ShanghaiTech University
上海科技大学
School of Information Science and Technology
信息科学与技术学院

Mobile Robotics Fall 2015

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ShanghaiTech University

Mobile Robotics

- Topic Mobile Robots and how to program them:
  - Applications of robotics, software design, locomotion, hardware, sensing, localization, motion planning, autonomy for mobile robots

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

Teaching Plan

- Change: 2 credit points!
- Textbook study:
  - You are expected to carefully read and understand selected chapters of the text books
    - Check the website regularly!
  - 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

Tue, Nov 17, 15	Introduction
Fri, Nov 20, 15	Software & Hardware
Tue, Nov 24, 15	ROS
Fri, Nov 27, 15	Kinematics
Tue, Dec 1, 15	Behavior Based Robotics
Fri, Dec 4, 15	Sensors
Tue, Dec 8, 15	Sensors
Fri, Dec 11, 15	Perception
Tue, Dec 15, 15	**Mid-Term**
Fri, Dec 18, 15	Perception
Tue, Dec 22, 15	Perception
Fri, Dec 25, 15	Computer Vision
Tue, Dec 29, 15	Localization
~~Fri, Jan 1, 16~~	
Tue, Jan 5, 16	SLAM
Fri, Jan 8, 16	Summary
~~Tue, Jan 12, 16~~	
~~Fri, Jan 15, 16~~	
Tue, Jan 19, 16	**Final**

Grading

- Grading scheme is not 100% fixed
  - Approximately:
  - Quizzes during lecture (reading assignments): 10%
  - Homework & Lab & Project: 40%
    - Homework: Hand out Tuesday; Friday Questions; due Monday 10:00 pm
    - Lab: Hands on robotics experiments – show results
    - Project: idea => write proposal => programming => experiments => report
  - Presentation: 10%
  - Exams (2 x mid-term): 2x 20%

Late Policy … Slip Days!

- Assignments due at 10:00:00PM
- Also good for Lab exercises or your project
- You have 3 slip day tokens (NOT hour or min)
- Every day your homework or project is late (even by a minute) we deduct a token
- After you've used up all tokens, it's 33% deducted per day.
  - No credit if more than 3 days late

Getting Help

- Piazza:
  - For discussions and announcements
  - http://piazza.com/shanghaitech.edu.cn/fall2015/morob
  - 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 homeworks are individual tasks!
- You may discuss the ideas and algorithms of homeworks 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.

Material

- Webpage
  - http://robotics.shanghaitech.edu.cn/teaching/robotics2015
  - Slides will be available on the webpage
- Piazza
  - http://piazza.com/shanghaitech.edu.cn/fall2015/morob
- Where to find us: Lab in research building http://robotics.shanghaitech.edu.cn/lab
- E-Mail:
  - soerensch@ShanghaiTech.edu.cn
  - yuty@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 14.04 (aka Trusty Tahr) (long term support) or later
  - ROS Jade (current version)

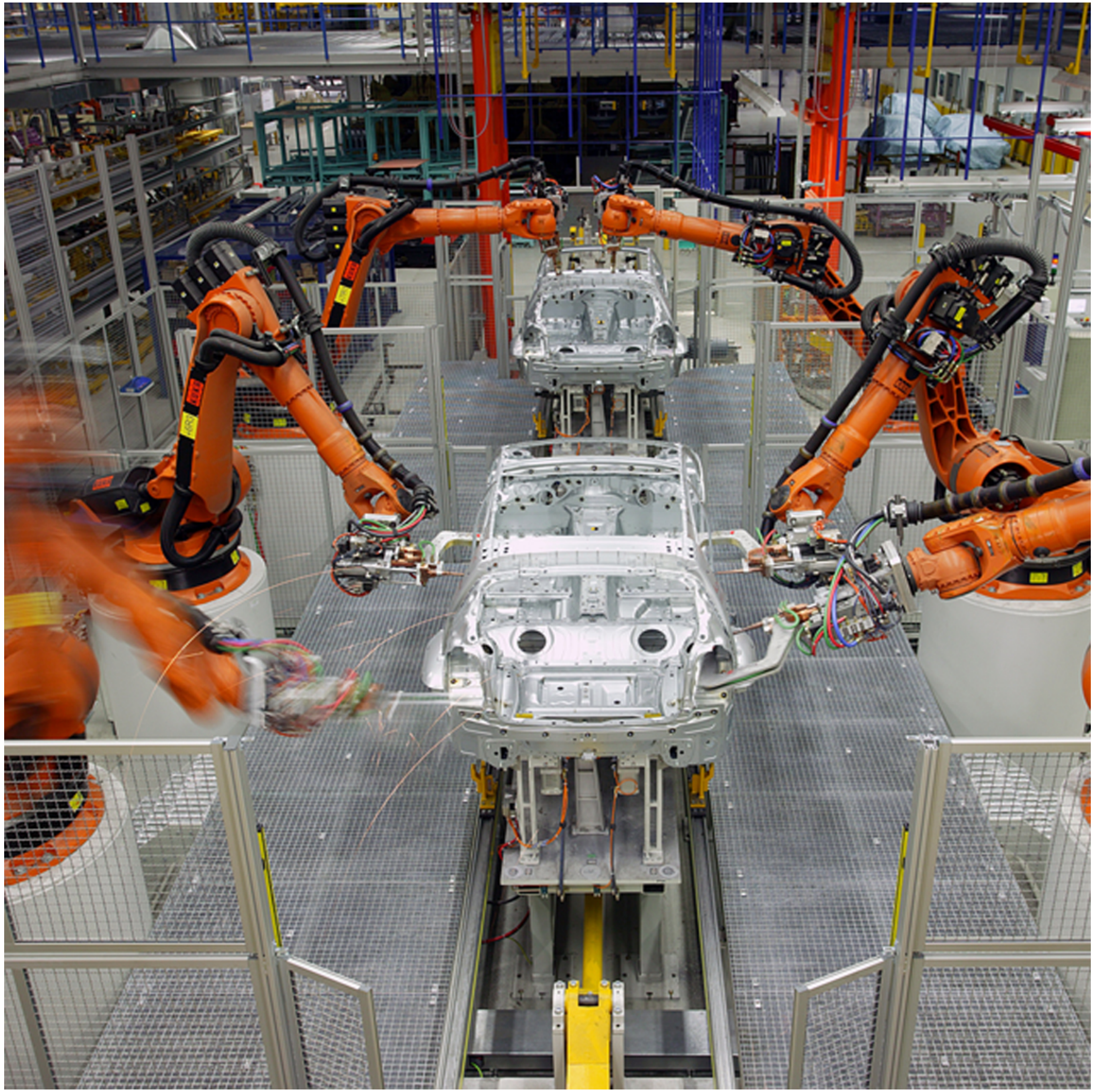
- Other tools: git, LaTeX, …

Outline

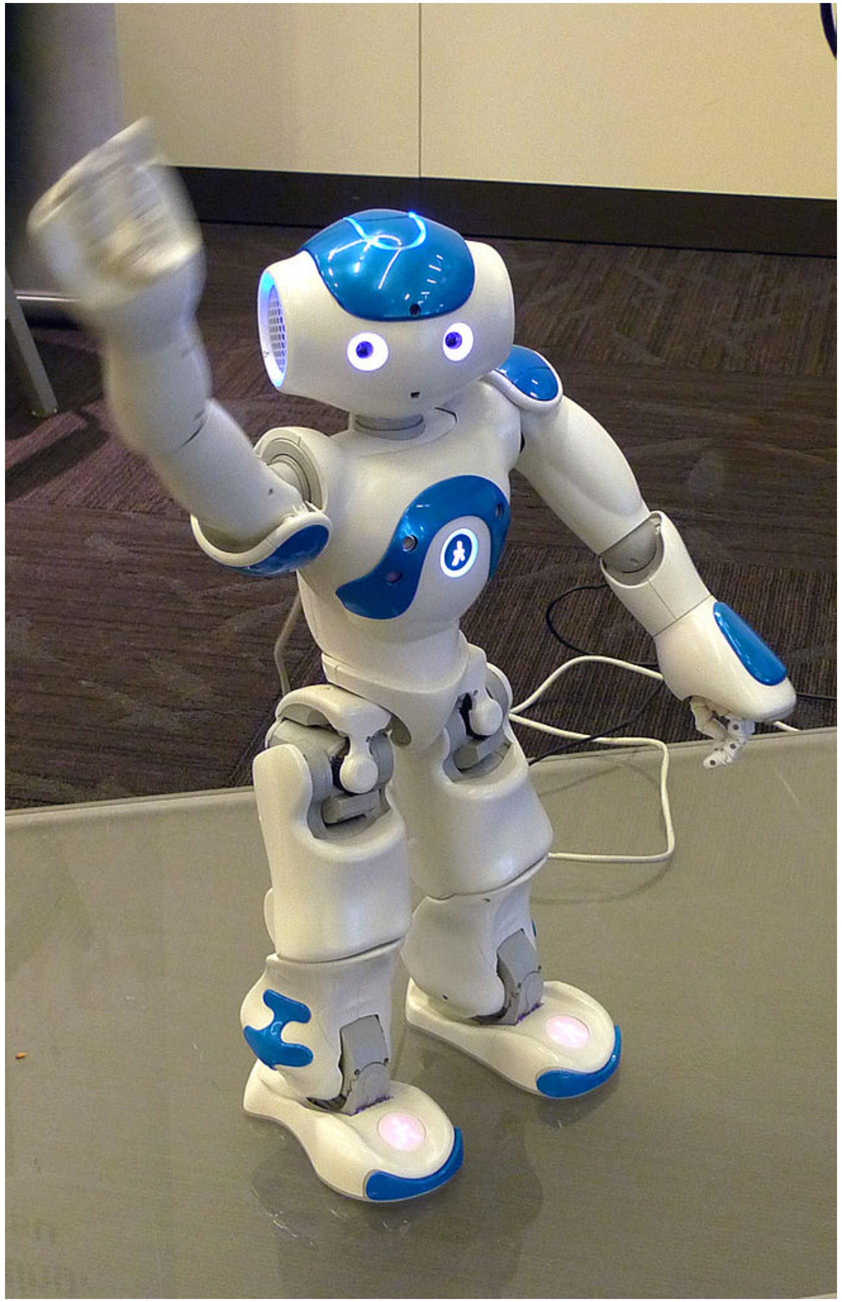
- What is a Robot?
- Why Mobile Robotics?
- Why Autonomous Mobile Robotics?
- Brief History
- Applications of Robotics

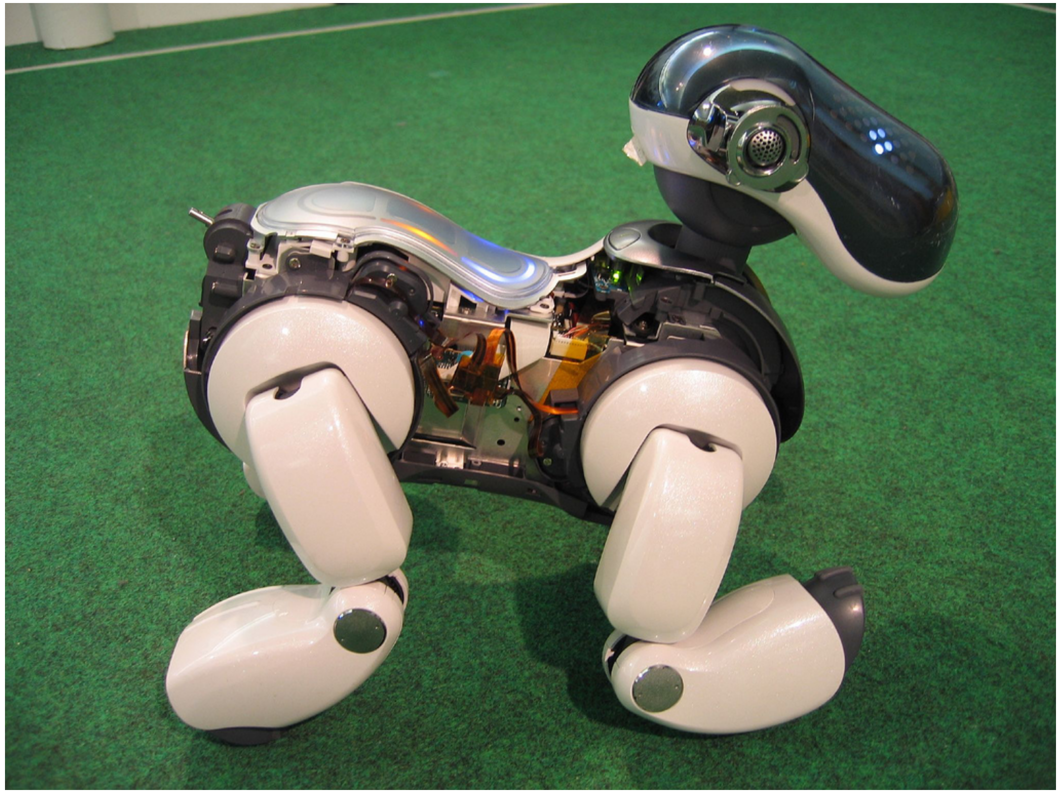
What is a Robot?

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




ASIMO
HONDA

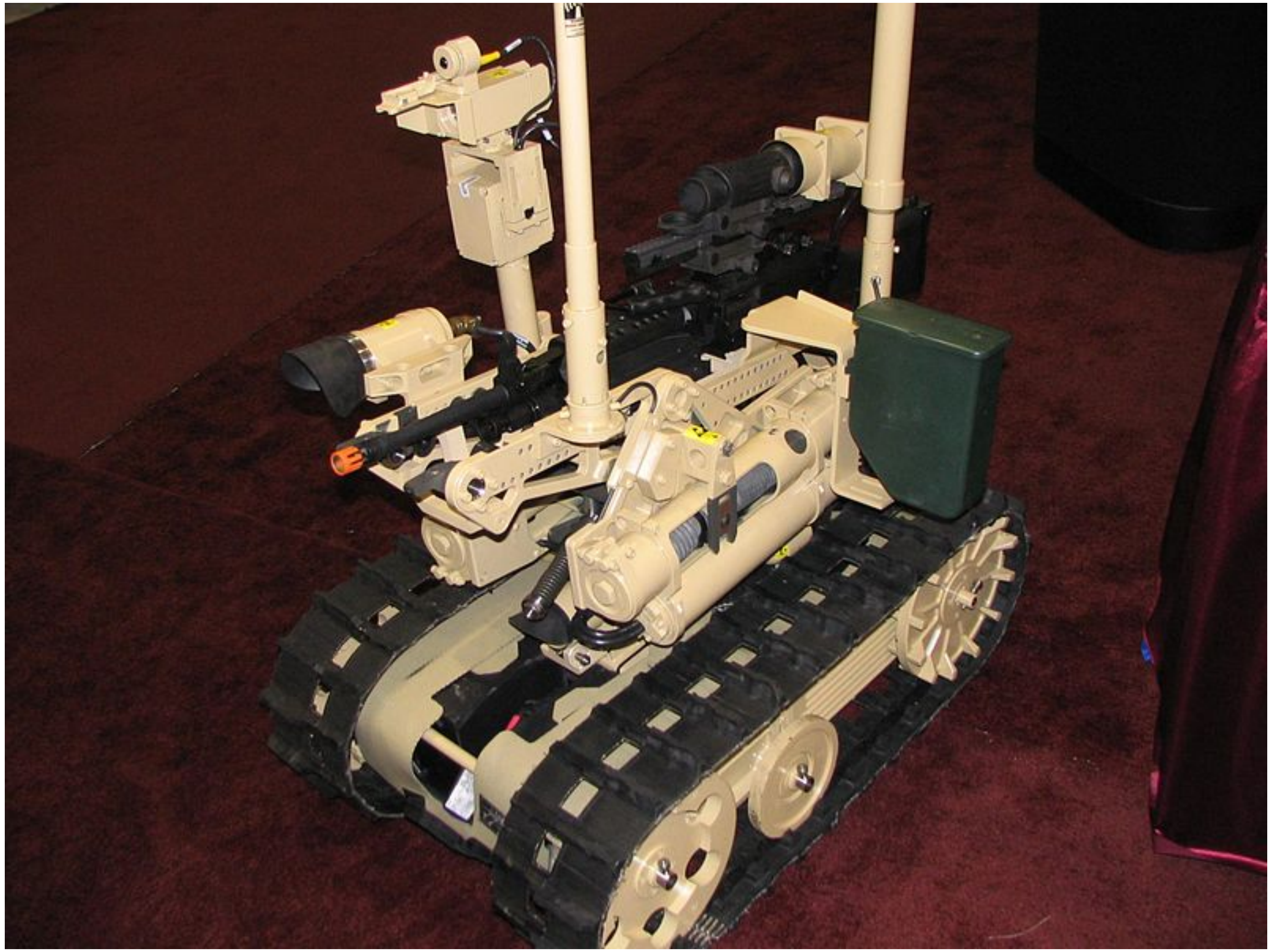




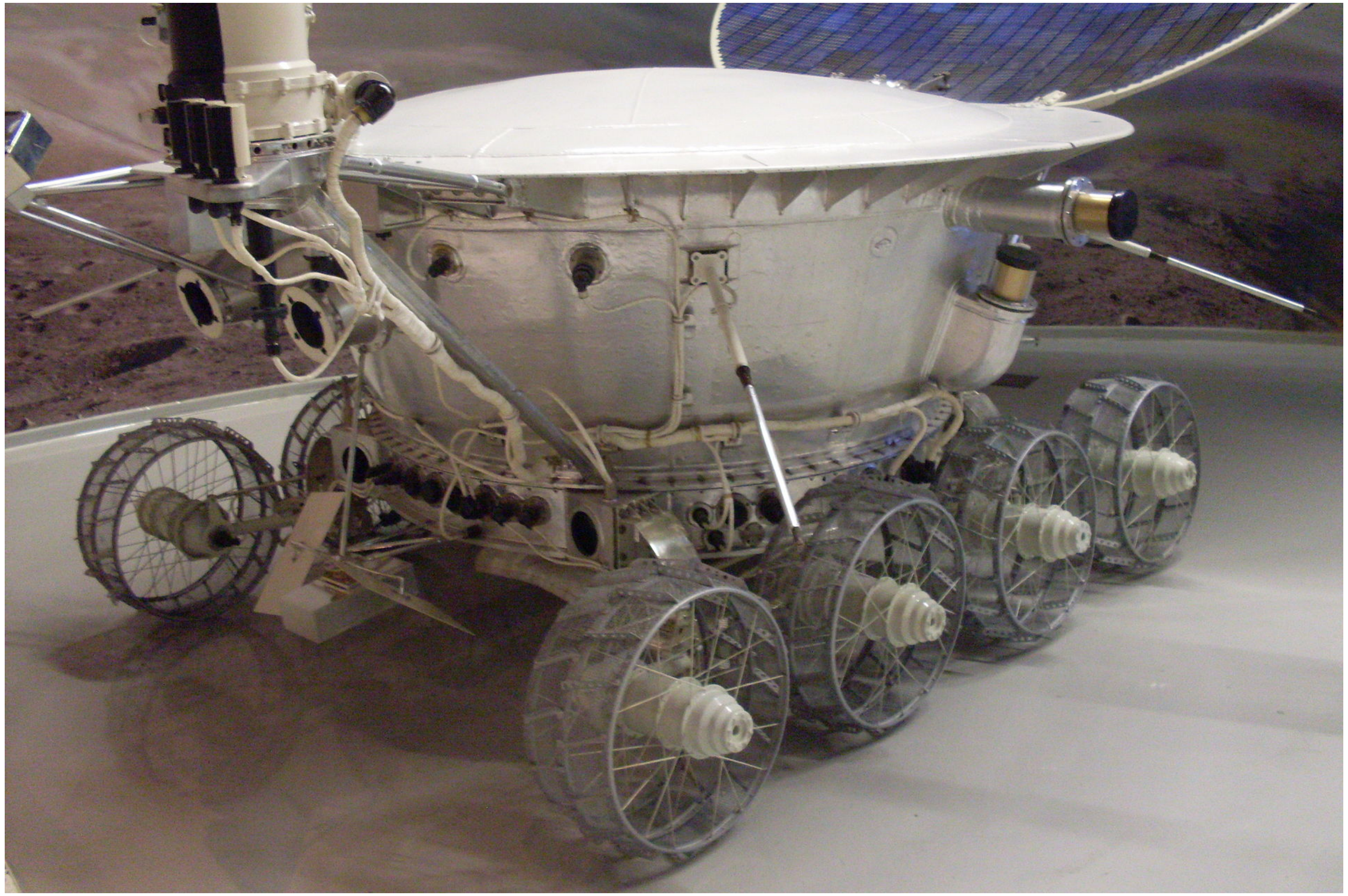

KEEP CLEAR

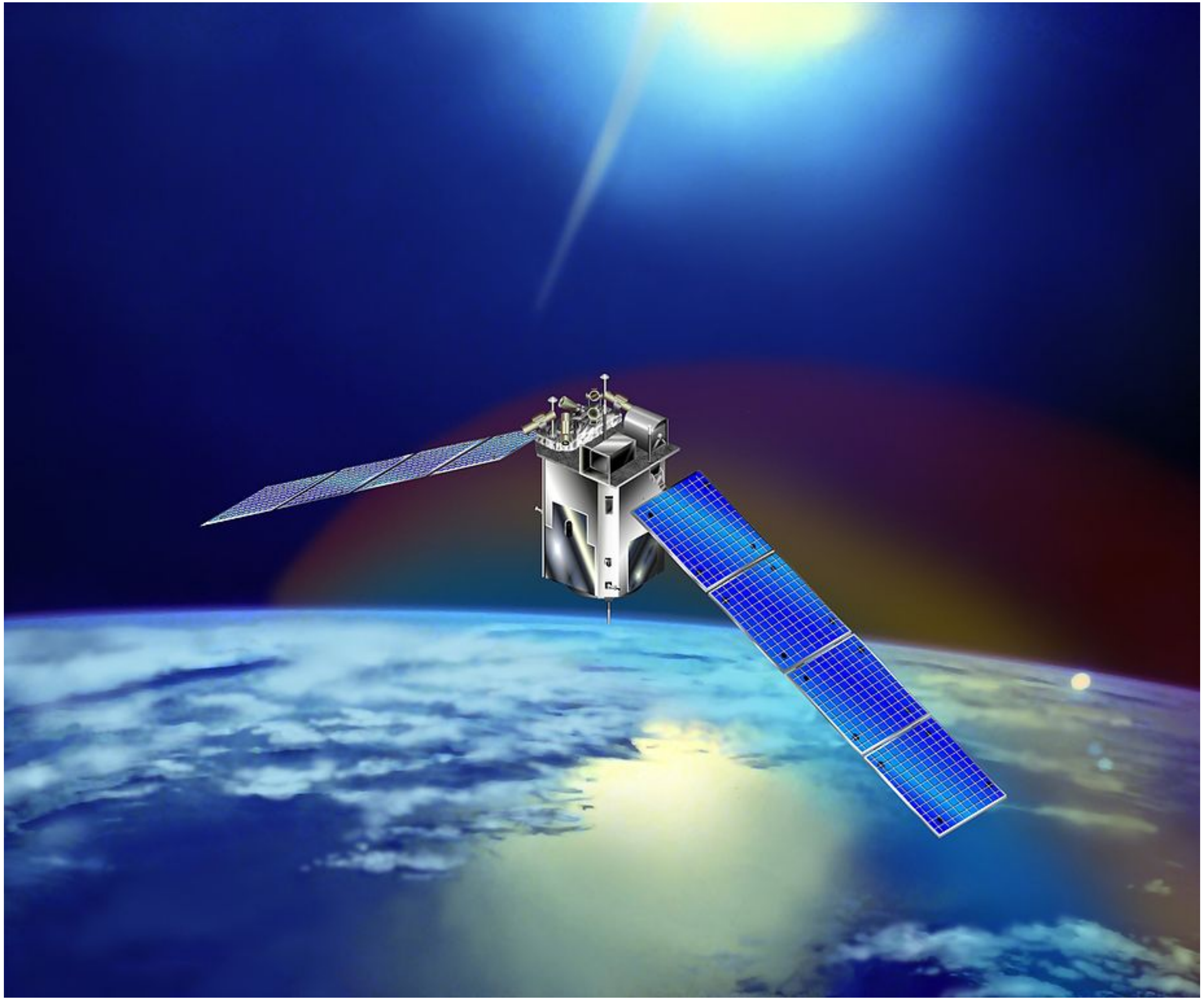

iRobot
Roomba
Robotic FloorVac
S
M
L
Select Room Size to Start / Stop
Always empty both sides
of Particle Bin after each use

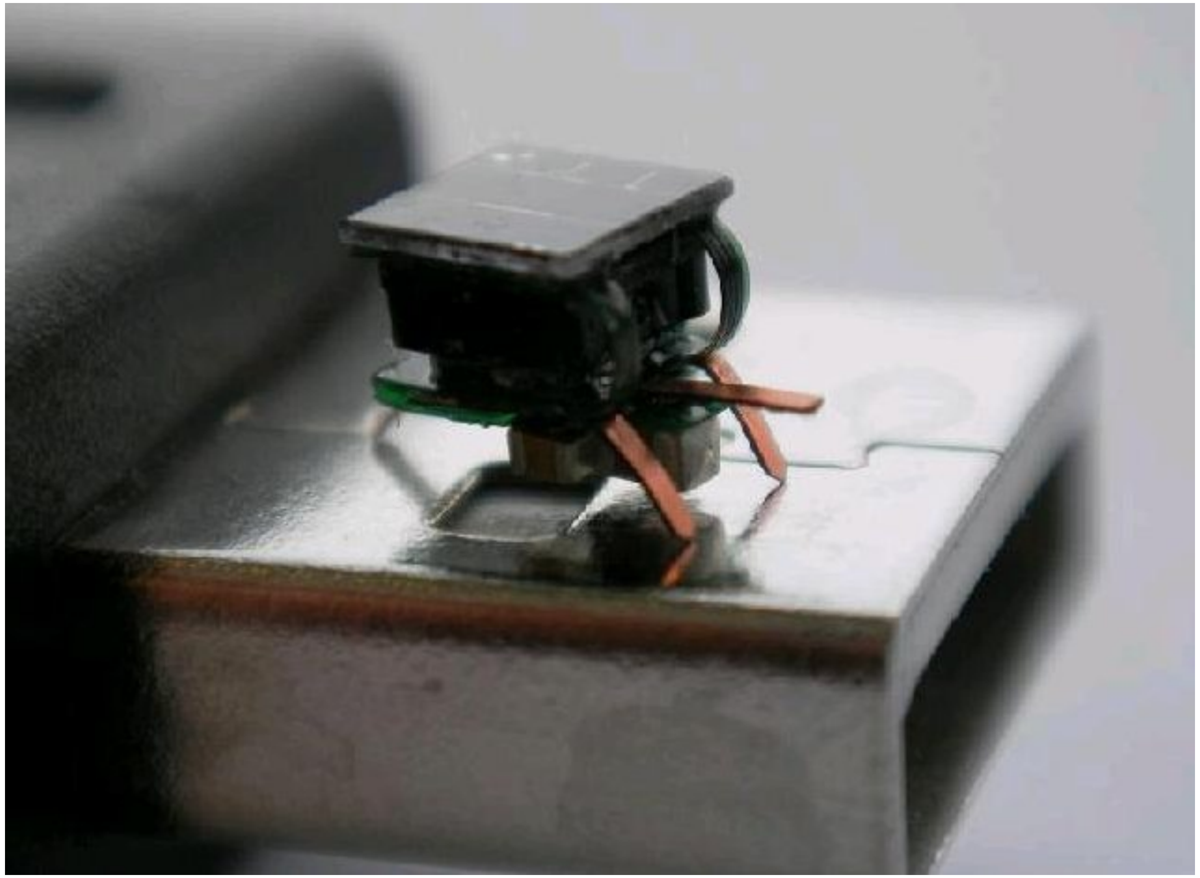

Robotics Technology
Development and Commercialization
Robots that Work in the Real World
Unmanned Vehicle
Systems Engineering
Engineering the Future of Unmanned Vehicles
Navigation Systems
NREC

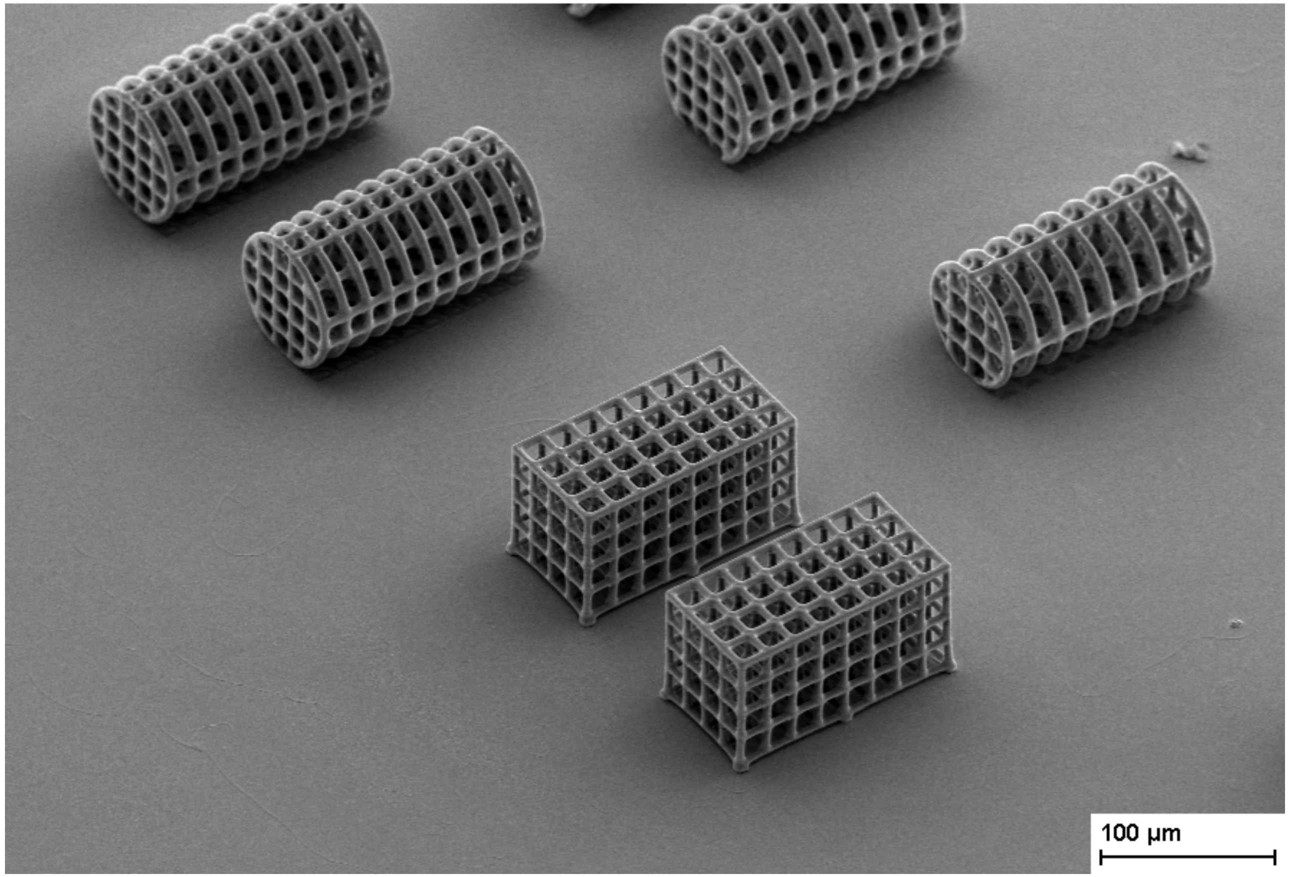



U.S. AIR FORCE
GLOBAL HAWK
HIGH ALTITUDE LONG ENDURANCE
UNMANNED AERIAL VEHICLE SYSTEM
Full Scale Mock-up
NORTHROP GRUMMAN



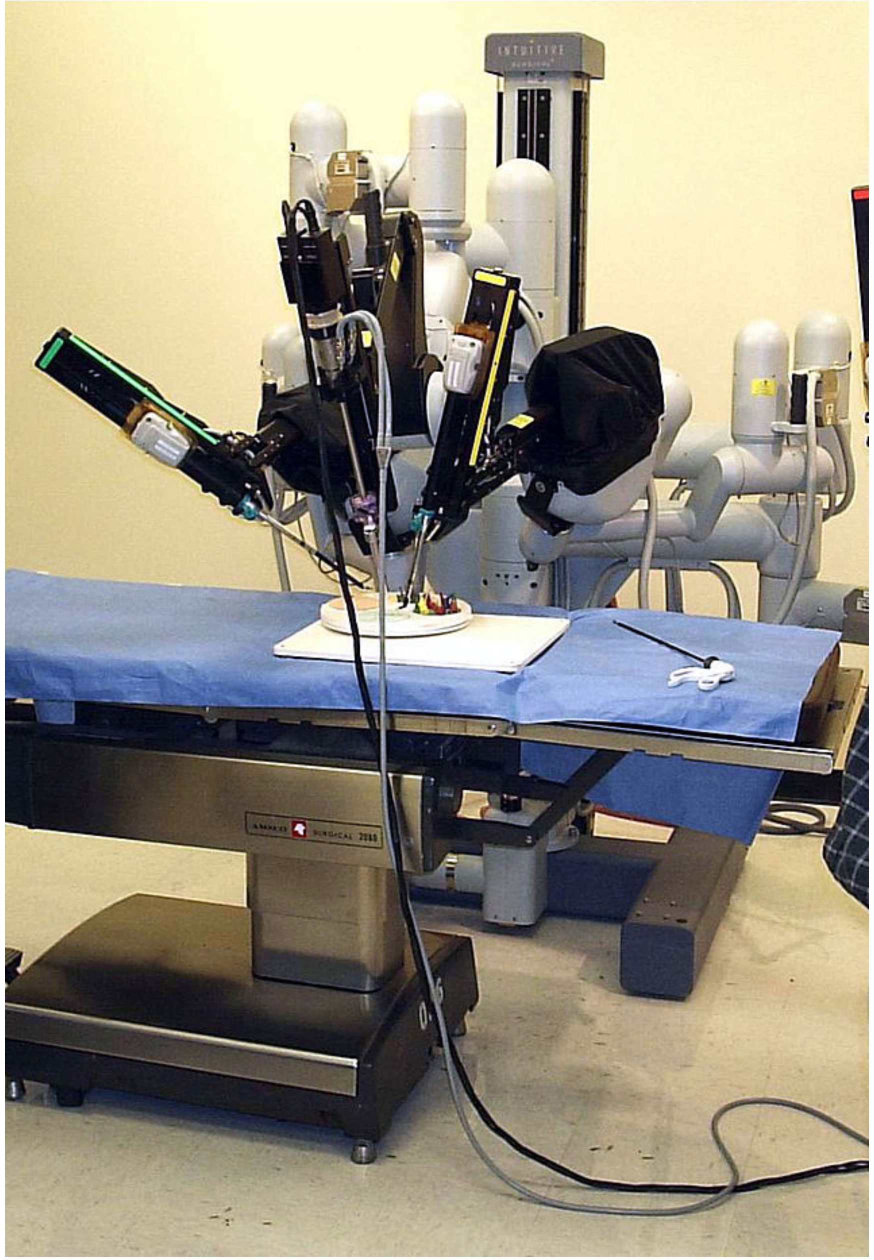





100 µm


EXPLOSIVE


JASON
WOODS HOLE
OCEANOGRAPHIC INSTITUTION

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NXP
CATERPILLAR


en-V

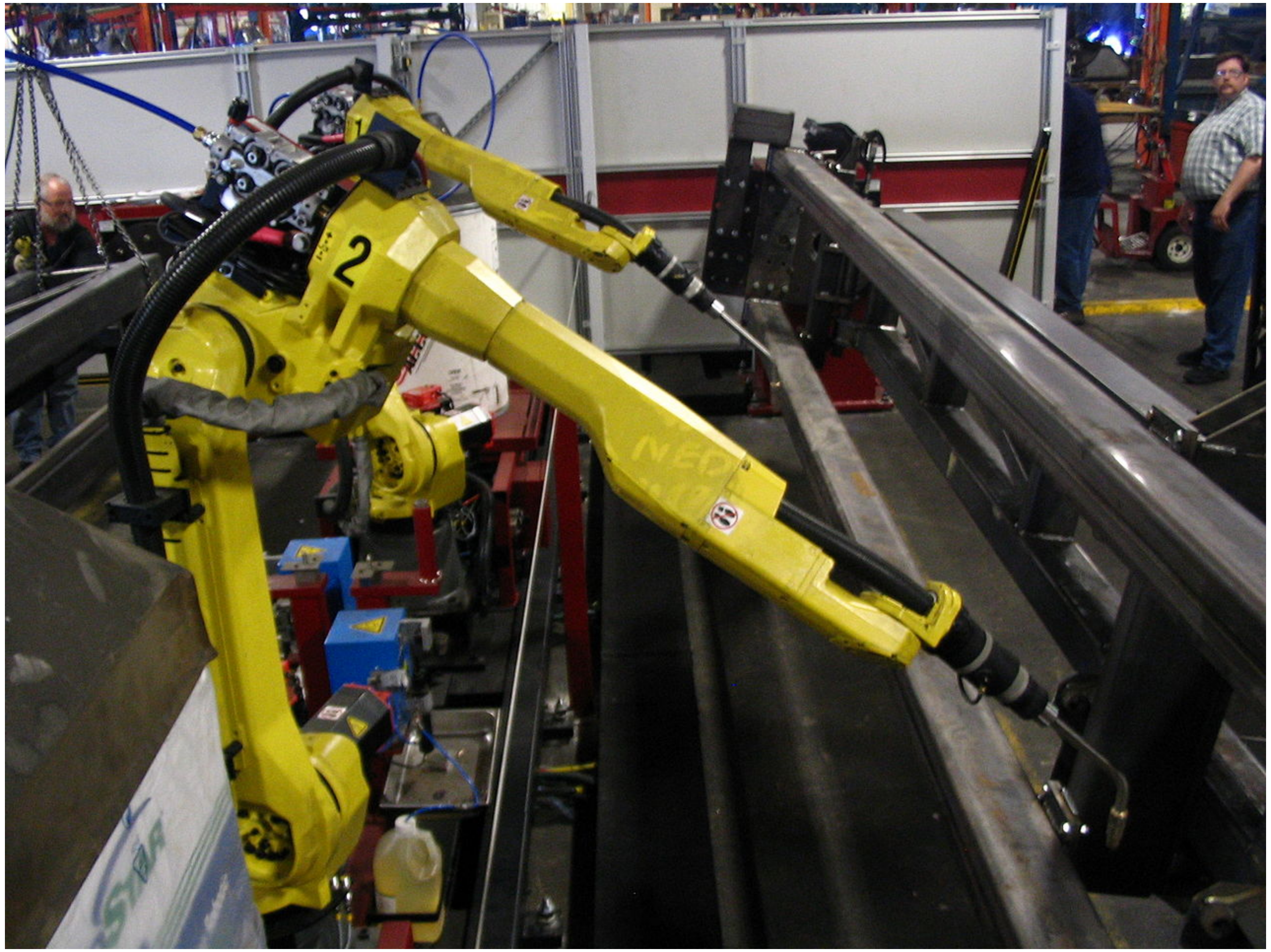
What is your definition for the term

ROBOT ?

Definitions: A Robot is ...

- A machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer (Oxford Dictionaries)
- A mechanical device that sometimes resembles a human and is capable of performing a variety of often complex human tasks on command or by being programmed in advance. (thefreedictionary.com)
- A machine or device that operates automatically or by remote control. (thefreedictionary.com)
- My definition: 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.

Why **Mobile** Robotics?



- 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-operated 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.

- Where am I?
  - Global Positioning System: outdoor, meters of error
  - Guiding system: (painted lines, inductive guides), markers, iBeacon
  - Model of the environment (Map), Localize yourself in this model
    - Build the model online: Mapping
    - Localization: determine position by comparing sensor data with the map
    - Do both at the same time: Simultaneous Localization and Mapping (SLAM)

- 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.

- 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

- 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.

- 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
    - Predict the behavior (motion) of other agents (humans, robots, animals, machines)
  - Planning:
    - Long distance path planning
    - What is the way, optimize for certain parameters

Most important capability

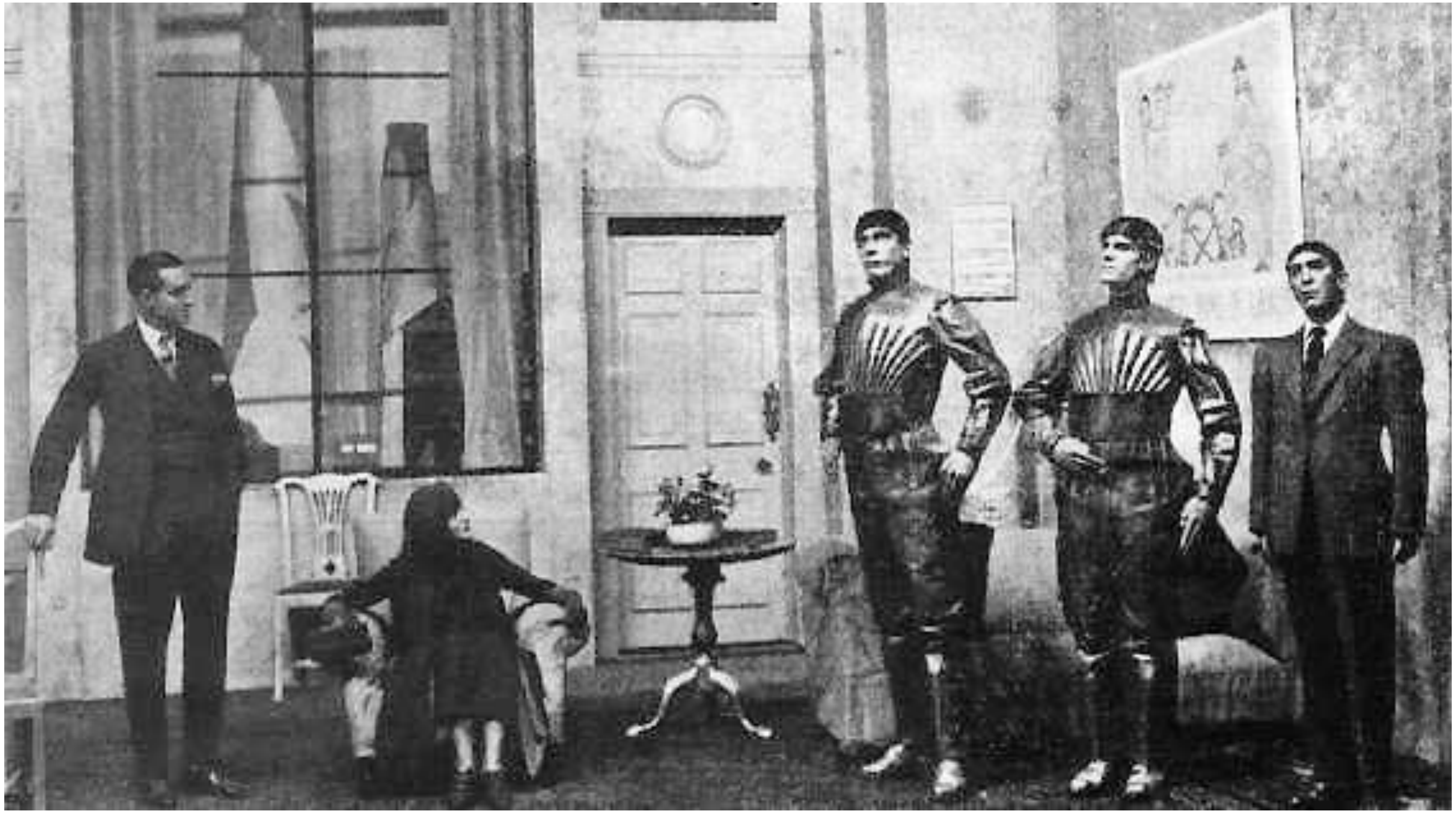
(for autonomous mobile robots)

How to get from place A to B?

(safely and efficiently)

Brief History

Robota “forced labor”: Czech, Karel Čapek R.U.R. 'Rossum's Universal Robots' (1920).



Isaac Asimov - Three Laws of Robotics (1942)

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

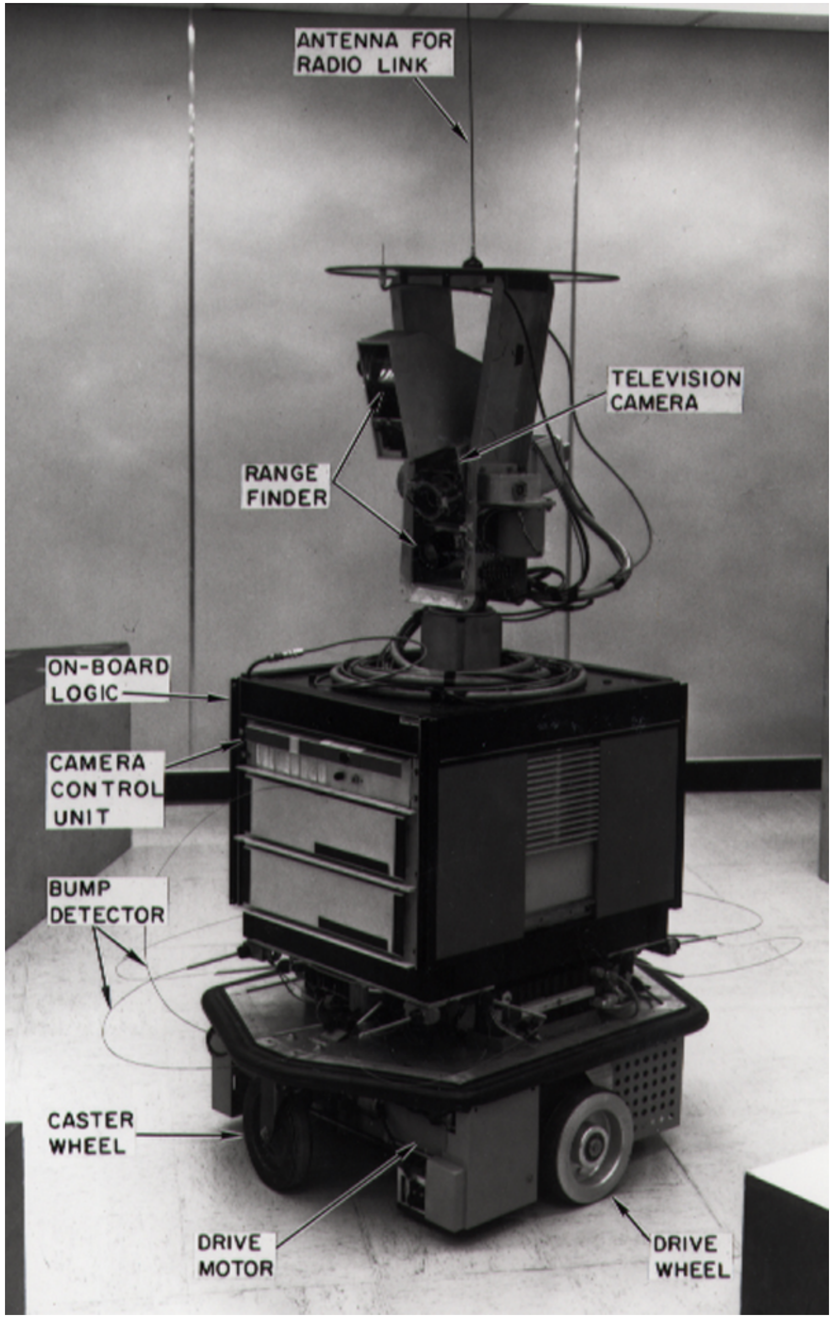
0. A robot may not harm humanity, or, by inaction, allow humanity to come to harm.

History

- First electronic autonomous robots 1949 in England (William Grey Walter, Burden Neurological Institute at Bristol)
  - three-wheeled robots: drive to recharging station using light source (phototaxis)
- Turing Test: 1950 (British mathematician Alan Turing)
- Unimate: 1961 lift hot pieces of metal from a die casting machine and stack them. First industry robot. Inventor: George Devol, user: General Motors.
- Lunokhod 1: 1970, lunar vehicle on the moon (Soviet Union)
- Shakey the robot: 1970
- 1989: Chess programs from Carnegie Mellon University defeat chess masters
- Aibo: 1999 Sony Robot Dog
- ASIMO: 2000 Honda (humanoid robot)

Shakey the robot (1970)

- First general-purpose mobile robot to be able to reason about its own actions
- Advanced hardware:
  - radio communication
  - sonar range finders
  - television camera
  - on-board processors
  - bump detectors
- Advanced software:
  - Sensing and reasoning
- Very big impact



Introductions

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

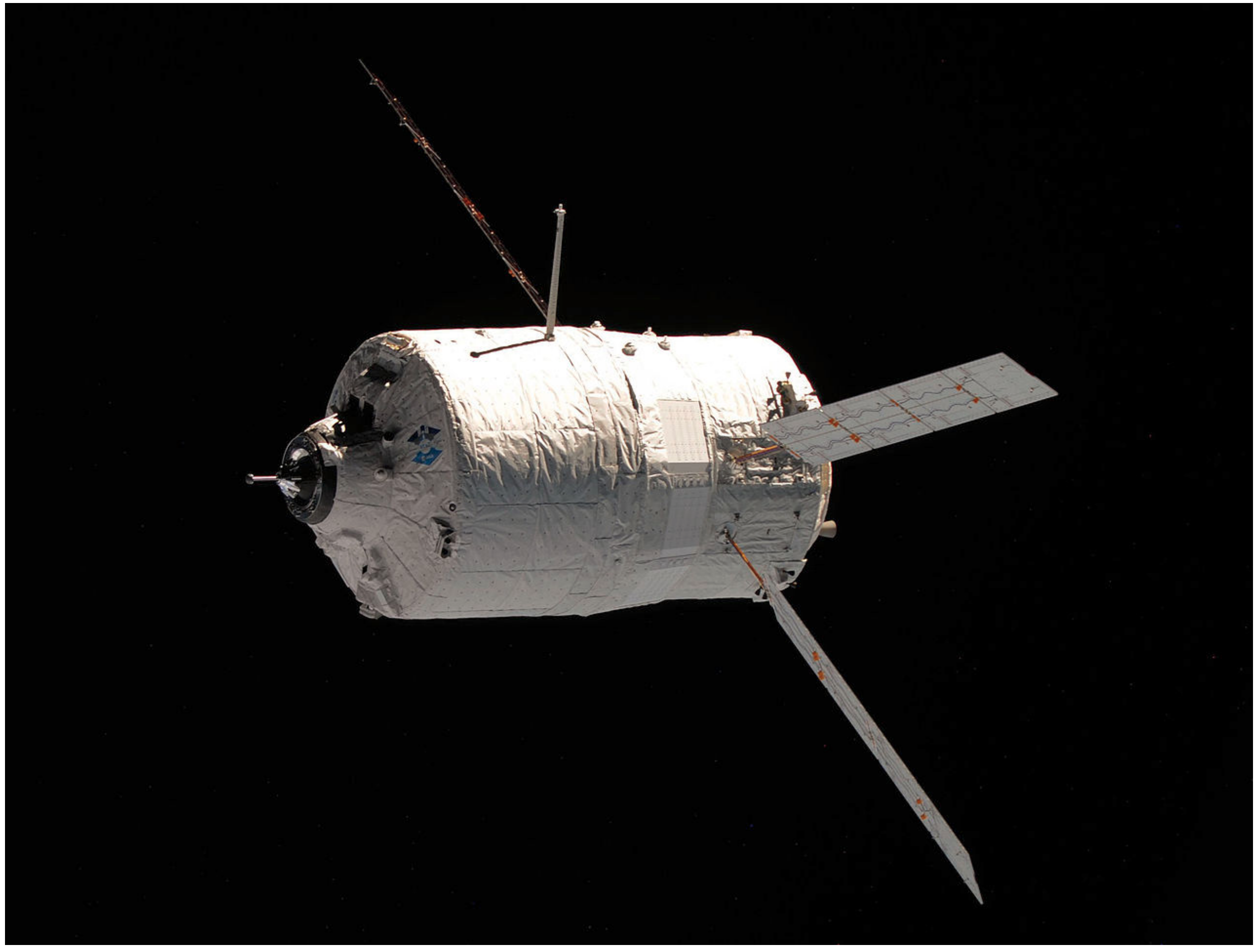
- Transport things from A to B
- In a warehouse, factory or hospital, lab …
- Navigation: guided – wires, tape, reflective markers localized with lasers, using map (SLAM)
- Safety measures when working together with humans!
- Why?
  - Efficiency
  - Speed
  - Safety

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

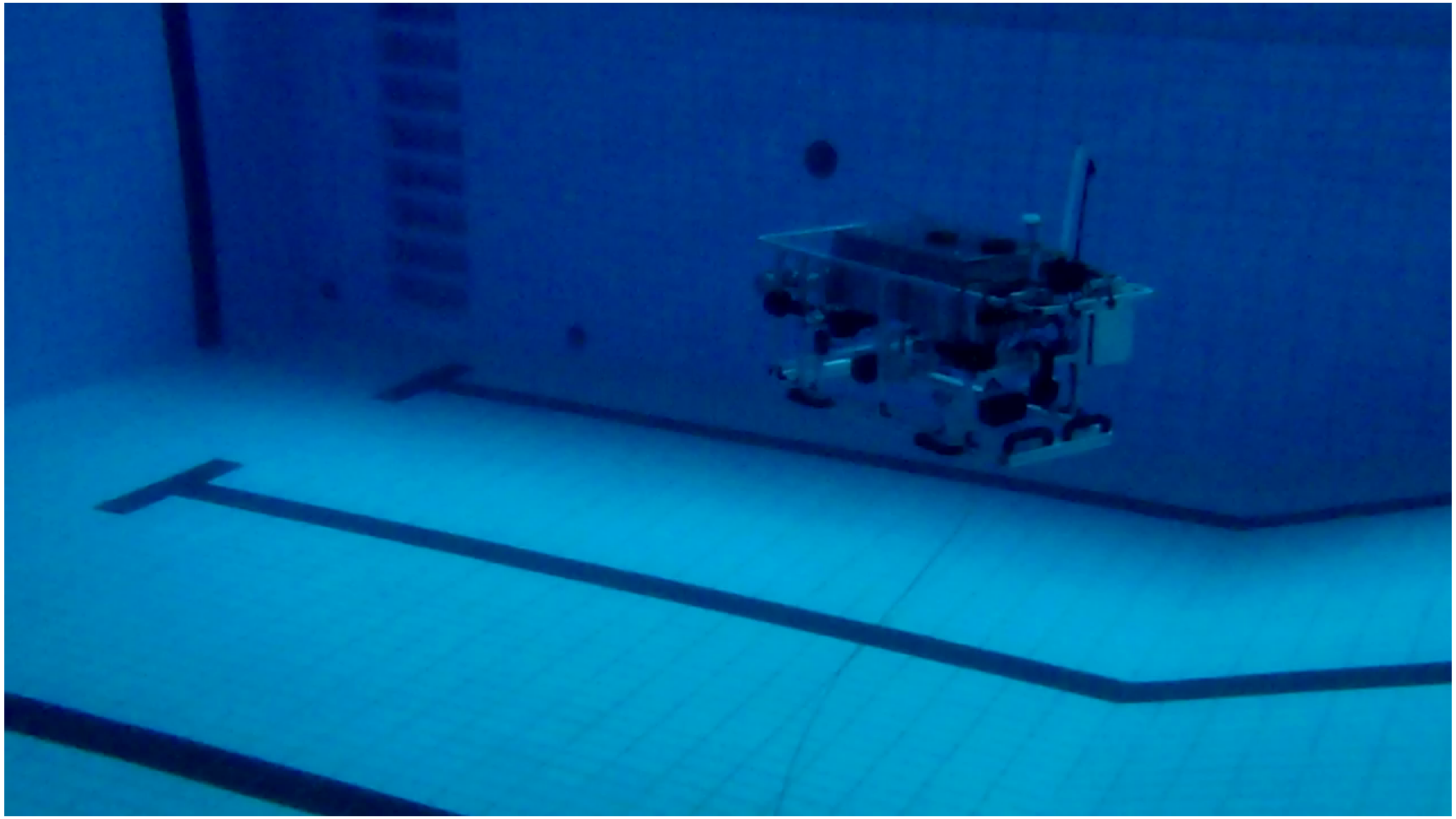
Automated Transfer Vehicle (ATV)

- Supply the International Space Station (ISS) with propellant, water, air, payload and experiments
- Autonomously flies towards the ISS
- Autonomously docks onto the ISS
- European Space Agency – build in Bremen by Airbus
- 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

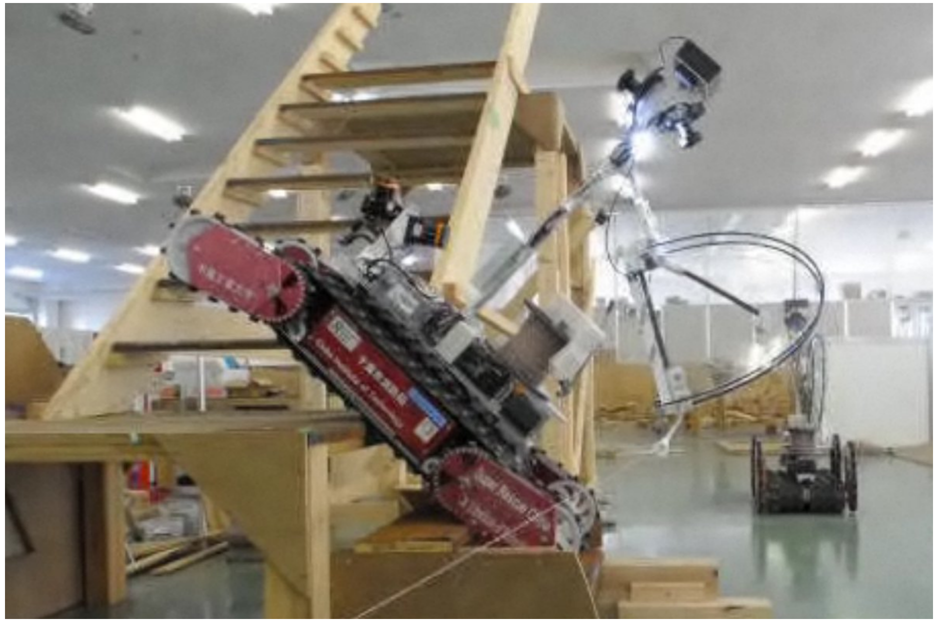


Urban Search and Rescue Robots

- 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

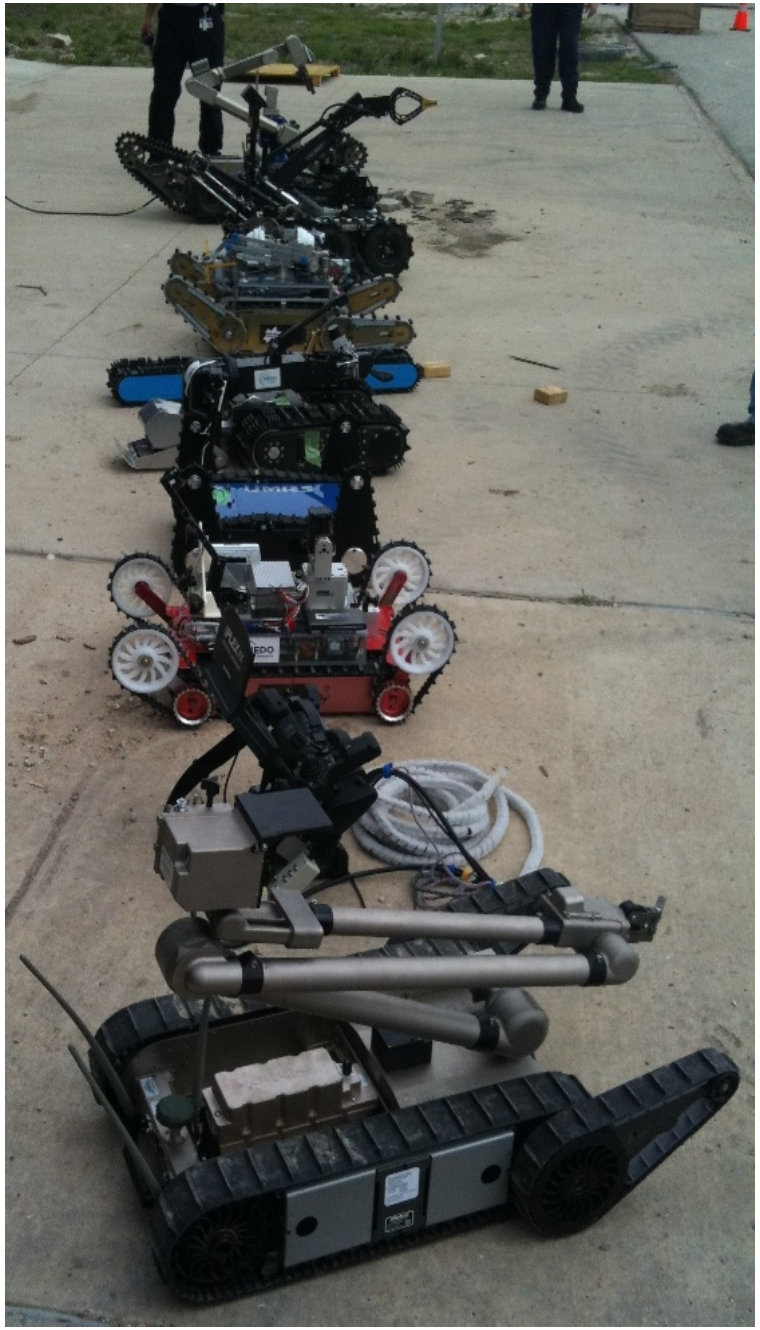
Rescue Robot in Fukushima

- 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!



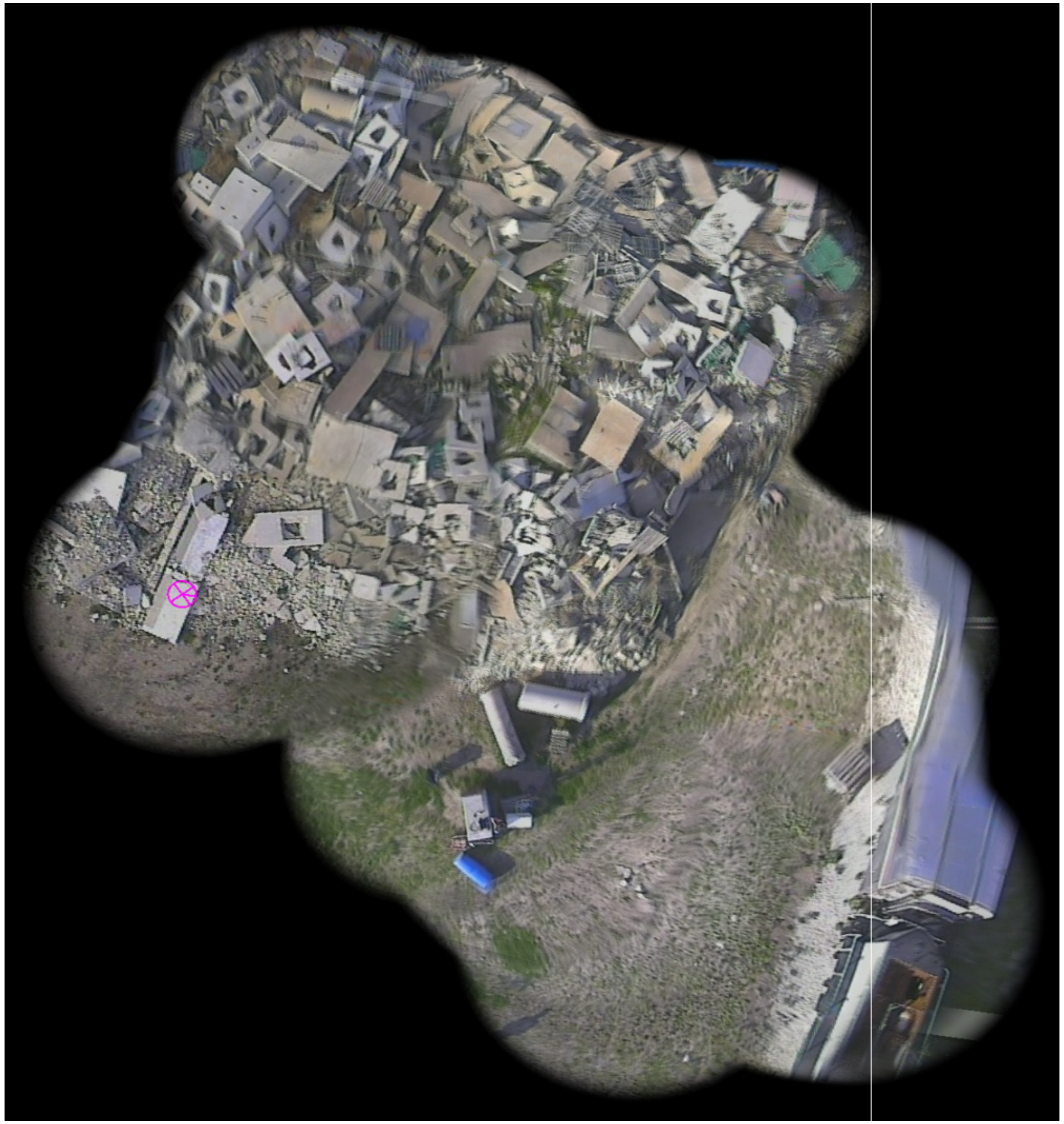
Flying search and rescue robot

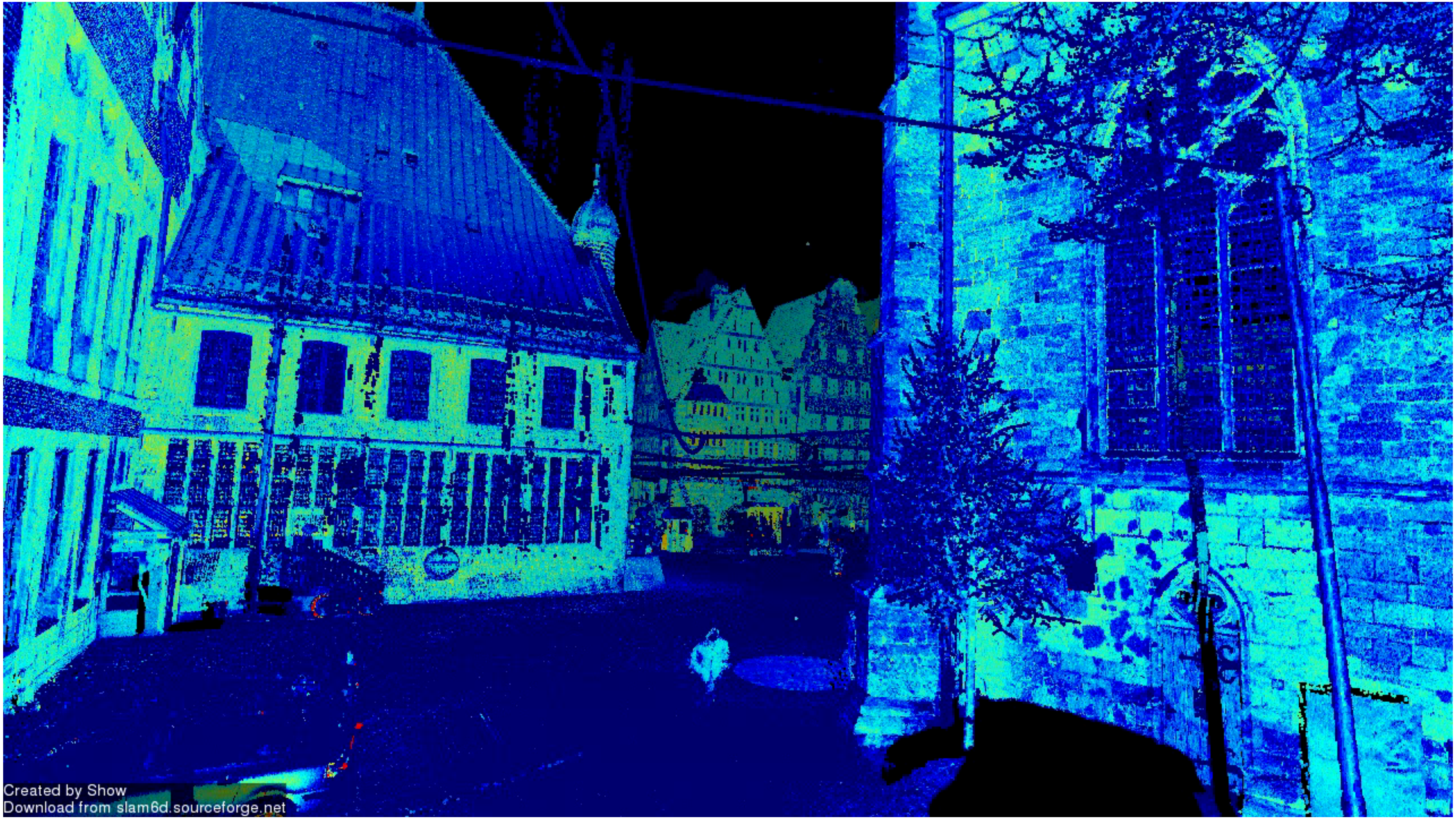
- AirRobot - Quadcopter
- To get overview images
- Image stitching algorithm to create big birds-eye maps

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

Aerial Map

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

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