上海科技大学
ShanghaiTech University

CS283: **Robotics Fall 2016**

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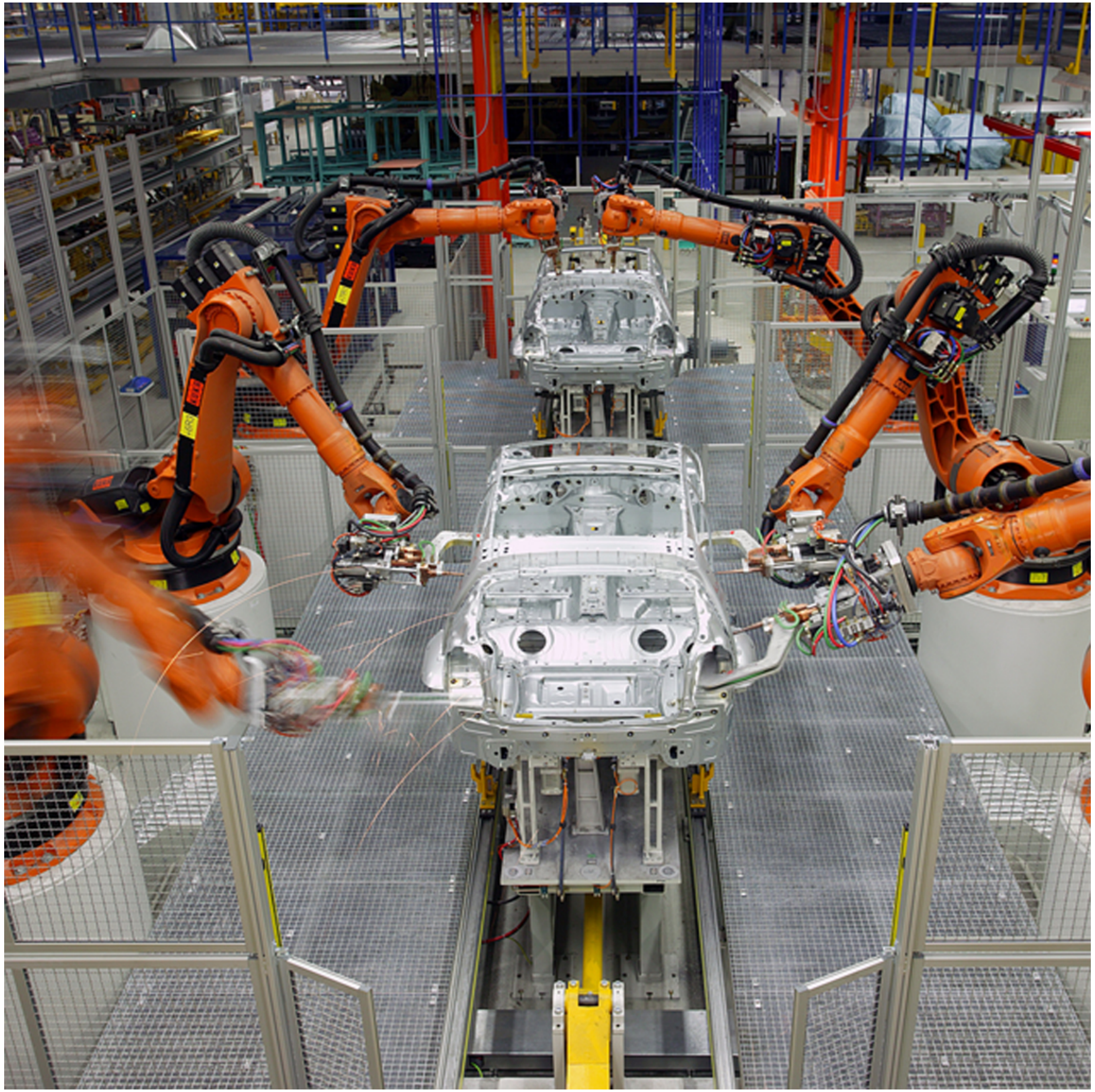
ShanghaiTech University

Outline

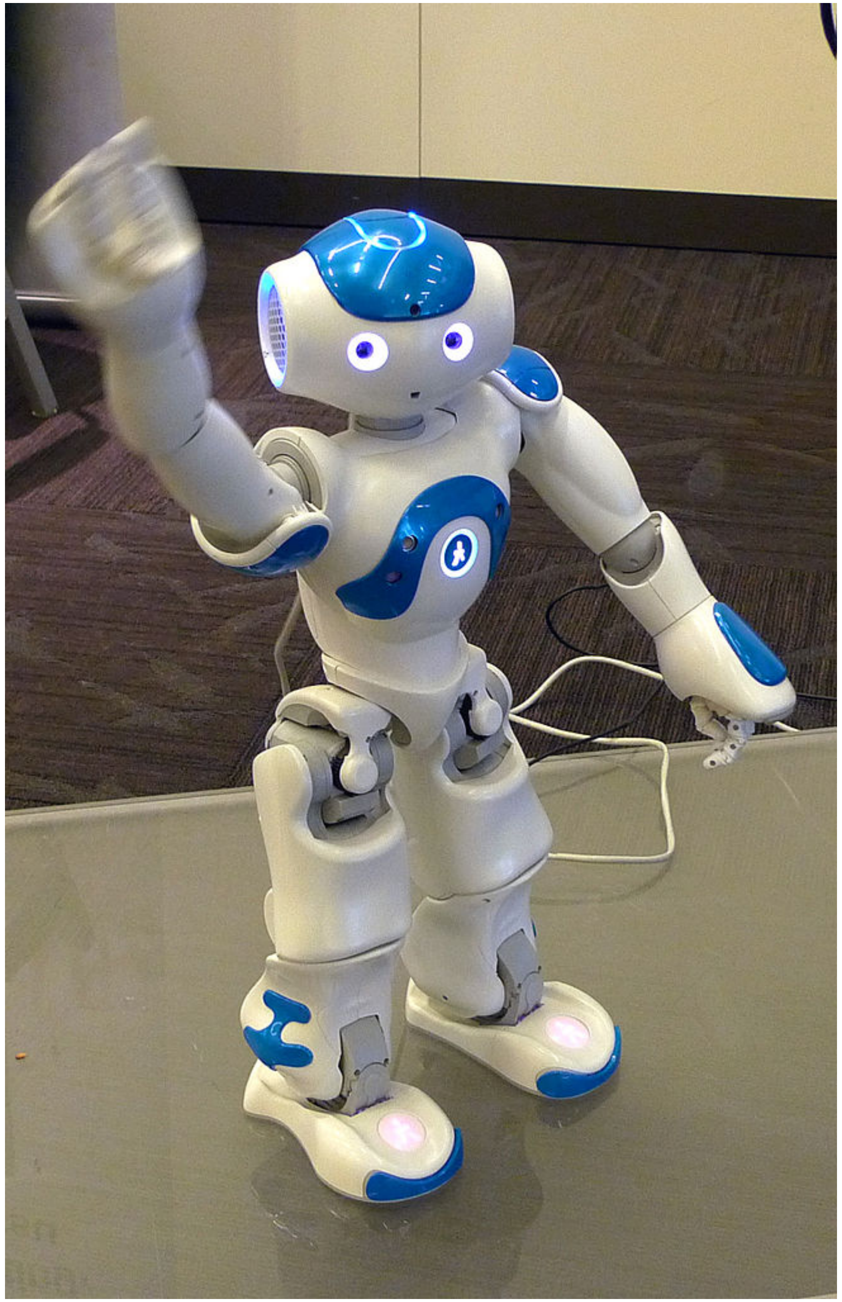
- What is a Robot?
- Why Mobile Robotics?
- Why Autonomous Mobile Robotics?
- Brief History
- Kinematics

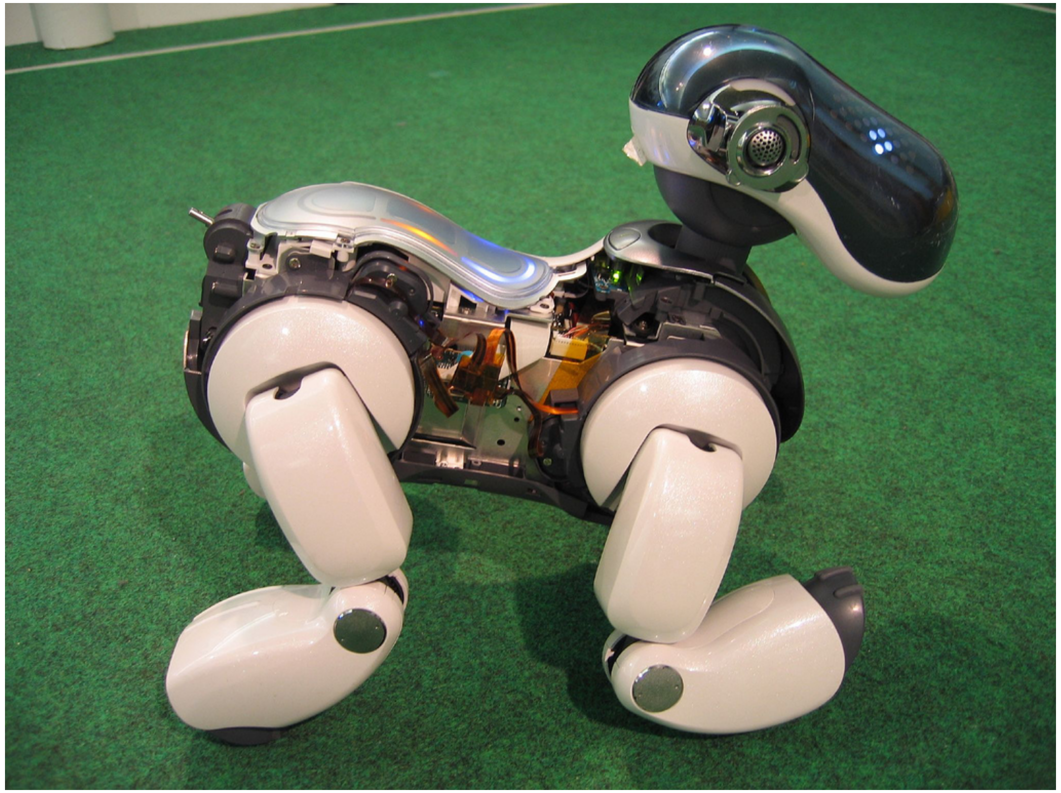
What is a Robot?

Pictures on the following slides all from http://commons.wikimedia.org




ASIMO
HONDA

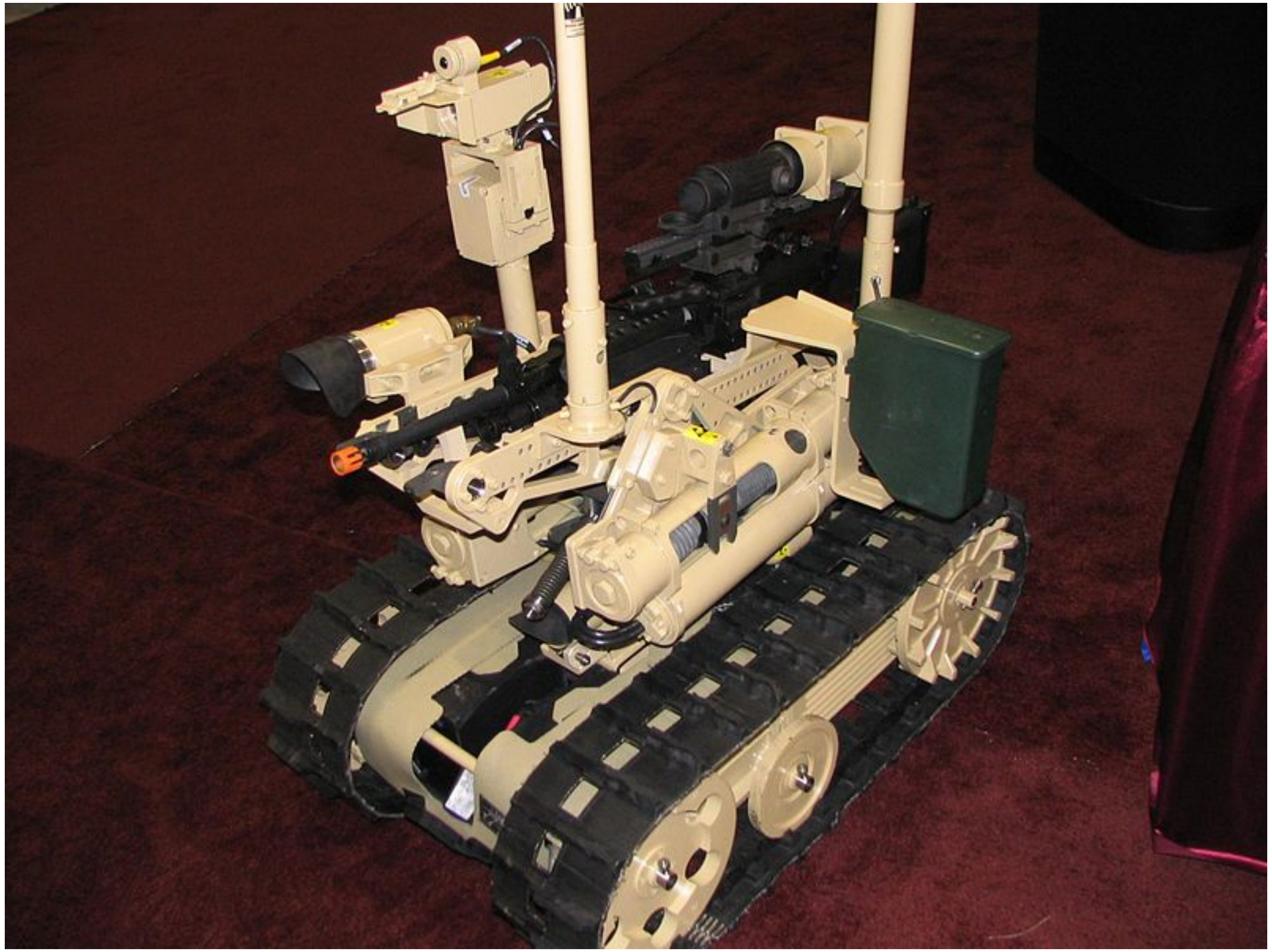




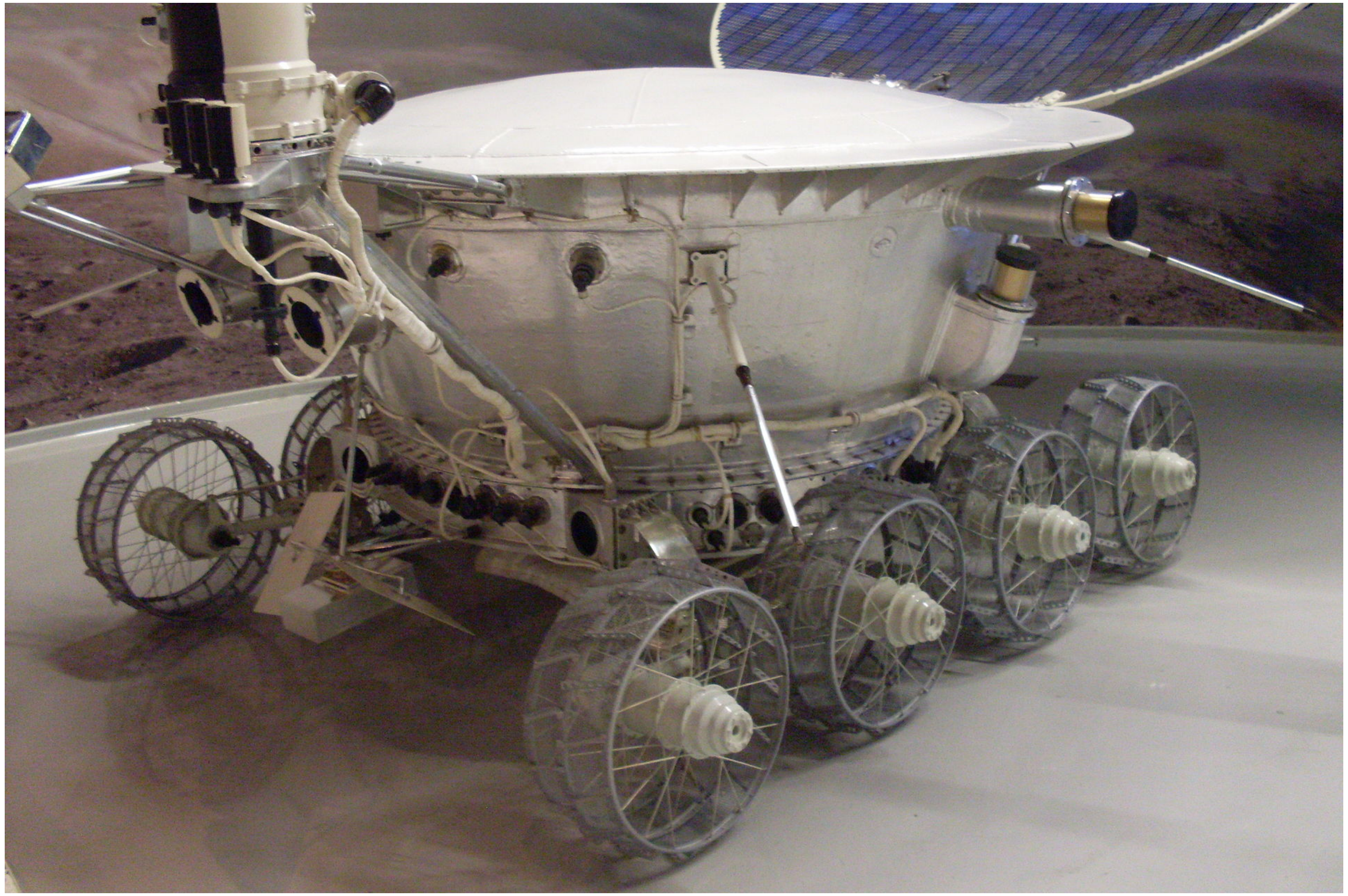

KEEP CLEAR

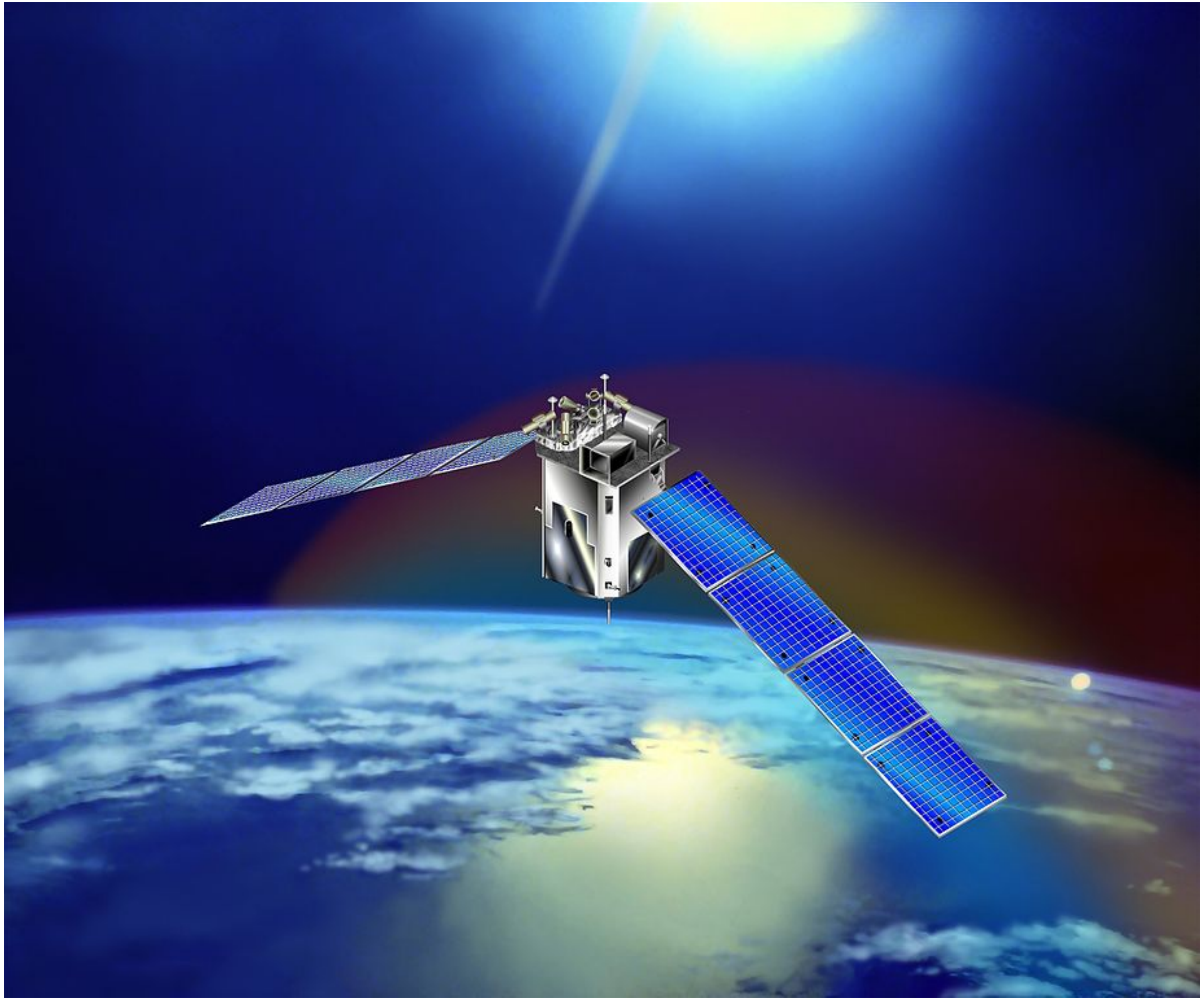

iRobot
Roomba
Robotic FloorVac
S
M
L
Select Room Size to Start / Stop

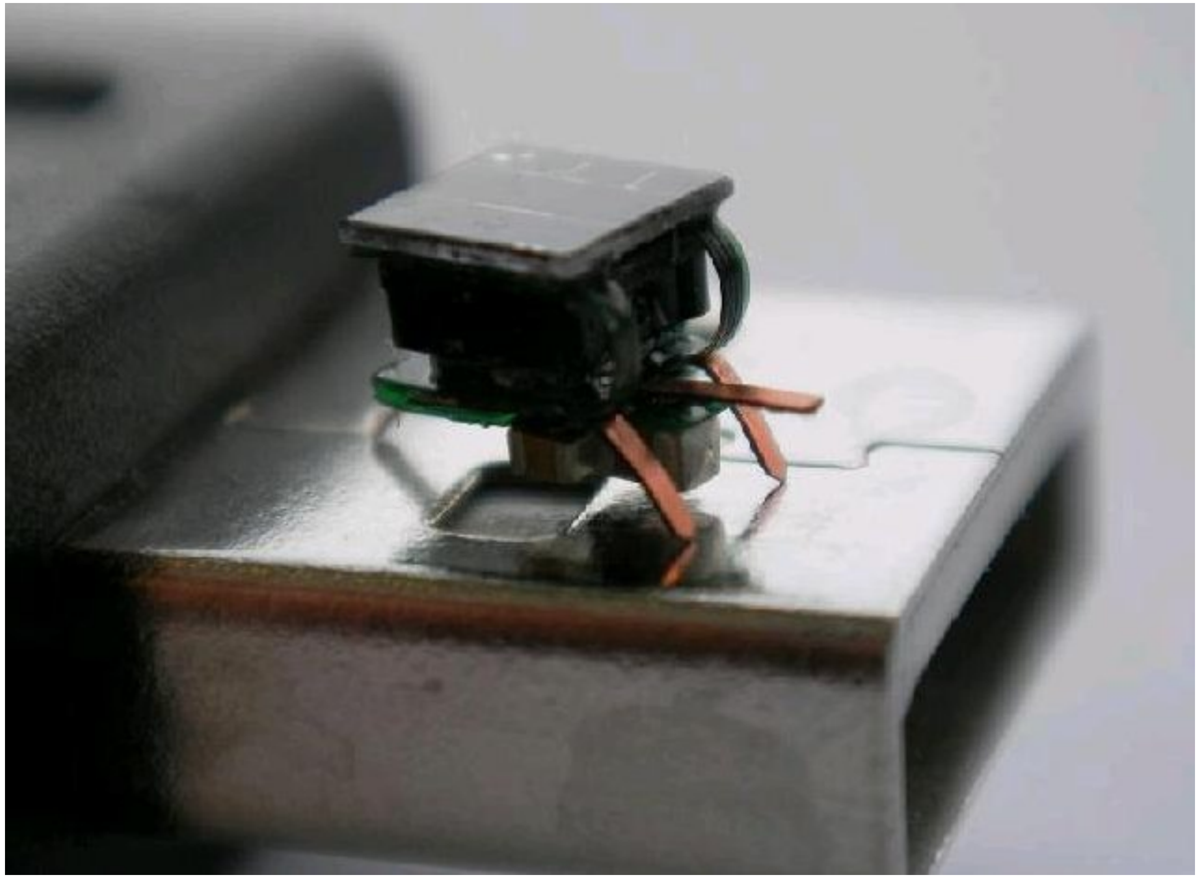

Robotics Technology
Development and Commercialization
Unmanned Vehicle
Systems Engineering
Navigation Systems

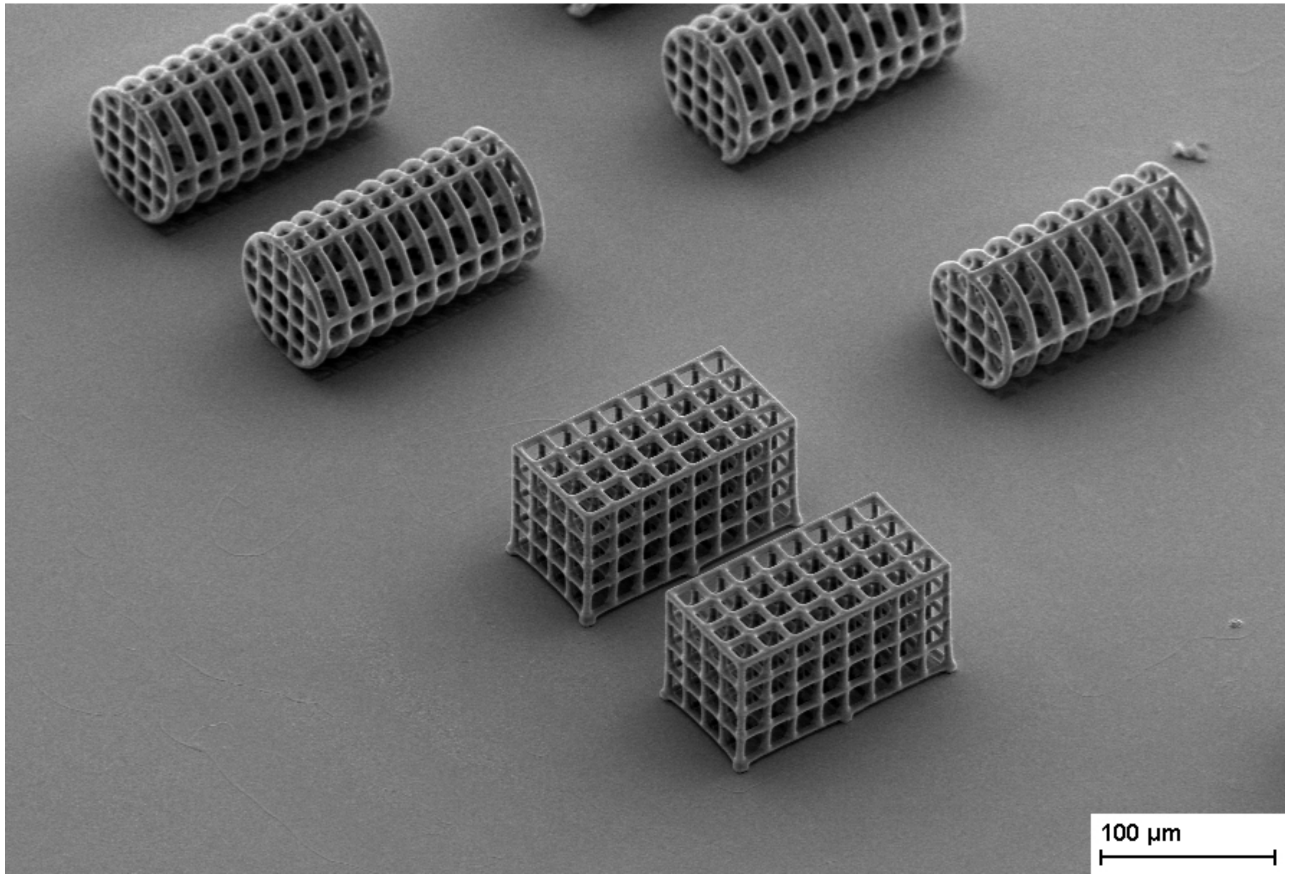



U.S. AIR FORCE
GLOBAL HAWK
HIGH ALTITUDE LONG ENDURANCE
UNMANNED AERIAL VEHICLE SYSTEM
Full Scale Mock-up
NORTHROP GRUMMAN



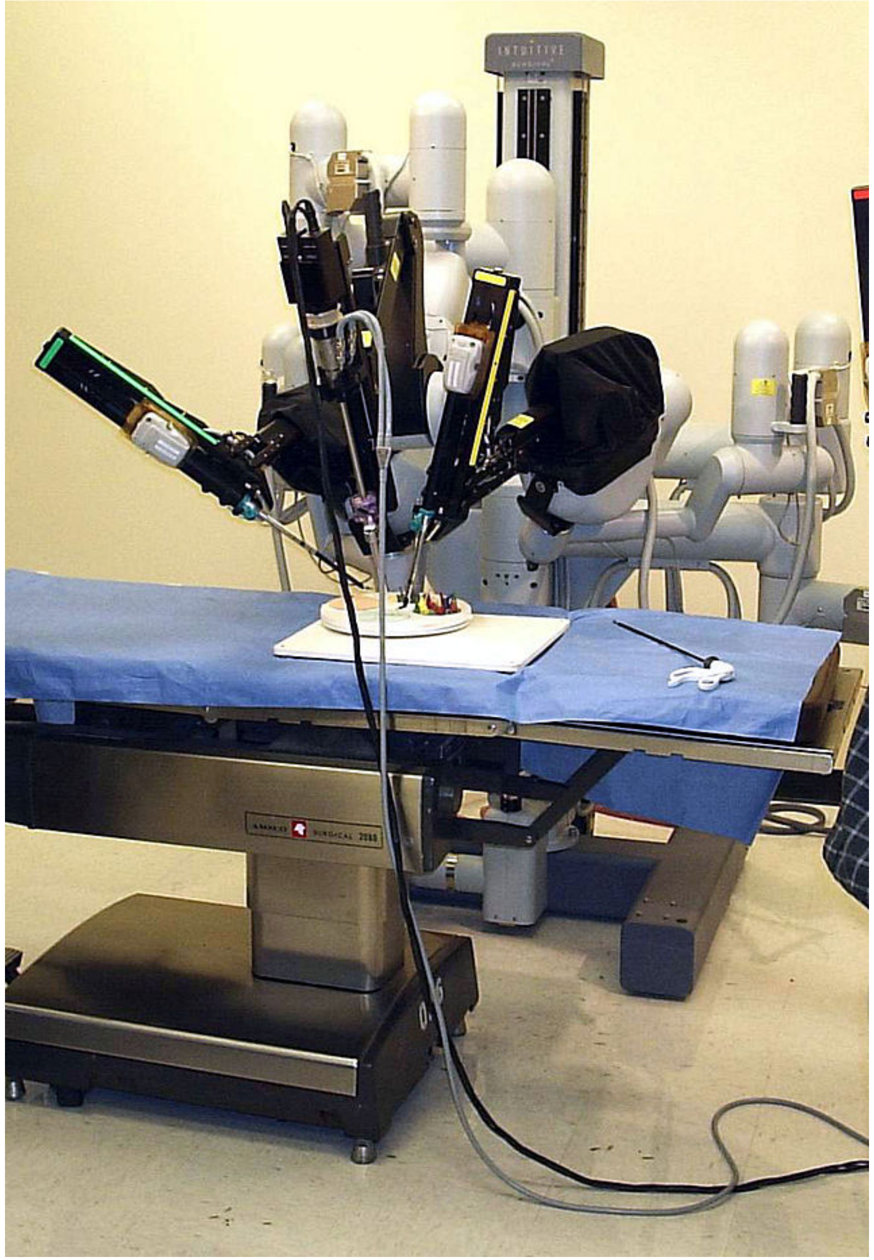





100 μm


EXPLOSIVE


JASON
WOODS HOLE
OCEANOGRAPHIC INSTITUTION


INTUITIVE


intel
MDV
MOHR DAVIDOW VENTURES
Red Bull
Powered by Diesel
CATERPILLAR


EN-V

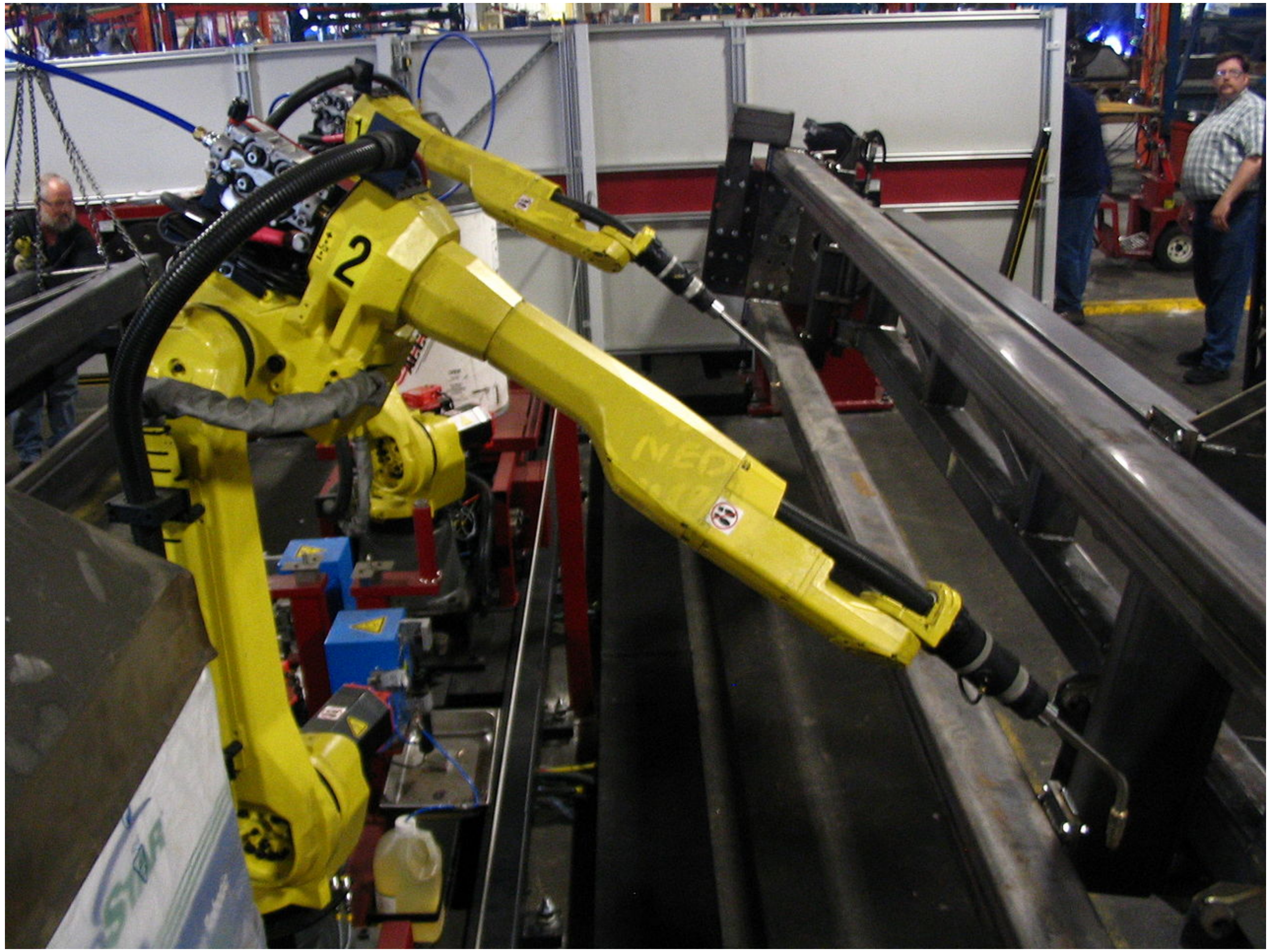
What is your definition for the term

ROBOT ?

Definitions: A Robot is ...

A machine
capable of performing complex tasks
in the physical world,
that is using sensors to perceive the environment
and acts tele-operated or autonomous.

Industry vs Mobile Robots



- Industrial Robots rule:
  - 2013: 179,000 industrial robots sold
  - Over 1.4 million industrial robots installed
  - China biggest robot market regarding annual sales - also fasted growing market worldwide
- Industrial Robots stay at one place!
- Almost all other robots move => **Mobile Robotics**

Why **Autonomous** Mobile Robotics?

- Tele-operating robots: boring and inefficient
- Autonomous robots: Robots that act by their own reasoning
  - Human operator might be present: Gives high level tasks
- Why autonomy?
  - Autonomous behaviors might be **better** than remote control by humans
  - Remote control might be **boring** or **stressful** and **tiresome**
  - Human operators might be a **scarce** resource or **expensive**
  - Multi robot approaches: One operator for many robots
- Semi-autonomy:
  - Autonomous behaviors that help the operator, for example:
  - Way-point navigation, autonomous stair climbing, assisted manipulation
  - Gradual development from tele-operation to full autonomy possible

- Autonomous mobile robots move around in the environment. Therefore **ALL** of them:
  - They need to know **where** they **are**.
  - They need to know **where** their **goal** is.
  - They need to know **how** to get there.

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- Where am I?
  - Global Positioning System: outdoor, error measured in meters
  - Guiding system: (painted lines, inductive guides), markers, iBeacon
  - Model of the environment:
    - Map, Localize yourself in this model
    - Mapping: Build the map while driving

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- Where is my goal?
- Two part problem:
  - What is the goal?
    - Expressed using the world model (map)
    - Using object recognition
    - No specific goal (random)
  - Where is that goal?
    - Coordinates in the map
    - Localization step at the end of the object recognition process
    - User input

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- Different levels:
  - Control:
    - How much power to the motors to move in that direction, reach desired speed
  - Navigation:
    - Avoid obstacles
    - Classify the terrain in front of you
    - Follow a path
  - Planning:
    - Long distance path planning
    - What is the way, optimize for certain parameters

Most important capability

(for autonomous mobile robots)

How to get from place A to place B?

(safely and efficiently)

How to get from A to B?

What are the components of a ROBOT?

Overview Hardware

Switches, LEDs, Plugs

Battery, Power DC/ DC

Sensors: IMU (Gyro, Accelerometer), Cameras, Laser Range Finders (LRF), GPS, Microphone

Wheel, Track, Joint, Finger, …

Motor

Motor Driver/ Motor Controller

Servos …

Battery management

Wheel

Motor

M
Mo

Computer:

Control and Navigation
Planning
Perception
Vision
Artificial Intelligence

troller:
ne,
nals,
d Output
d Output

Computer:
Sensing, Computing, Storage

Speed sensor
Quadrature Encoding

Mechanics:
Structure, Housing, Tracks, Flippers

Micro Controller

Micro Controller

Storage (Hard Disk)

Networking

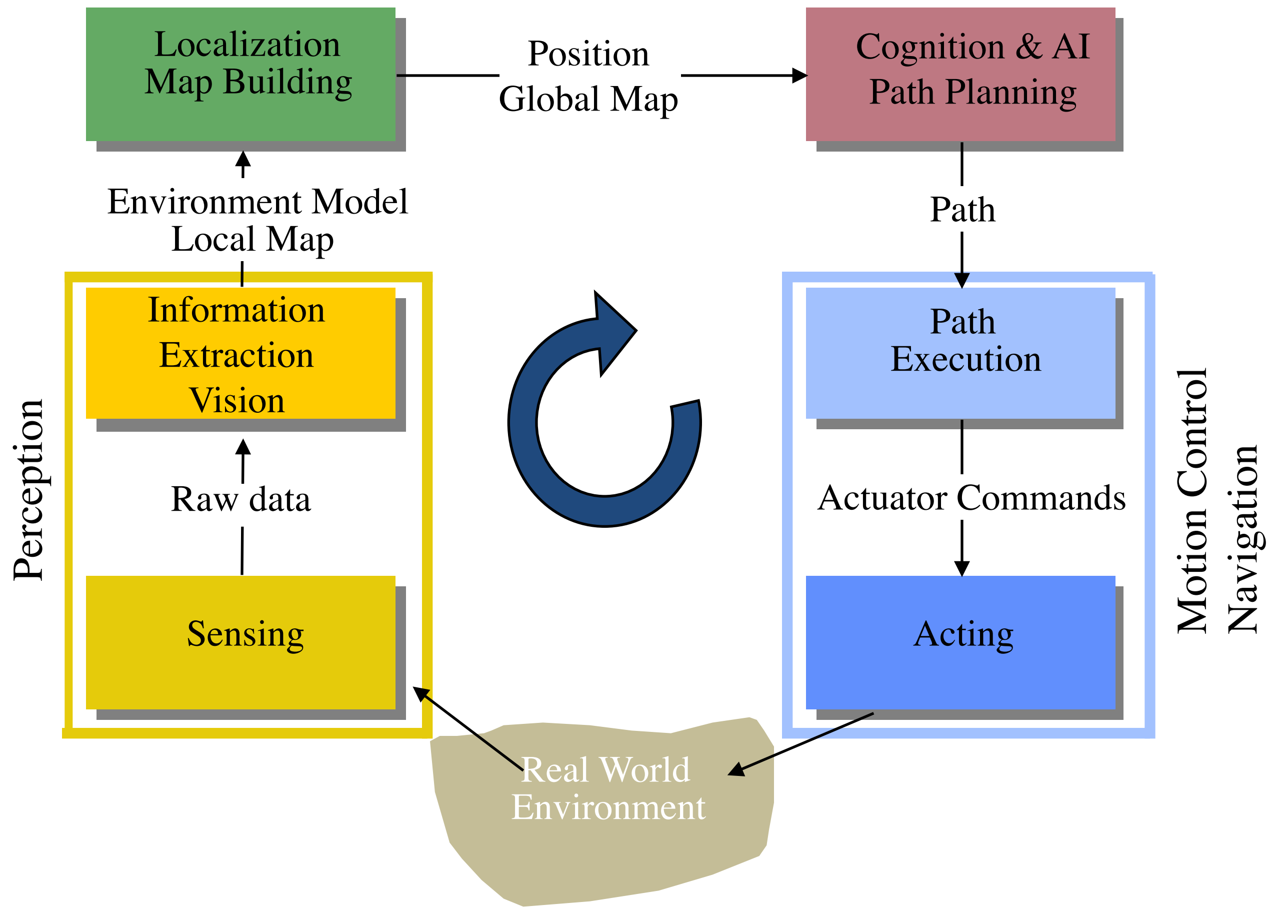
Operator Interface

Other Robots

How to get from A to B?

How to program an intelligent ROBOT to go from A to B?

General Control Scheme for Mobile Robot Systems



ADMINISTRIVIA

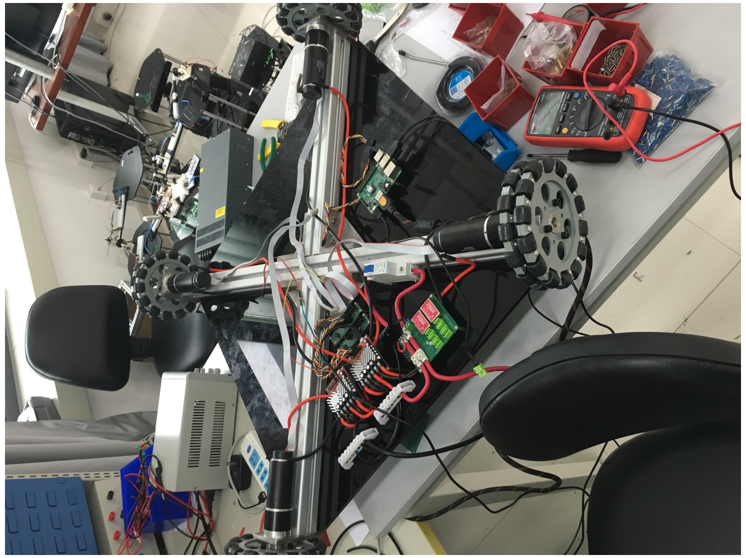
Teaching Plan

- Textbook study:
  - You are expected to carefully read and understand selected chapters of the text books
  - You will have the opportunity to ask question during tutorials and on piazza
  - Short quizzes might test if you understand the assigned texts
- Homework
  - Homework of different kinds: write texts, solve problems, programming, robot experiments

Teaching Plan cont.

- Lectures
- Presentation about robotics paper
- Two small exams
- Projects
  - Two parts, most likely related…
  - 3 or 4 persons per team
  - Oral ”exams” to evaluate the contributions of each member

Shanghai**T**ech **A**utomation and **R**obotics Center – **STAR**-Center



Grading

- Grading scheme is not 100% fixed
  - Approximately:
  - Quizzes during lecture (reading assignments): 5%
  - Homework: 20%
  - Project: 40% (2x 20%)
  - Presentation: 5%
  - Exams (2x): 30% (2x 15%)

Getting Help

- Piazza:
  - For discussions and announcements
  - https://piazza.com/shanghaitech.edu.cn/fall2016/cs283
  - Ask questions regarding your reading assignments and homework
  - You are not allowed to give the solutions – just guidance
- Ask questions during the lecture!
- Upon request we can organize a tutorial session
- Only if everything else fails: write e-mails

Policy on Plagiarism

- The homework are individual tasks!
- You may discuss the ideas and algorithms of homework with others but:
  - At no time should you read the source code or possess the source files of any other person, including people outside this course.
  - We will **detect plagiarism** using automated tools and will **prosecute** all violations to the fullest extent of the university regulations, including failing this course, academic probation, and expulsion from the university.

Mobile Robotics

- Topic Robots and how to program them:
  - Applications of robotics, software design, locomotion, hardware, sensing, localization, motion planning, autonomy for mobile robots
  - Also one or two lectures about robotic arms

- **Literature:**
- Mobile Robotics Mathematics, Models, and Methods
  - Alonzo Kelly
  - ISBN 978-1-107-03115-9
- Introduction to Autonomous Mobile Robots
  - Roland Siegwart, Illah R. Nourbakhsh, Davide Scaramuzza
  - ISBN: 978-0-262-01535-6

Material

- Webpage
  - https://robotics.shanghaitech.edu.cn/teaching/robotics2016
  - Slides will be available on the webpage
- Piazza
  - https://piazza.com/shanghaitech.edu.cn/fall2016/cs283
- Where to find us: Lab in research building http://robotics.shanghaitech.edu.cn/lab
- E-Mail:
  - soerensch@ShanghaiTech.edu.cn

Prerequisite: Robot Operating System

- Program in C++ (or python) and ROS (wiki.ros.org)
- Prerequisite for that: Operating System Ubuntu Linux (www.ubuntu.com)
  - **Best option:** Dual boot on your own Laptop/ Computer – needs min. 40 GB from HD
  - Very sub-optimal option: Run Ubuntu in a virtual machine (suggestion: VirtualBox) – needs 40 GB and a modern Laptop (at least 4GB RAM – more is better)
- Preferred version: Ubuntu 16.04 (aka Xenial Xerus) (long term support)
  - ROS Kinetic (current version)
- Other tools: git, LaTeX, …

Schedule

- May change – take a look at webpage for most recent version!

	Topic	HW/ Project	Other
Week 1	Intro	HW1	
Week 2	Hardware/ Software	HW2	
Week 3	Control/ Sensors	HW3	
Week 4	Perception	HW4	
Week 5	-------		
Week 6		HW5	Presentations
Week 7	Localization		
Week 8	ICP	Project 1.1	
Week 9	SLAM		
Week 10	Navigation		Mid-term
Week 11			
Week 12	Robot Arms		
Week 13	Planning	Project 1.2	
Week 14			
Week 15			
Week 16			
			Final

Prepare for next weeks

- Join the lecture on piazza
- Organize access to the two text books
- For the dual-boot installation of Ubuntu:
  - Backup your all your data
  - Free enough space (40 GB)
  - Download Ubuntu

APPLICATIONS OF MOBILE ROBOTS

Current applications

- Industry
  - Manufacturing, Transportation, **Logistics**
- Service
  - Transportation (in Hospitals)
  - Clean windows
  - **Pipeline inspection** (tele operated)
- Medical
  - Surgery
- Household
  - Carpet cleaning, lawn mowing
- Toys
- Military
- Research (**Space, Underwater**)

Future applications

- Autonomous cars
- Mobile manipulation/ manufacturing
- Autonomous delivery using drones
- Atomic Power Plant decommissioning
- Humanoid household robots
- Military
  - Autonomous air combat
  - Autonomous ground robots
  - Autonomous underwater robots (Torpedo 2.0)
- **Search and Rescue Robotics**

Pipeline inspection

- Tele operated tracked robot
- Inspect pipelines
- Main sensor: video camera with light source
- Additional sensors: laser measurement (diameter)

- Why use robot?
- Inaccessible to men (non-destructive)

Automated Guided Vehicles (AGV) in Industry and Service

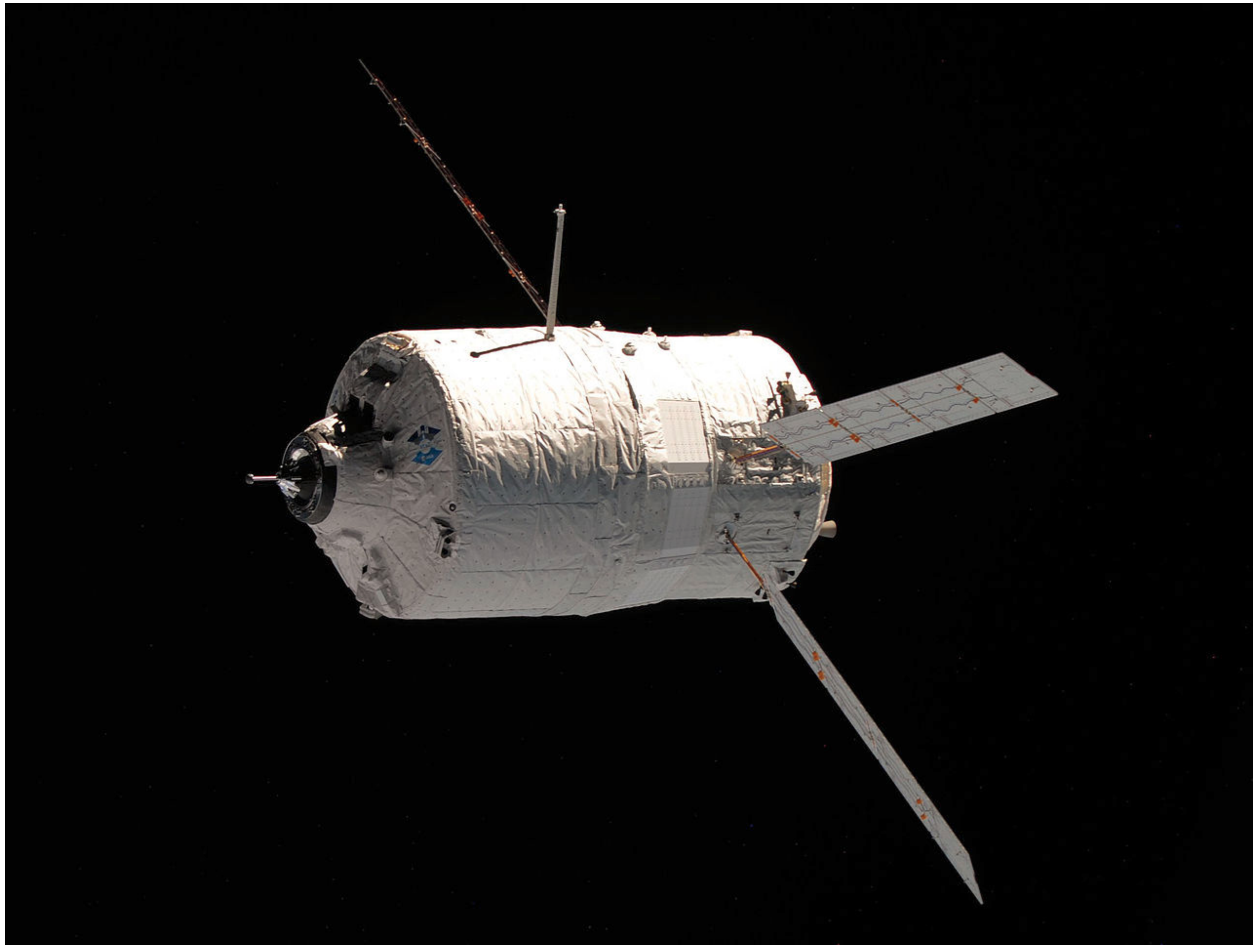
- Transport things from A to B
- In a warehouse, factory or hospital, lab …
- Navigation: guided – wires, tape, reflective markers localized with lasers, using map (SLAM)
- Safety measures when working together with humans!
- Why?
  - Efficiency
  - Speed
  - Safety

Automation of Logistic Processes: Container unloading

- Object Recognition of heterogeneous goods
- Grasp and motion planning
- Fully autonomous unloading of containers
- Using a single RGB-D camera

Automated Transfer Vehicle (ATV)

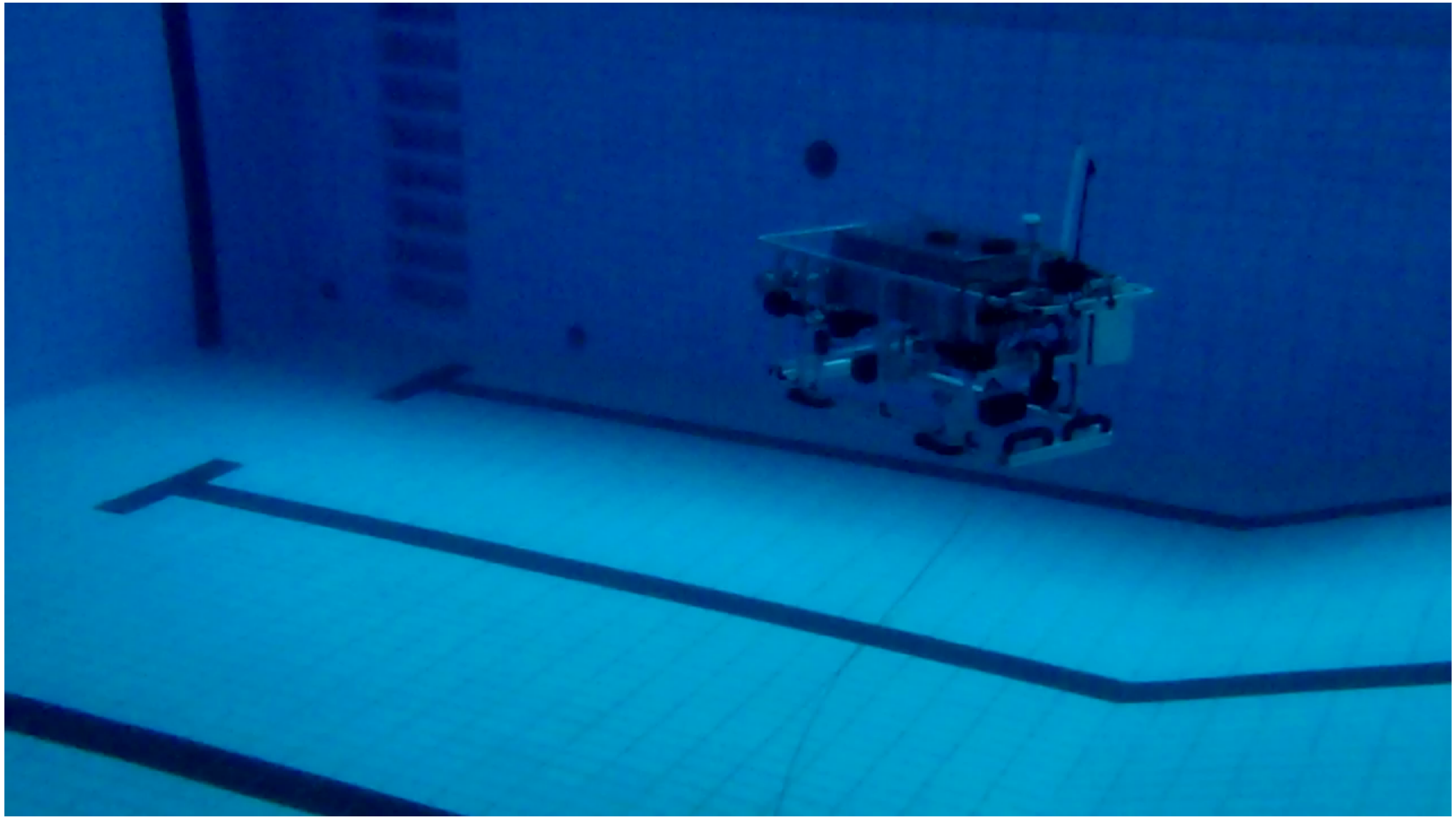
- Supply the International Space Station (ISS) with propellant, water, air, payload and experiments
- Autonomously flies towards the ISS
- Autonomously docks onto the ISS



- GPS and star tracker for localization
- From 250m distance: vision for object recognition (dock) and tracking
- Why automation: Saver than human control!

Applications for Underwater Robotics

- Oil industry: Remotely Operated Vehicles (ROV) – construction and maintenance of Oil drilling platforms
- Research: Biology, Oceanography, Geology
  - Explore the subsea
  - Mapping (2D and 3D)
  - Autonomy
- Military
  - Surveillance
  - Harbor security
  - Mine hunting
  - Attack
- Inspection
- Search and Rescue

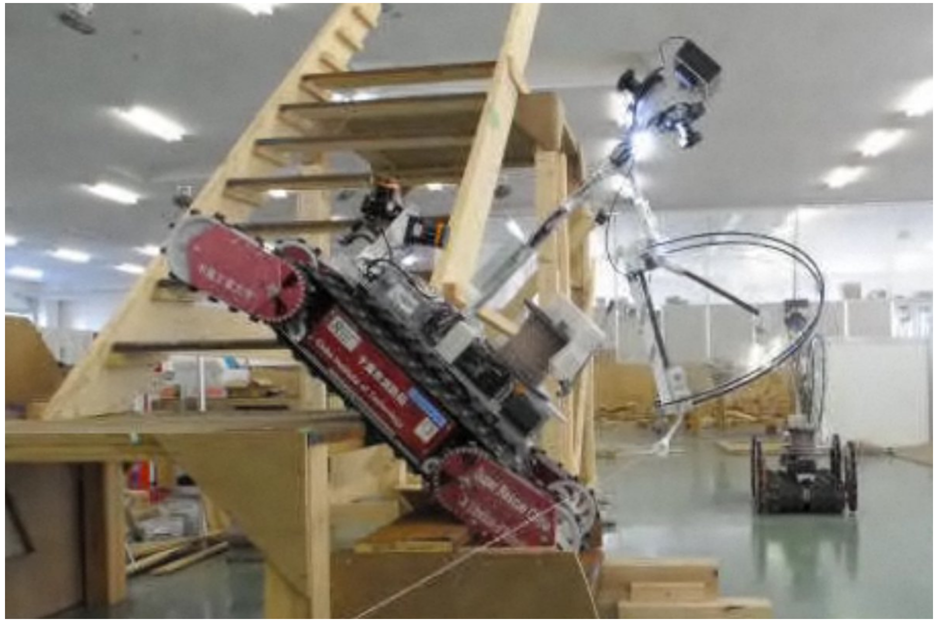


Urban Search and Rescue Robots

- Scenarios:
  - Earthquakes
  - Gas, bomb explosions
  - Hazardous material accidents
  - Nuclear accidents
- Tasks
  - Locating victims, their state or absence
  - Locating hazards (gas, fire, smoke)
  - Provide information (maps & situational awareness)
- Advantages of Robots
  - Can take high risks
  - Many sensors & network connections
- Most critical disadvantages of robots (currently):
  - locomotion
  - cost
  - usability

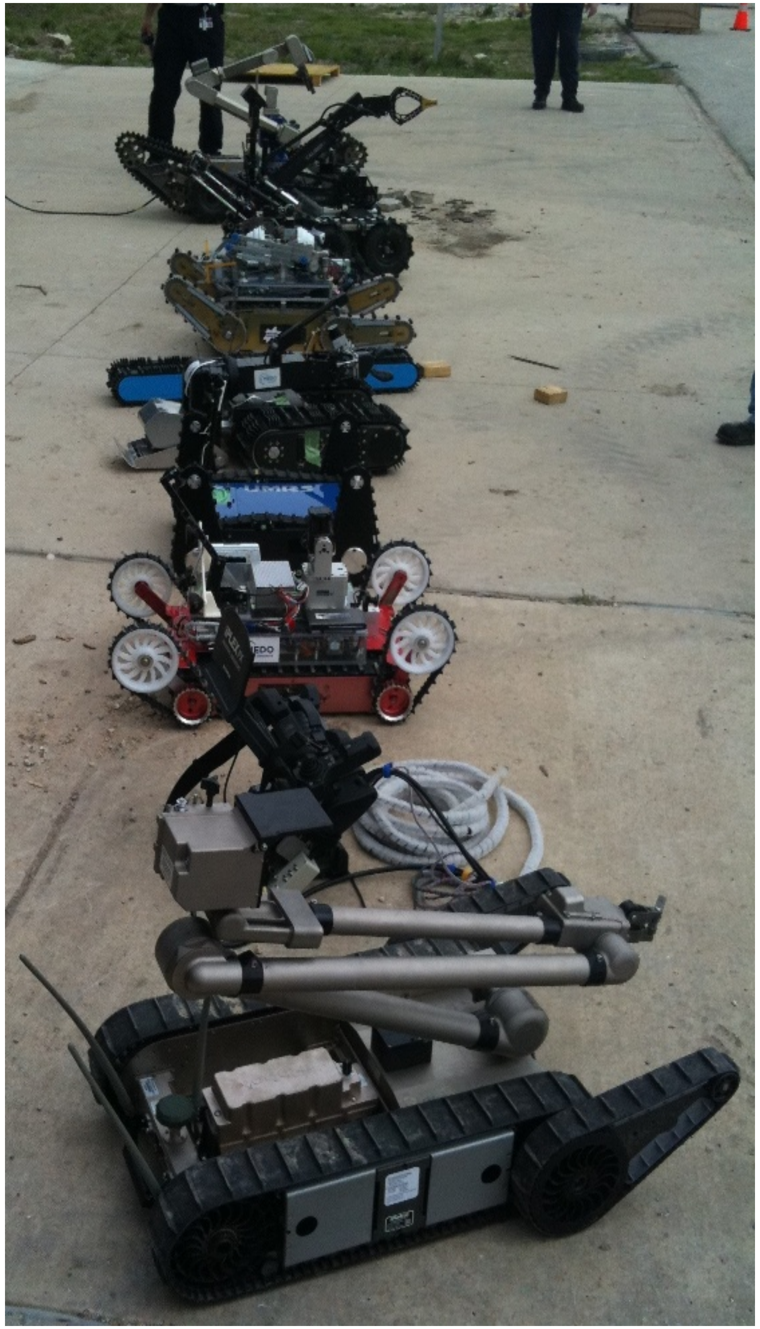
Rescue Robot in Fukushima

- Fukushima Daiichi nuclear disaster 2011
- RoboCup Rescue Robot Quince:
  - Developed in Tohoku University, Japan
  - 2 Units deployed to Fukushima plant
  - One robot stranded on third floor of reactor Number 2



Rescue Robots

- Different shapes
- But: All tracked!
- Flippers/ sub-tracks for advanced mobility
- Arms for directed sensing and manipulation
- Mobile manipulation big topic => combines industrial robots with mobile robots!



Flying search and rescue robot

- AirRobot - Quadcopter
- To get overview images
- Image stitching algorithm to create big birds-eye maps

- Currently still teleoperated
- Analog video transmission
- Radio distance: up to 500m

Aerial Map

- Rubble pile and train
- 435 frames
- Real time generation of map