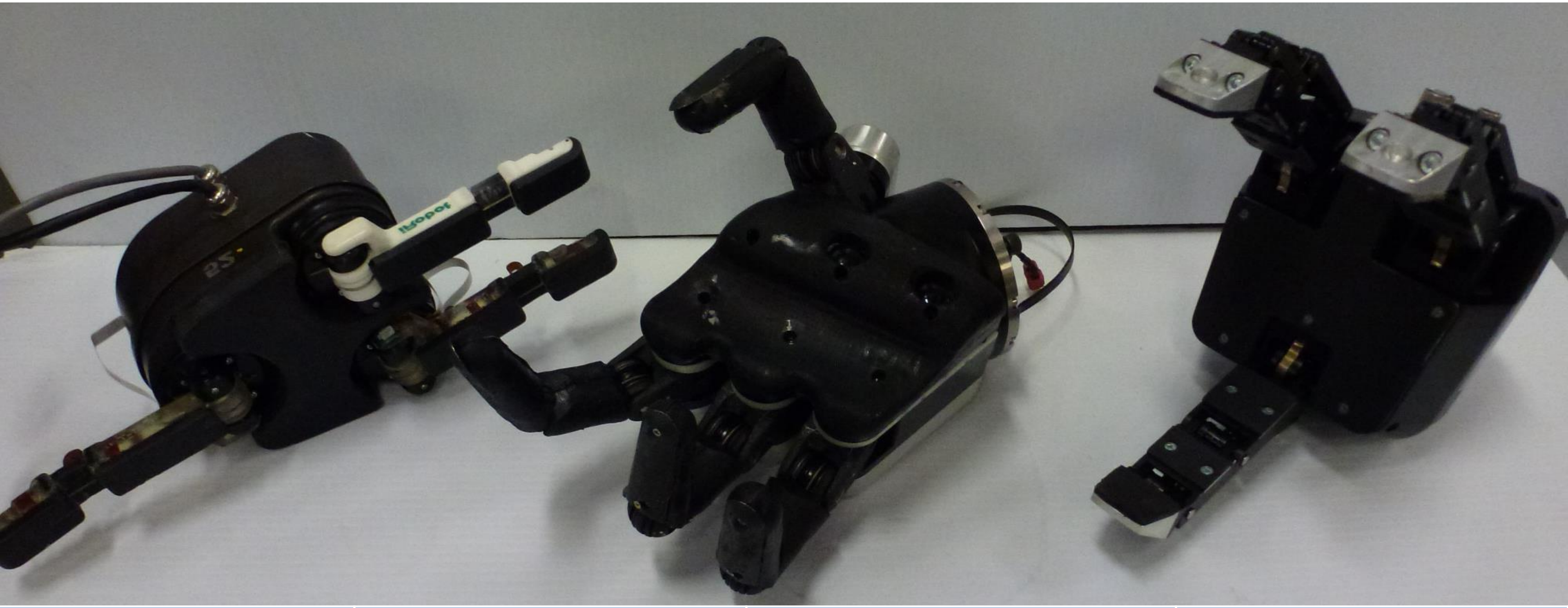
- 28 DOF
  - 6 per limb
  - 3 back
  - 1 neck (pitch)
- Interchangeable hands
  - Sandia / iRobot / Robotiq
  - Custom-made pipes
- Sensors
  - MultiSense Head
  - KVH IMU
  - Foot pressure sensors
- Power
  - Hydraulic with on-board pump
  - Tether for 480V / Cooling / Comms

Joints



R ARM UWY
R ARM MWX
R ARM ELY
R ARM ELX
NECK AY
R ARM USX
R ARM SHY
BACK BKX
BACK BKY
BACK BKZ
L LEG HPZ, L LEG HPX
L LEG HPY
L LEG KNY
L LEG AKX, L LEG AKY
z
y
x

Hands



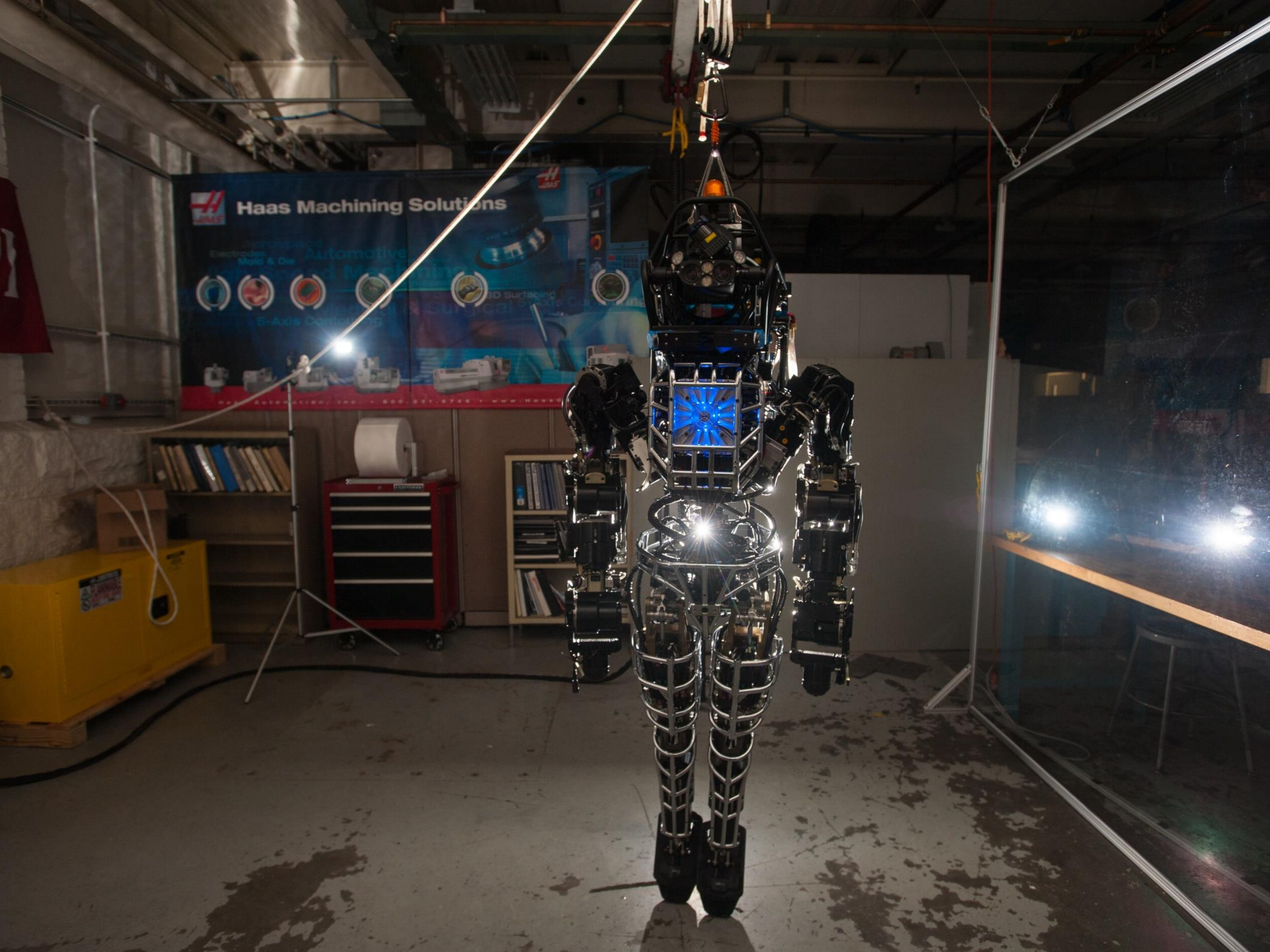
	iRobot	Sandia	Robotiq
Fingers	3	4	3
DoF	5	12	4
Wt (kg)	1.5	3.0	2.3
Drive	Worm gear	Gears	Worm gear
Max tensile stress (lbs)	3 / 11 / 5	17 / 24 / 1	Palm: 50+ / 50+ / 20 Tip: 50+ / 20 / 20
Max shear stress (lbs)	32 / 14	11 / 9	Palm: 25 / 45 Tip: 17 / 25

Head

Carnegie Robotics

MultiSense SL

- Stereo
- LIDAR
- Video


Haas Machining Solutions
Automotive
3D Surfacing
5-Axis Contouring

Situational Awareness Cameras

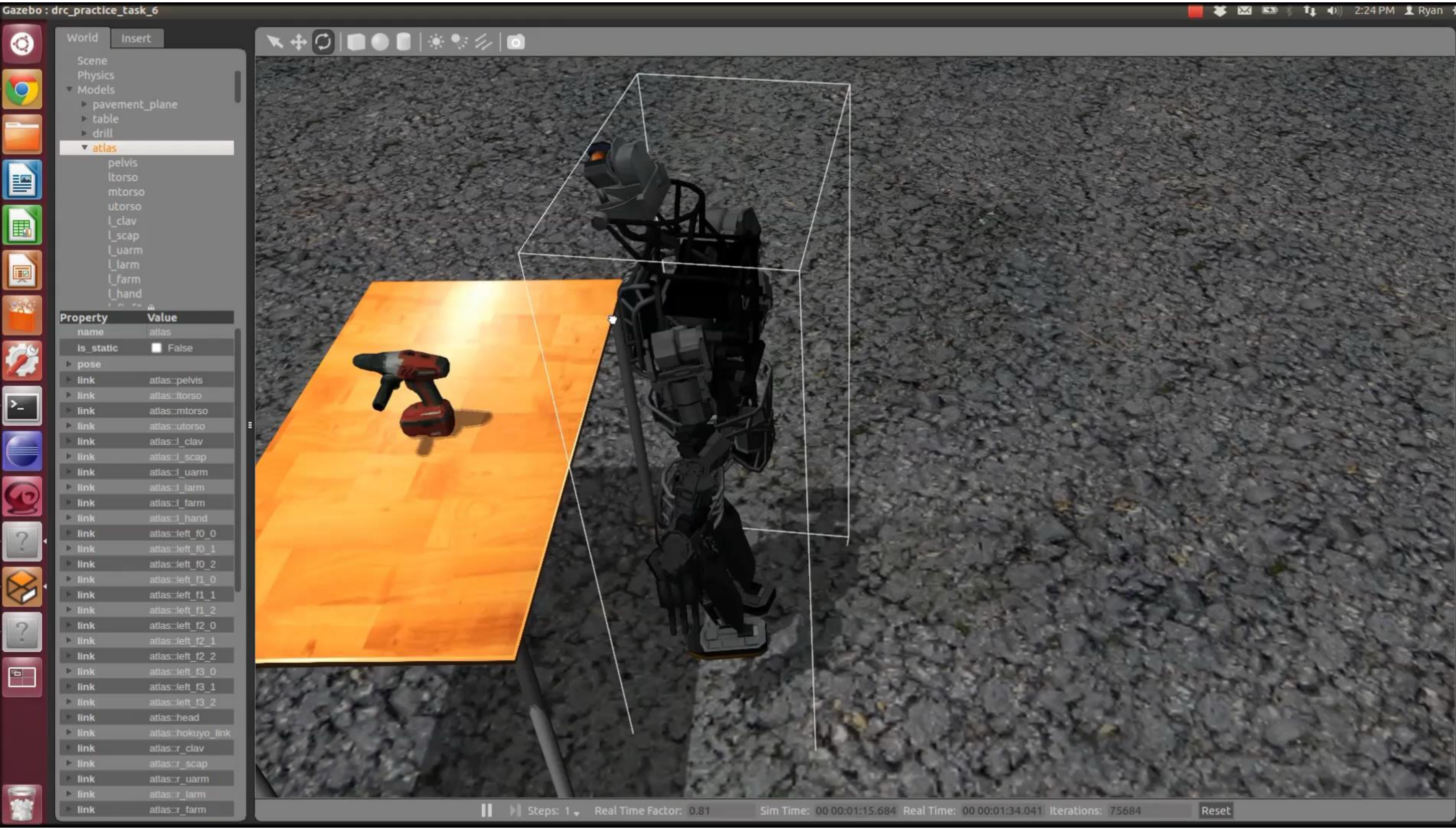
WPI-CMU DARPA Robotics Challenge Team

WPI

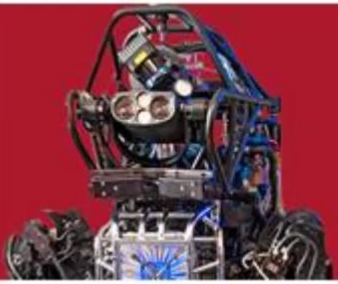
Carnegie Mellon University

Software Packages

- Robot Operating System (ROS)
- Gazebo – Simulation
- MoveIt! – Manipulation
- RVIZ – Visualization
- OpenCV – Open source Computer Vision Lib
- Point Cloud Library


Gazebo : drc_practice_task_6
2:24 PM
Ryan
World
Insert
Scene
Physics
Models
pavement_plane
table
drill
atlas
pelvis
ltorso
mtorso
utorso
l_clav
l_scap
l_uarm
l_larm
l_farm
l_hand
Property
Value
name
atlas
is_static
False
pose
link
atlas::pelvis
atlas::ltorso
atlas::mtorso
atlas::utorso
atlas::l_clav
atlas::l_scap
atlas::l_uarm
atlas::l_larm
atlas::l_farm
atlas::l_hand
atlas::left_f0_0
atlas::left_f0_1
atlas::left_f0_2
atlas::left_f1_0
atlas::left_f1_1
atlas::left_f1_2
atlas::left_f2_0
atlas::left_f2_1
atlas::left_f2_2
atlas::left_f3_0
atlas::left_f3_1
atlas::left_f3_2
atlas::head
atlas::hokuyo_link
atlas::r_clav
atlas::r_scap
atlas::r_uarm
atlas::r_larm
atlas::r_farm
Steps: 1
Real Time Factor: 0.81
Sim Time: 00 00:01:15.684
Real Time: 00 00:01:34.041
Iterations: 75684
Reset

Door Handle Move It



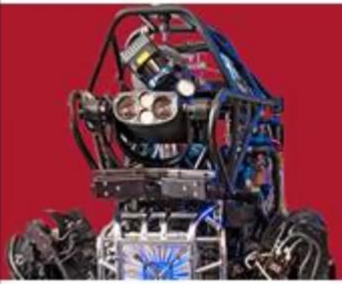
WPI-CMU DARPA Robotics Challenge Team

WPI

Carnegie Mellon University

Door Reality

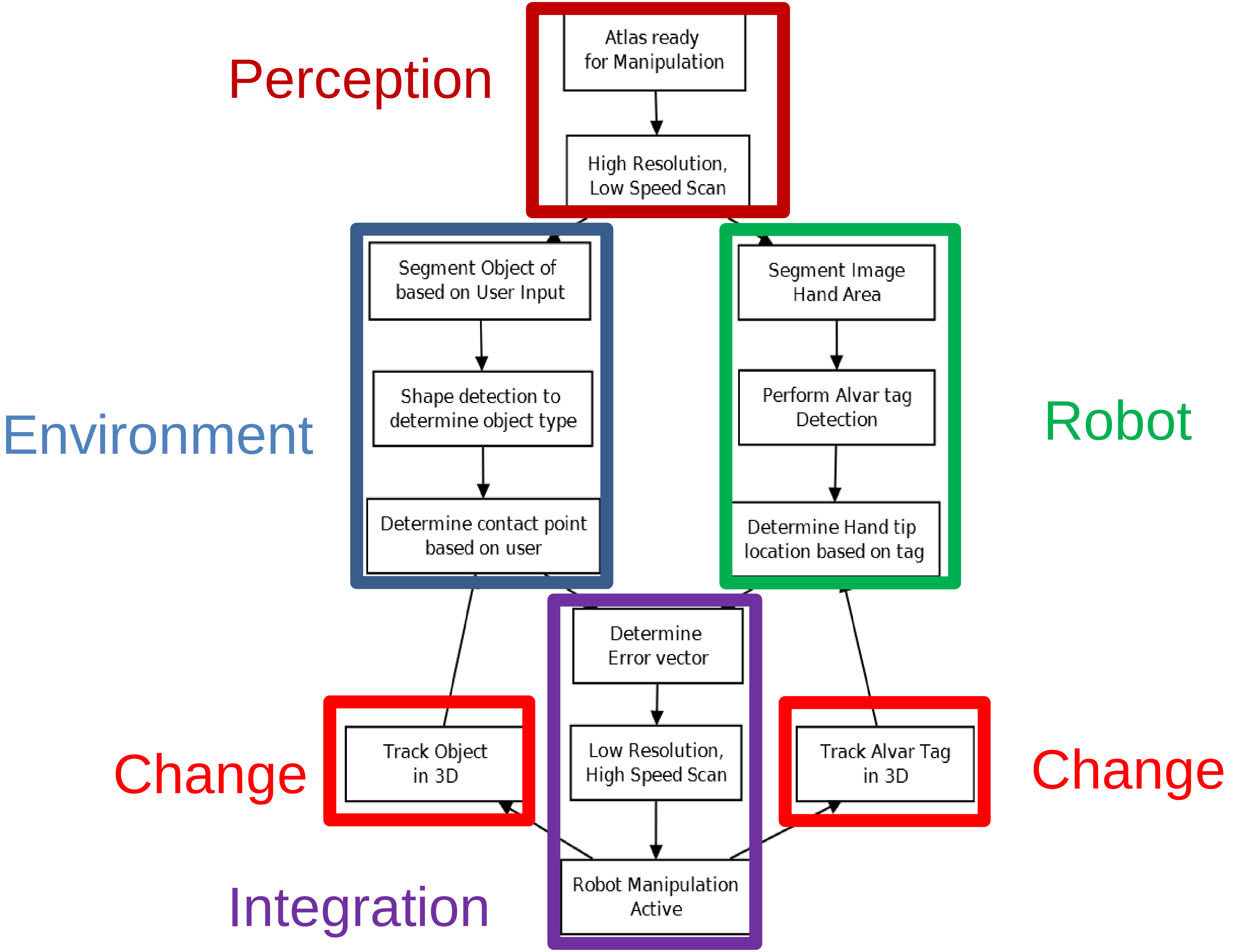
MoveIt Valve Turn



WPI-CMU DARPA Robotics Challenge Team

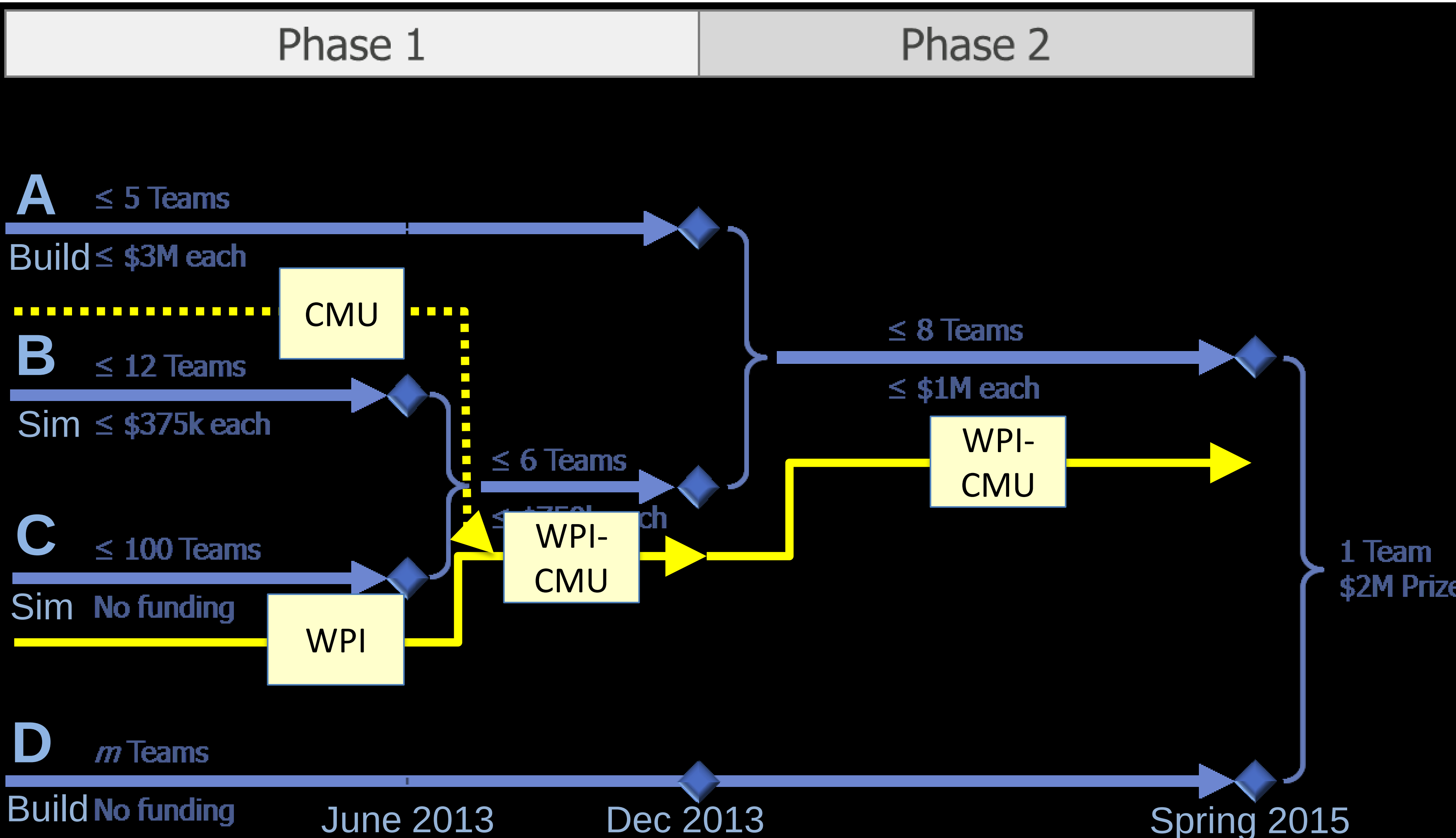
WPI

Carnegie Mellon University



Perception
Atlas ready for Manipulation
High Resolution, Low Speed Scan
Environment
Segment Object of based on User Input
Shape detection to determine object type
Determine contact point based on user
Robot
Segment Image Hand Area
Perform Alvar tag Detection
Determine Hand tip location based on tag
Determine Error vector
Low Resolution, High Speed Scan
Robot Manipulation Active
Integration
Change
Track Object in 3D
Change
Track Alvar Tag in 3D

DARPA Robotics Challenge



How We Did It

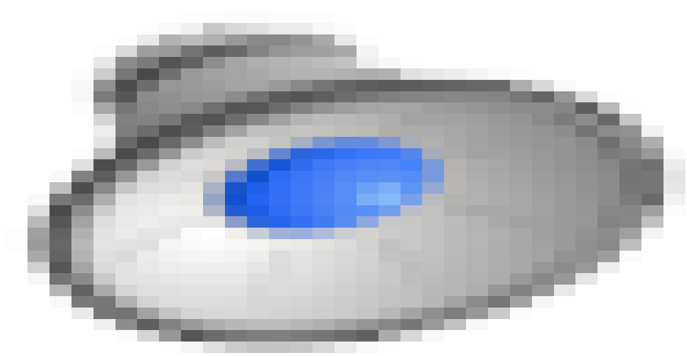
- Kept eye on the prize
- Understood our strengths & weaknesses
- Compensate for shortcomings by
  - Partnering with engineers & CMU
  - Get ready for ATLAS before anyone else
  - Use ATLAS the most (312 hrs vs. 260 hrs)
- Maintain *esprit de corps*

Wrap Video

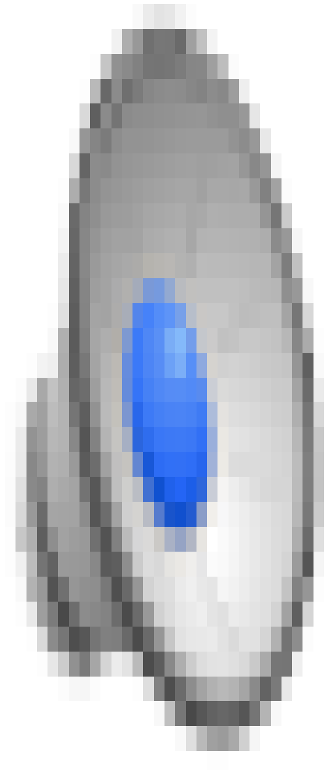
In Progress

- Full body control
- Razor controller
- Better collision detection
- Fall & recovery behavior

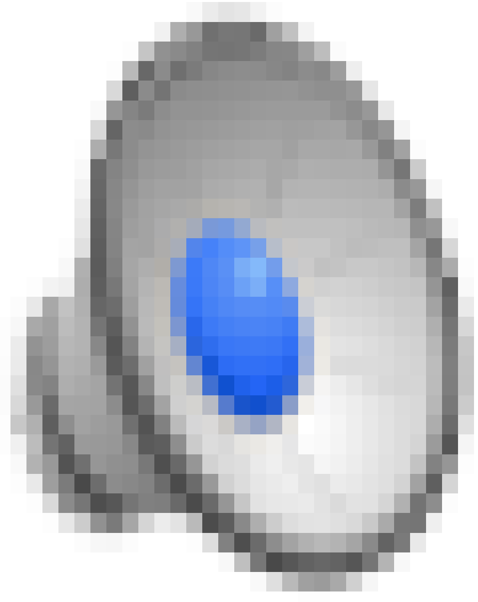
Full Body Controller



Full Body Controller



Self-Collision Detection



What’s Happening Now

http://drcvideo.wpi.edu/zm/index.php

Talk Roadmap

Technology Context

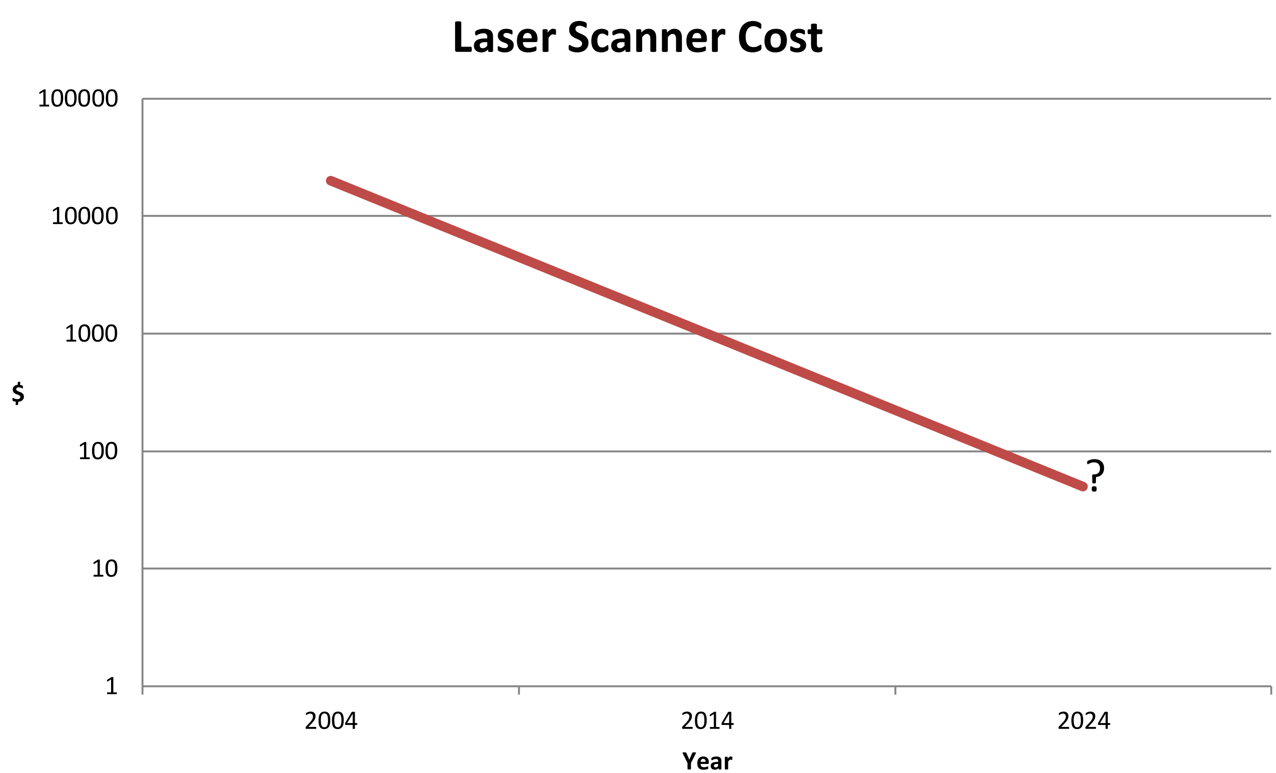
Current State of Robotics

Robots as Co-X

Future Robotic Ecosystem

Tech Drivers

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

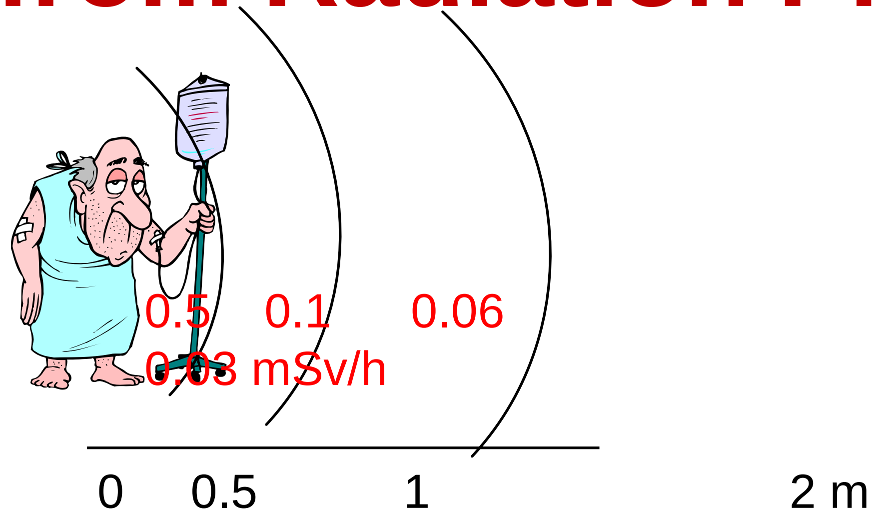


Robotics Ecosystem

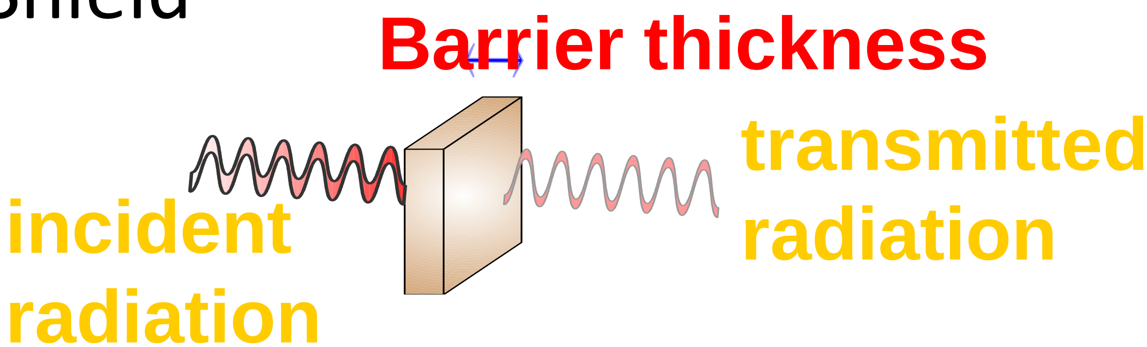
- Systems Engineering
  - Life cycle analyses
  - DOTMLPF
- Software
  - How to engineer & compose behavior
- Simulation
  - For developing future systems
  - In future systems
  - Need better physics-based simulation
- Human-in-the-loop
  - Cyber-Physical Systems (CPS)

Lessons from Radiation Protection

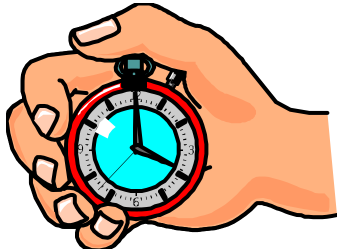
- Distance



- Shield



- Time



Robotic Warfighter Protection

- Distance

  Packbot

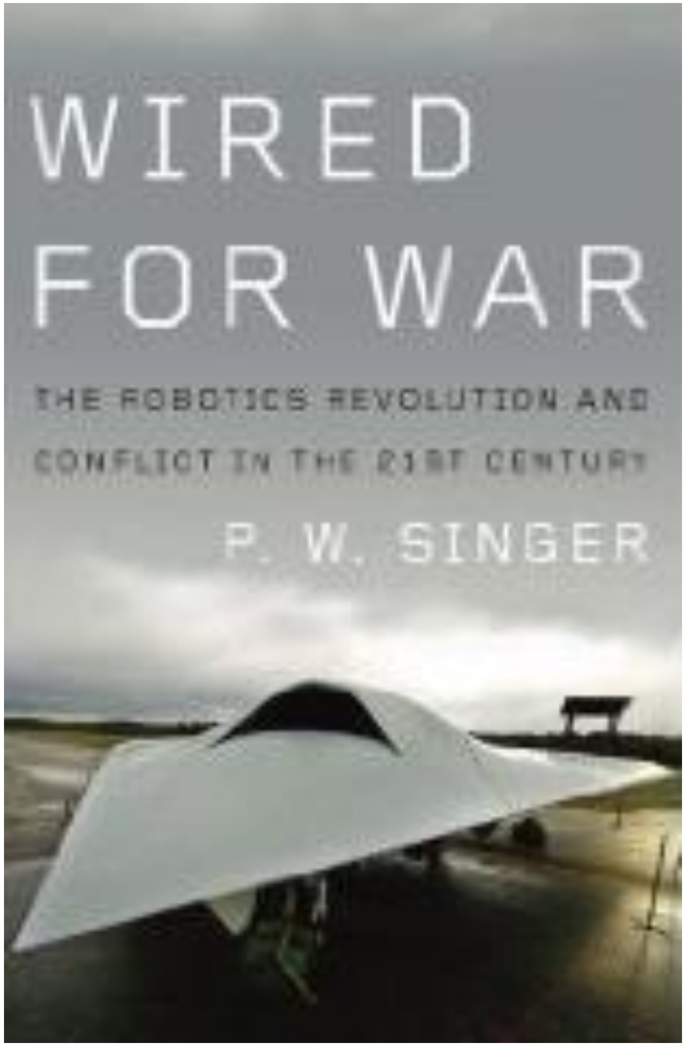
- Shield

  Talos “Iron Man”

- Time

  Challenge: Can we use robotics to increase speed of operation?

The Next Disruptive Technology



The Future … … Is Here

Acknowledgements

- This work is sponsored by the Defense Advanced Research Project Agency, DARPA Robotics Challenge Program under Contract No. HR0011-14-C-0011.
- Equipment: NVIDIA, Axis Communications
- Thanks to many colleagues and contributors

Thank You!