Lecture 1 – Friday March 8, 2012

Introduction to Robotics

Objectives

When you have finished this lecture you should be able to:

- Understand what robots are and how they can be classified.
- Recognize how science fiction has become science fact in robot history.
- Understand what robots are for, how they can be used, and what they can do.
- Understand the current state-of-the-art of robotics.

Outline

- What is a Robot?
- What is Robotics?
- Science Fiction
- Science Facts
- Robots Today
- Robot Statistics
- Robots' Future
- Summary

Outline

- **What is a Robot?**
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What is a Robot?

What is a Robot?

- **What is the difference between these two VW?**

Stanley, Stanford Racing Team The winner of the 2005 DARPA Grand Challenge

This is a Robot

Original Volkswagen Touareg

This is not a Robot

Why!?

What is a Robot?

- **DARPA Grand Challenge**

  The DARPA Grand Challenge is a prize competition for **driverless cars**.

  - **First Grand Challenge:**

    Date:2004 ,13 hcraM
    Task:veN ,mmirP ot .laC ,wotsraB morf gnihcterts esruoc tresed . (142 mile)
    Winner: .rehsinif a ecudorp ton did
    Only 7.4 mile

  - **Second Grand Challenge:**

    Date:2005 ,8 rebotcO
    Winner: maeT gnicaR drofnatS
    ni esruoc elim-132 eht detelpmoc
    7 rednu tsujhours to win a US$2M prize. (2nd place in 2007 Urban chanllenge)

What is a Robot?

- **DARPA Grand Challenge**
  - **Urban Challenge:**

    Took place on November 3, 2007 The course involved a 96 km (60 mi) urban area course, to be completed in less than 6 hours. Rules included obeying all traffic regulations while negotiating with other traffic and obstacles and merging into traffic.

  - **Google driverless car**

    The Google driverless car is a project by Google that involves developing technology for driverless cars.

What is a Robot?

- **What is the difference between these two VW?**

A robot is a machine that **imitates** the actions and sometimes appearance of an intelligent creature, usually a human

Perceiving Environment: gnitteg sgnidnuorrus sti morf noitamrofni

Doing something physical: such as move or manipulate objetcs, based on environmental information

What is a Robot?

- **Robot vs. Computer**

Term	Computers	Robots
Inputs	Input symbols are static and well behaved	Sensory signals are noisy and unreliable
Results	Operations give consistent results	An action have different responses
Environment	Environment is fixed and repeatable	Objects may move about independently
Influences	System only receives intended inputs	Influences from external agents can interfere
Performance	Perfect performance assumed for computing environment	Operating environment is unreliable, dynamic and incomplete

What is a Robot?

- **Robot vs. Human**

Term	Human	Robots
speed, precision, repeatability, working in harsh environments	Low performance	Perform better
Creativity	Creative	Uninspired
Permanency of Intelligence	Human intelligence is perishable.	Robot intelligence is permanent
Ease of duplication and dissemination of knowledge	Length process, some expertise can never be duplicated	Knowledge can be copied from a robot and easily moved to another one.
Initial Cost	Lower	Higher
Running Cost	Higher	Lower

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What is Robotics?

- Robotics is the intelligent connection of perception to action.

M. Brady, "Artificial Intelligence and Robotics," Artificial Intelligence, 26, pp.79-121, 1985.

- Robotics is the discipline which involves:

a) The design, manufacture, control, and programming of robots;

b) The use of robots to solve problems;

c) The study of the control processes, sensors, and algorithms used in humans, animals, and machine; and

d) The application of these control processes and algorithms to the design of robots.

MP. J. McKerrow. *Introduction to Robotics*. Addison-Wesley, 1992.

Outline

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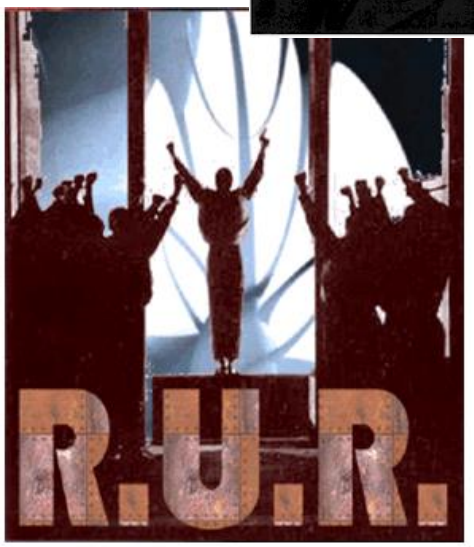
Science Fiction

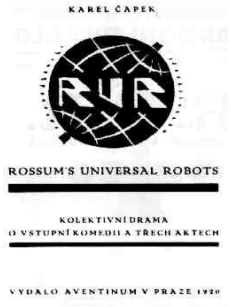
- **Rossum's Universal Robot (R.U.R)**

Karel Capek (1890-1938) was a Czech novelist who introduced the word `robota' in a 1920 play titled Rossum's Universal Robots (RUR).

Robota in Czech (Robot in English) is a word for **worker or servant**.

The word Robot displaced older words such as **automaton or android** in languages around the world.





Science Fiction

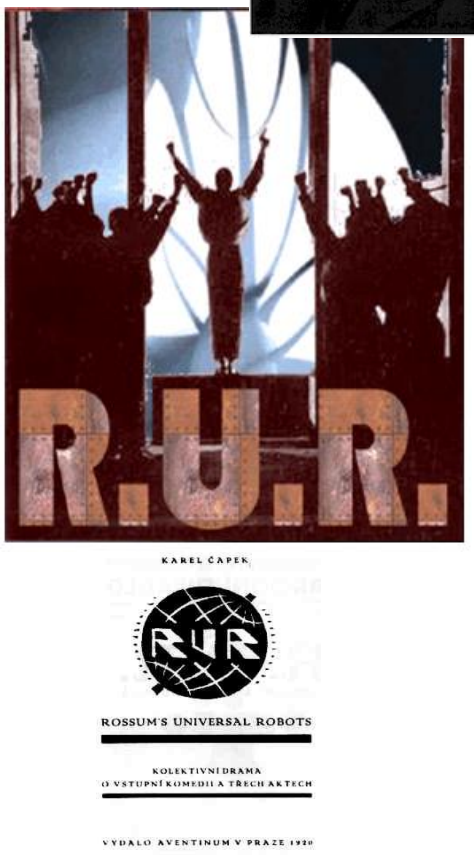
- **Rossum's Universal Robot (R.U.R)**

Domin: Practically speaking, what is the best kind of worker?

Helena: The best? Probably the one who-- who-- who is honest-- and dedicated.

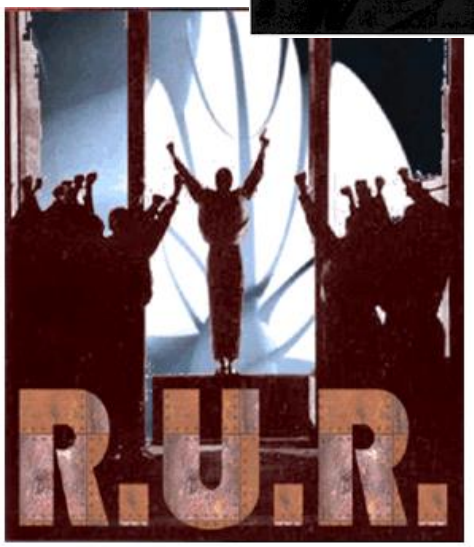
Domin: No, it's the one that's the cheapest. The one with the fewest needs...

[Young Rossum] chucked out everything not directly related to work, and [in] doing that he virtually rejected the human being and created the Robot.



Science Fiction

- **Rossum's Universal Robot (R.U.R)**



The play RUR featured robots that nearly took over the world.

They stopped only when they could not answer the question:

"What do we do after we have destroyed all of the humans?"

Science Fiction

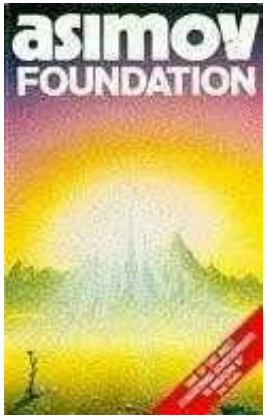
- **Laws of Robotics - Isaac Asimov**

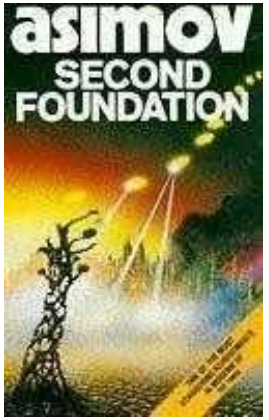
Law 1:

A robot may not injure a human being or through inaction, allow a human being to come to harm.

Law 2:

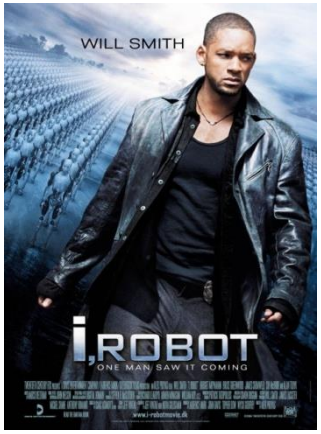
A robot must obey the orders given it by human beings, except where such orders would conflict with the 1st Law.

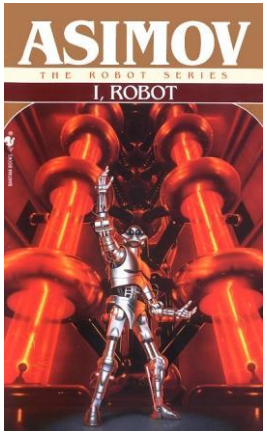


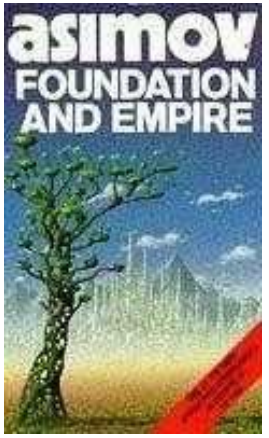


Law 3:

A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.







Zeroth Law:

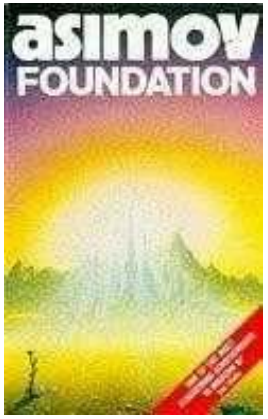
A robot may not injure humanity, or, through inaction, allow humanity to come to harm.

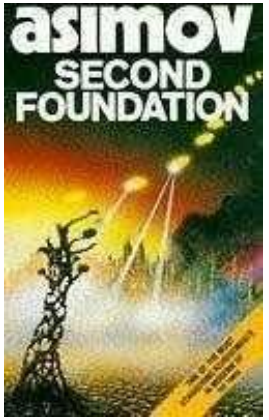
Science Fiction

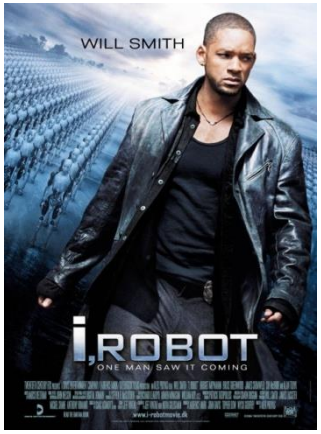
- **Laws of Robotics - Isaac Asimov**

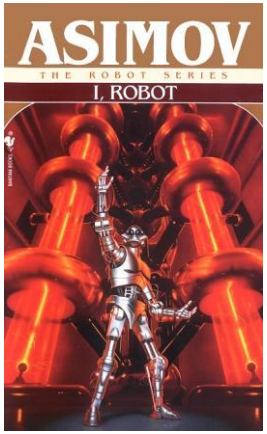
Using robots to kill without violating the laws of robotics

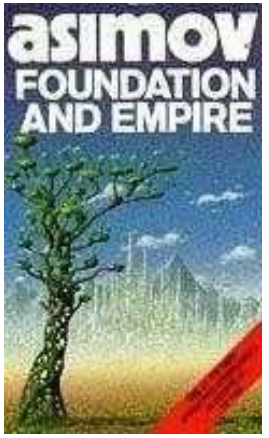
- Telling a robot to build a bear trap on the woods (to protect humans!) and
- a second robot (independently) to take a man for a walk in the woods (to protect this man!)





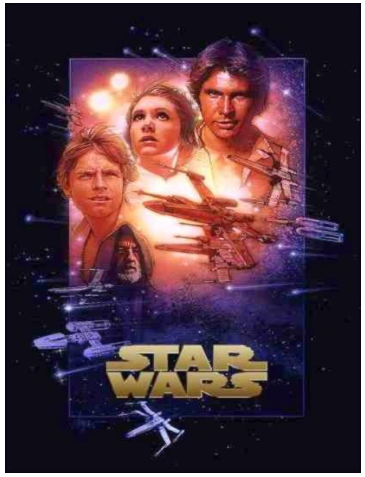


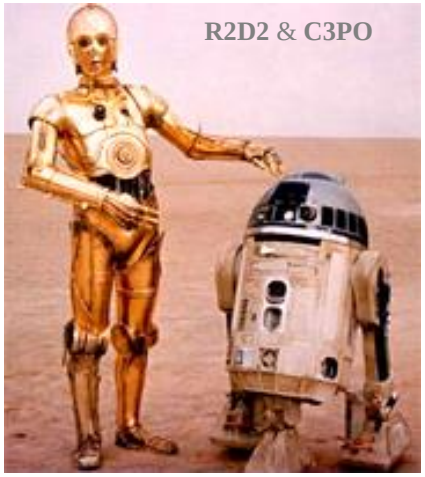


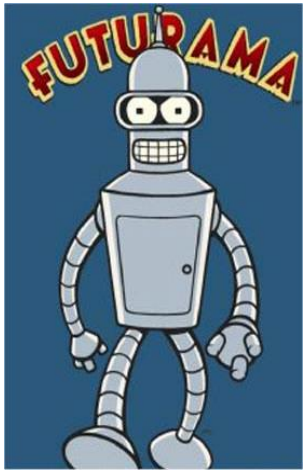


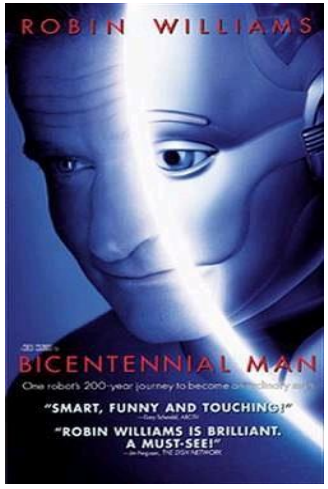
Science Fiction

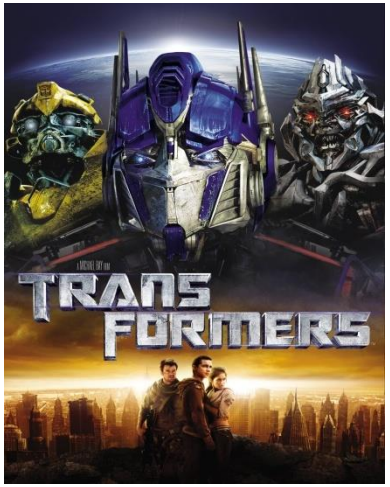
- **Science Fiction Classics & Movies**











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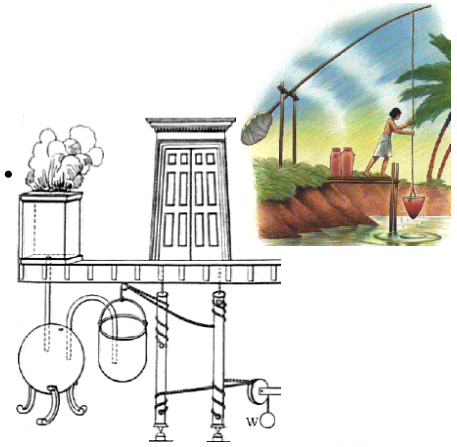
Science Facts

- **Mechanical Automata**



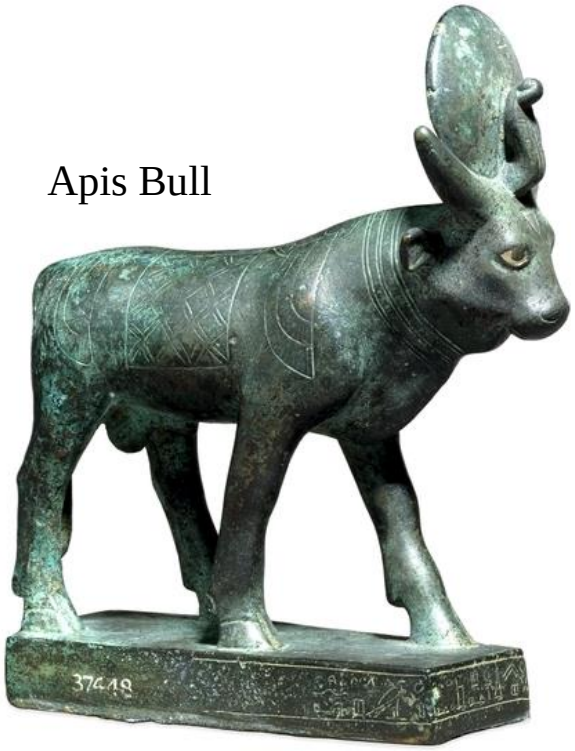
➢ Ancient Greece & Egypt Water powered for ceremonies.

➢ Apis Bull God

"Then he brought out (of the fire) before the (people) the image of a calf: It seemed to low: so they said: This is your god, and the god of Moses, but (Moses) has forgotten!", Holy Qur'an, Surat Ta-ha verse 88.

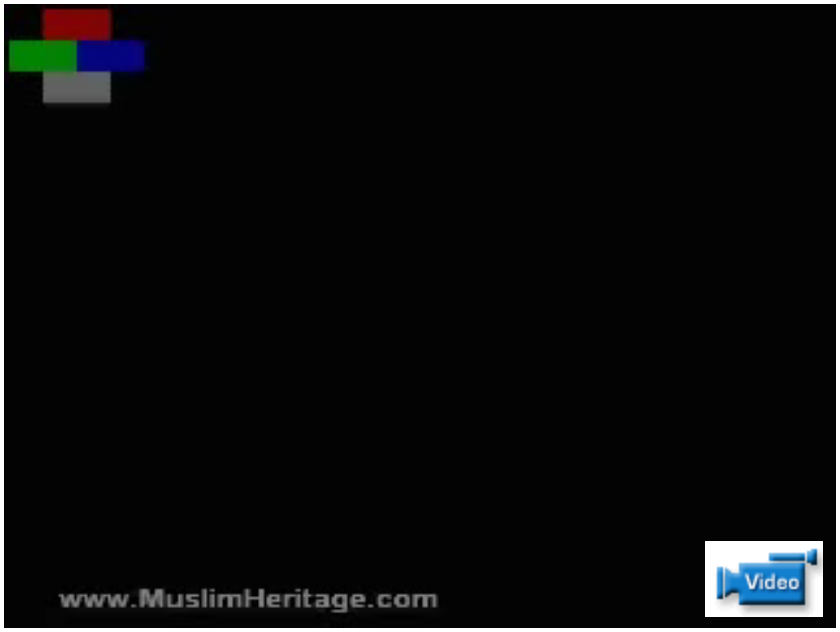
"And all the people brake off the golden earrings which were in their ears, and brought them unto Aaron. And he received them at their hand, and fashioned it with a graving tool, after he had made it a molten calf: and they said, These be thy gods, O Israel, which brought thee up out of the land of Egypt." – Holy Bible, Exodus 32:3,4

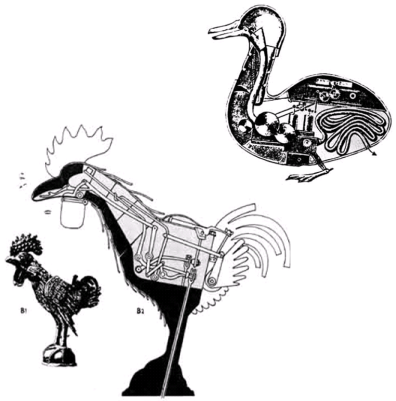
Apis Bull



Science Facts

- **Mechanical Automata**
  - The Elephant Clock: Leaf from The Book of Knowledge of Ingenious Mechanical Devices by Al-Jazari (1206 AD).





  - 14th – 19th century Europe Clockwork driven for entertainment.

Science Facts

- **Mechanical Automata**
  - Mechanical Dolls – Droz Family (1770)

  - Maillardet (1805)

Science Facts

- **History of Robots**
  - 1928: First motor driven automata
  - 1961: First industrial robot (Unimate)
  - 1962: First robot company (Unimation)
  - 1967: Shakey Autonomous mobile research robot

Shakey

  - 1969: Stanford Arm Dexterous, electric motor driven robot arm.

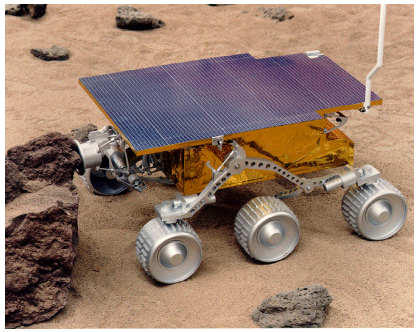
George Devol

Joseph F. Engelberger

Unimate

Science Facts

- **History of Robots**
  - 1978: The PUMA (Programmable Universal Machine for Assembly) robot is developed by Unimation with a General Motors design support.
  - 1980s: The robot industry enters a phase of rapid growth. Many institutions introduce programs and courses in robotics. Robotics courses are spread across mechanical engineering, electrical engineering, and computer science departments.



SCARA (Selective Compliance Assembly Robot Arm) invented by Makino in 1982.

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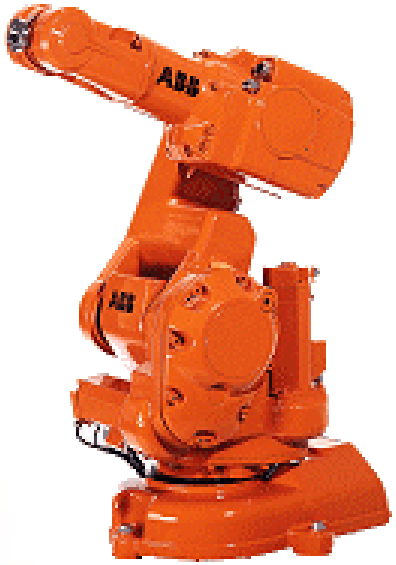
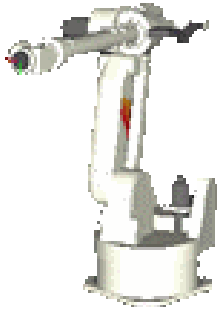
Robots Today

- **Industrial Robots or Manipulators**





Robots Today

- **What Can Industrial Manipulators Do?**

➢Material handling

➢Material transfer

➢Machine loading and/or unloading

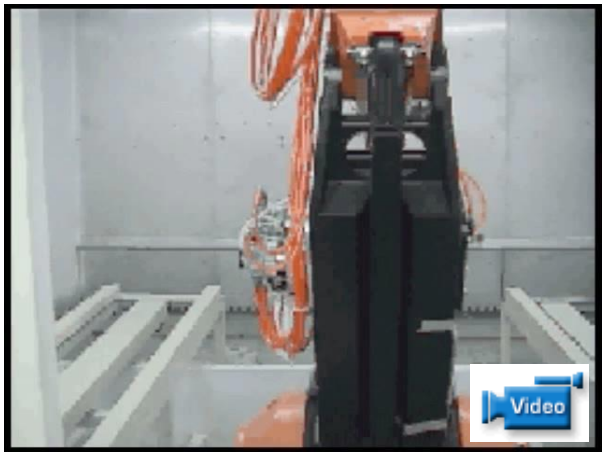
➢Spot welding

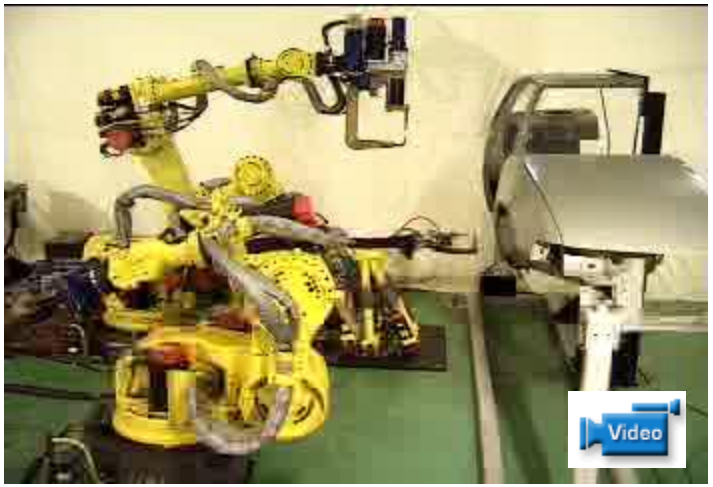
➢Continuous arc welding

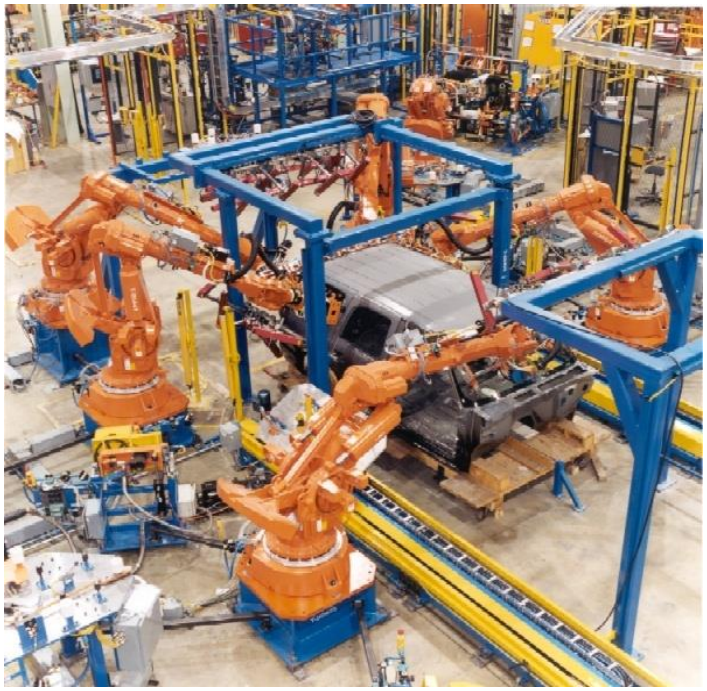
➢Spray coating

➢Assembly

➢Inspection







Robots Today

- **Mobile Robots**

  A mobile robot is a robot that can move in the real world and can be completely autonomous

  The main features:

  - Reprogrammability
  - The ability to navigate
  - Autonomy

Robots Today

- **Mobile Robots: Indoor Robots**

B21

Koala

Magellan Pro

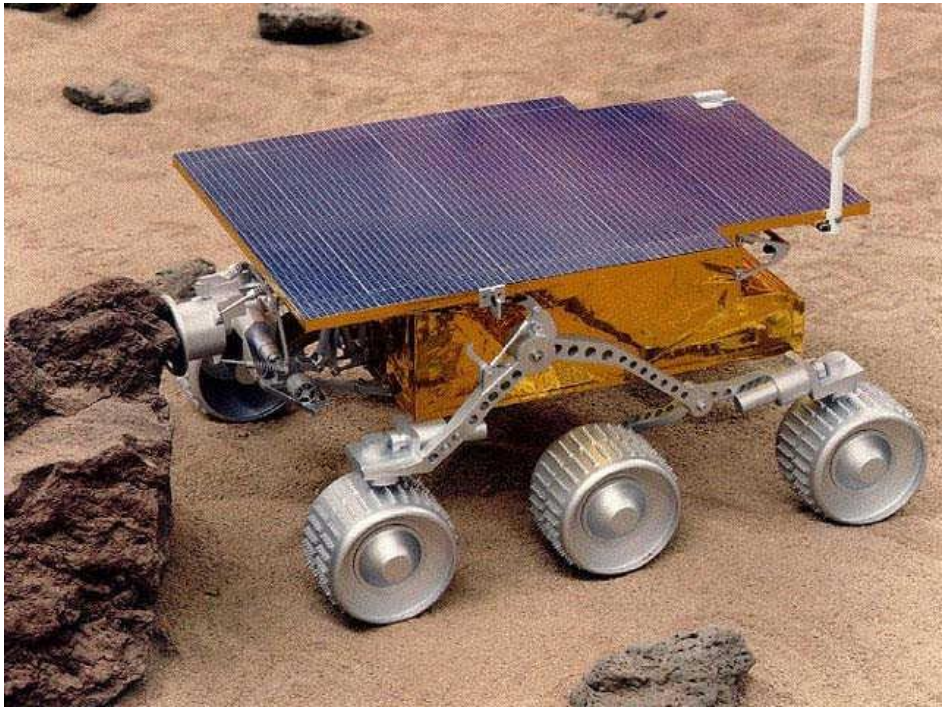
Hemisson

Khepera

Cybor

Robots Today

- **Mobile Robots: Outdoor Robots**



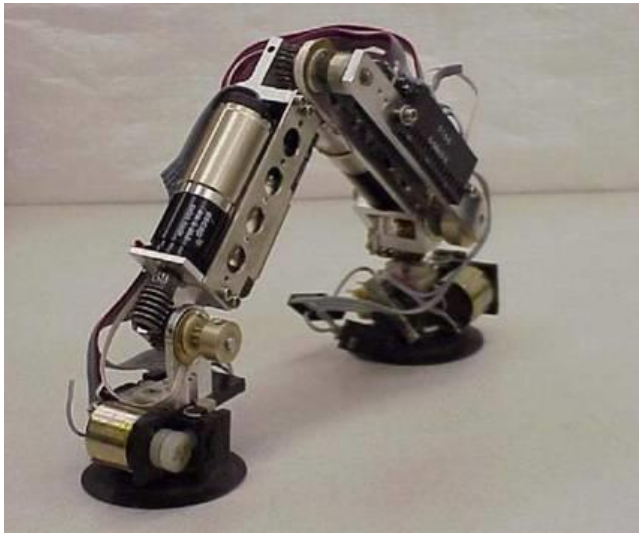
Sojourner

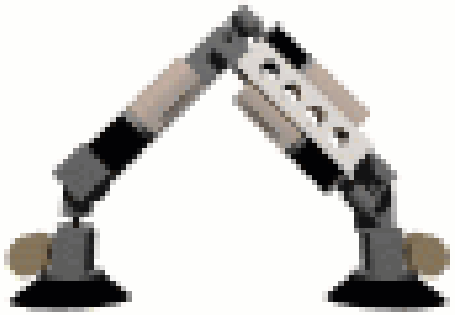
PackBot Explorer

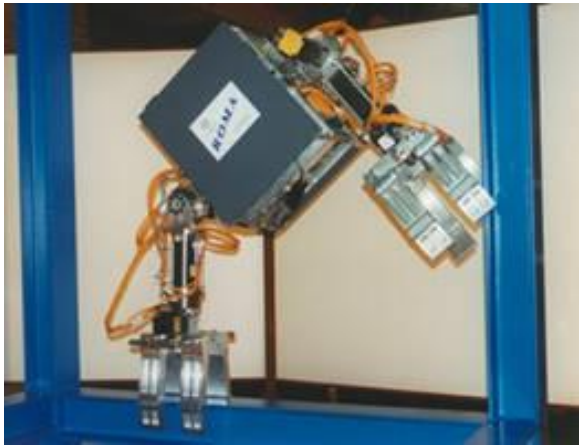
ROCA (UC3M)

Robots Today

- **Climbing Robots**







ROMA-I (UC3M)

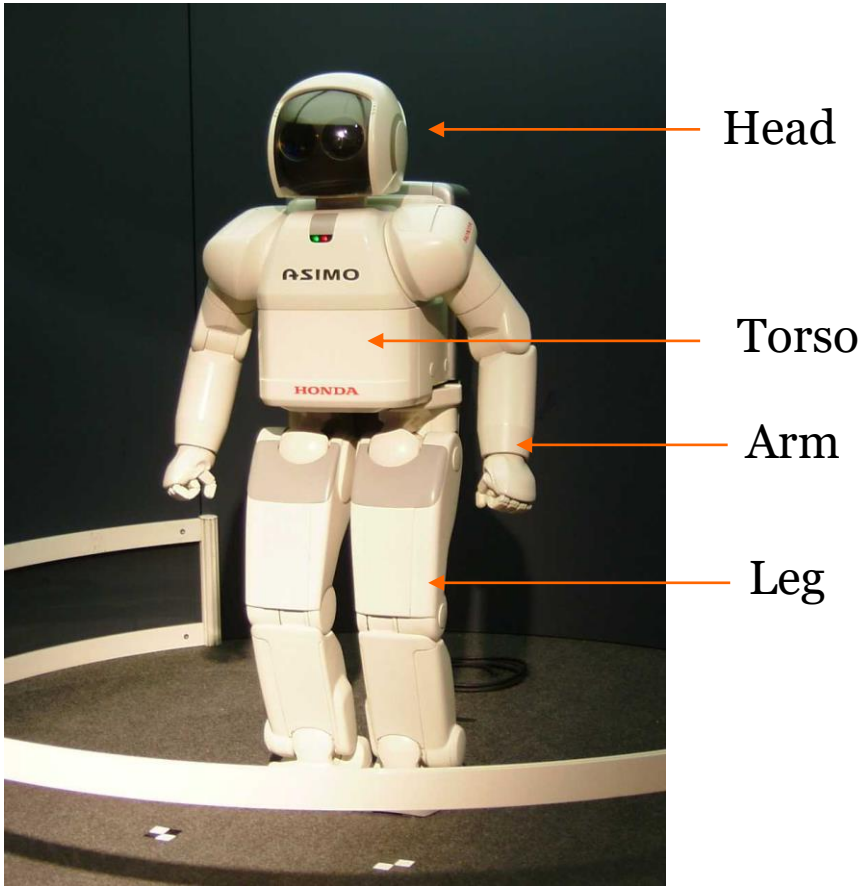
Robots Today

- **Humanoid Robots**

A humanoid robot is a robot with its overall appearance based on that of the human body. In general humanoid robots have a torso with a head, two arms and two legs, although some forms of humanoid robots may model only part of the body, for example, from the waist up.

male ➢ Androids

female ➢ Gynoids



Robots Today

- **Humanoid Robots**

Physically anthropomorphic

ASIMO

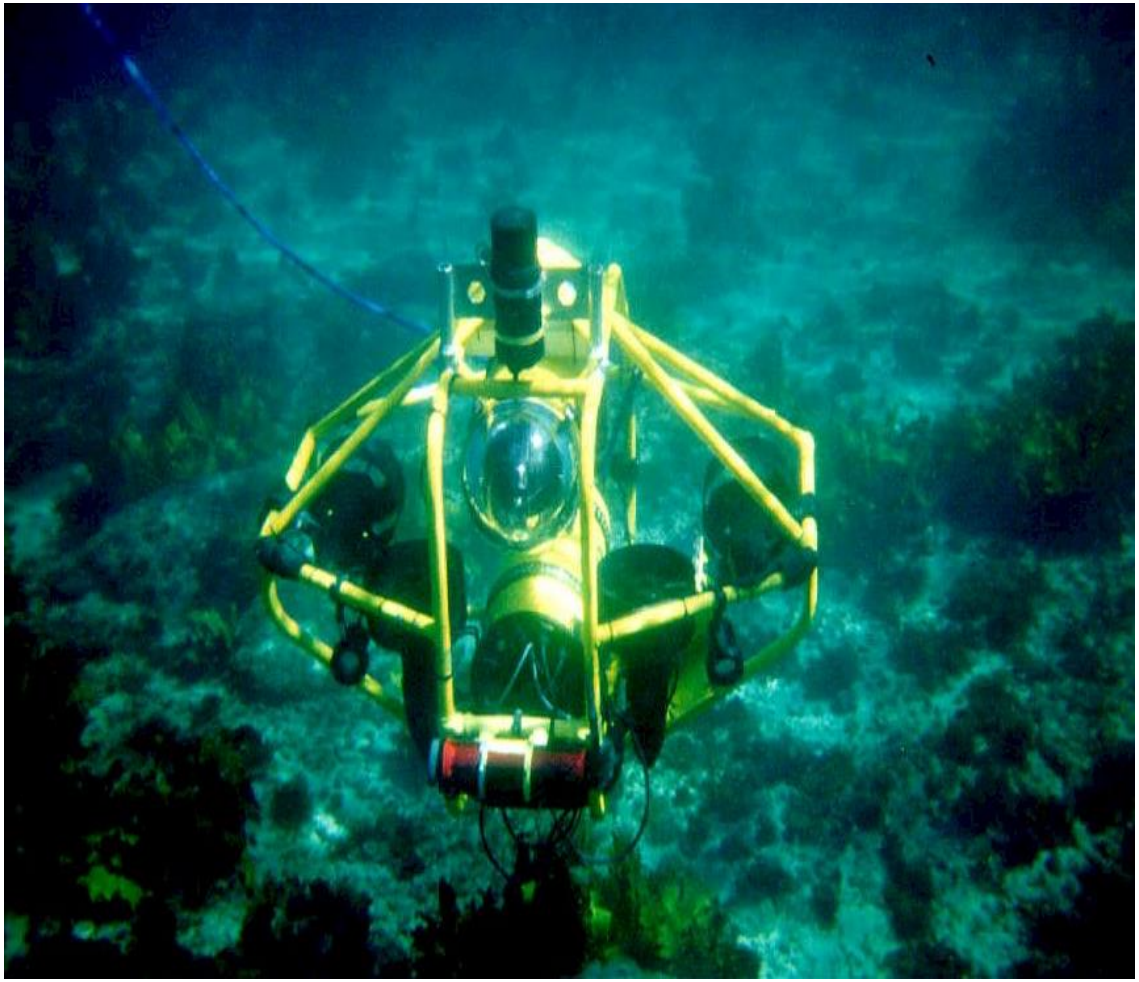
QRIO

RH-1 (UC3M)

Bicycling robot - Murata Boy

Robots Today

- **Underwater or Submarine Robots**

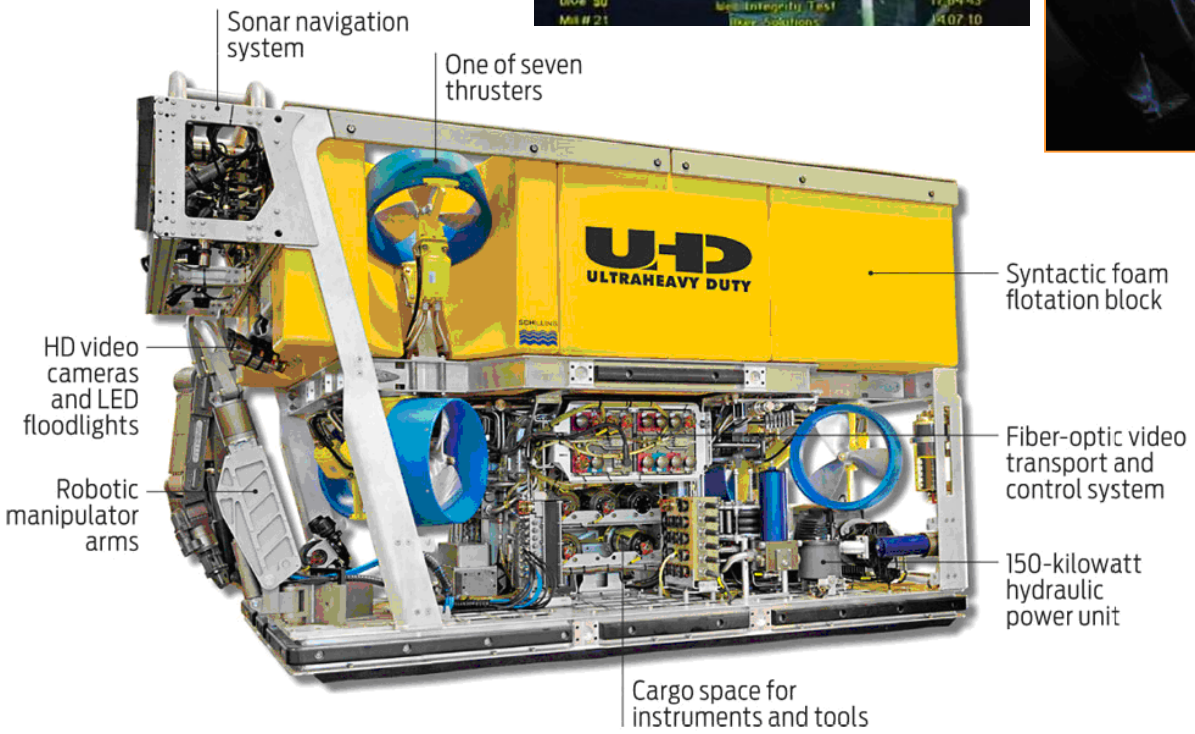


Robots Today

- **Underwater or Submarine Robots**

BP's Deepwater Horizon oil rig problem in the Gulf of Mexico

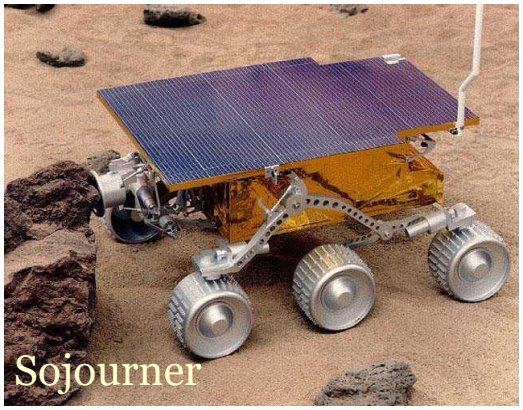
U.S. Coast Guard

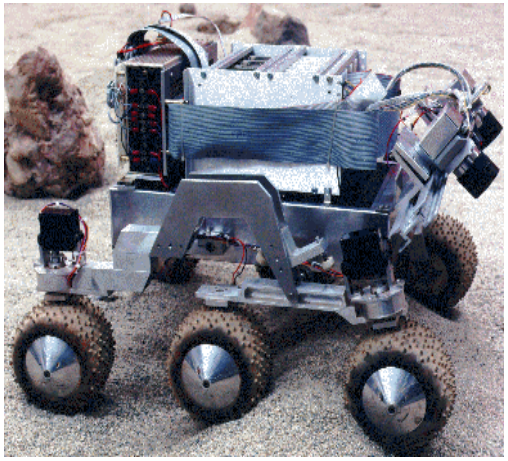


Work-class ROVs are designed by Schilling Robotics to do power-intensive work hundreds of meters below the surface

Robots Today

- **Space Exploration Robots**





Robots Today

- **Space Exploration Robots**

NASA Mars mission

The Curiosity rover is designed to travel Mars studying climate and geology. The rover is looking for signs of carbon, the building blocks of life. Some of the rover's features:

Robotic arm
Used to examine and manipulate soil and rocks; it also has two scientific instruments, one uses X-rays to determine materials' composition and the other is a magnifying camera

Laser
Burns small holes in rocks and soil up to 23 feet away and identifies chemical elements

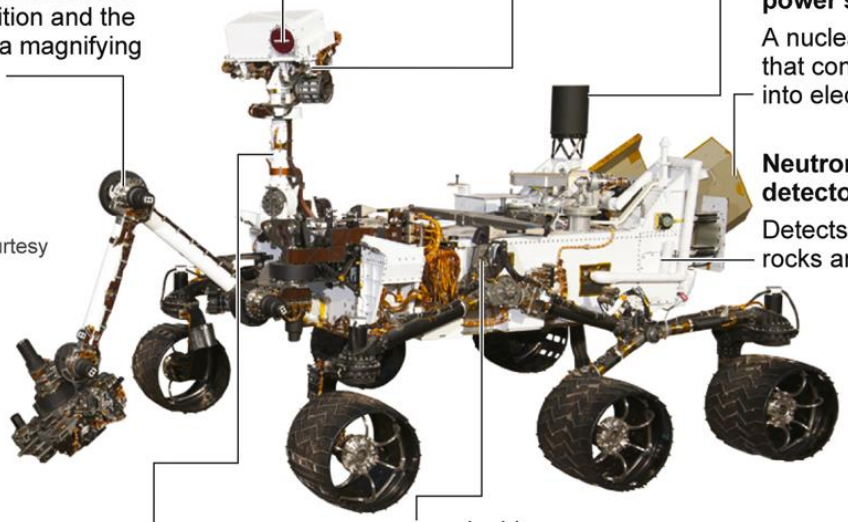
Color cameras
Stereo mastcams on either side of the rover's mast take color pictures and movies in 3-D

UHF antenna
Primary transmission antenna

Plutonium power source
A nuclear battery that converts heat into electricity

Neutron detector
Detects water in rocks and soil

Photo courtesy of NASA



Weather station
Records wind speed/ direction, air pressure, humidity, temperature and UV radiation

Radiation detector
Measures radiation from the sun, supernovae and other sources

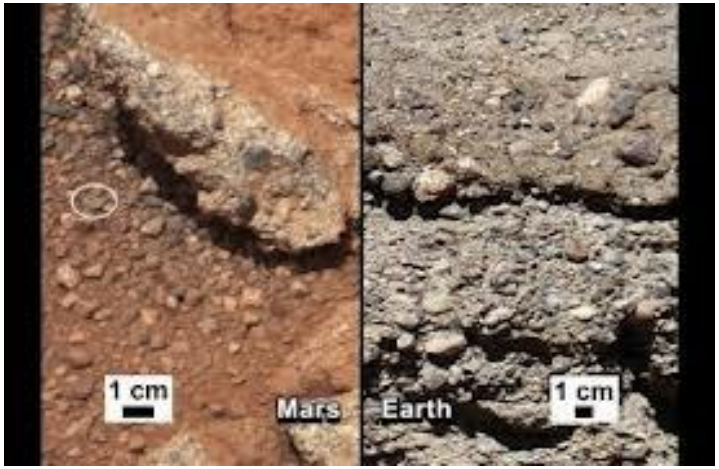
Inside:

Chemistry lab
Analyzes rock and soil samples for organics

Mineral detector
Shines an X-ray beam at a rock or soil sample to identify types of minerals

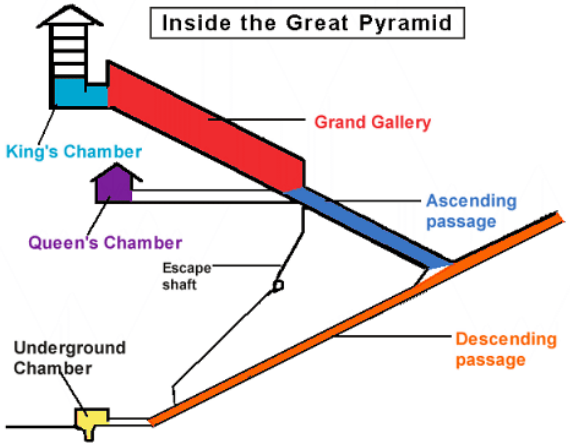
SOURCE: NASA AP

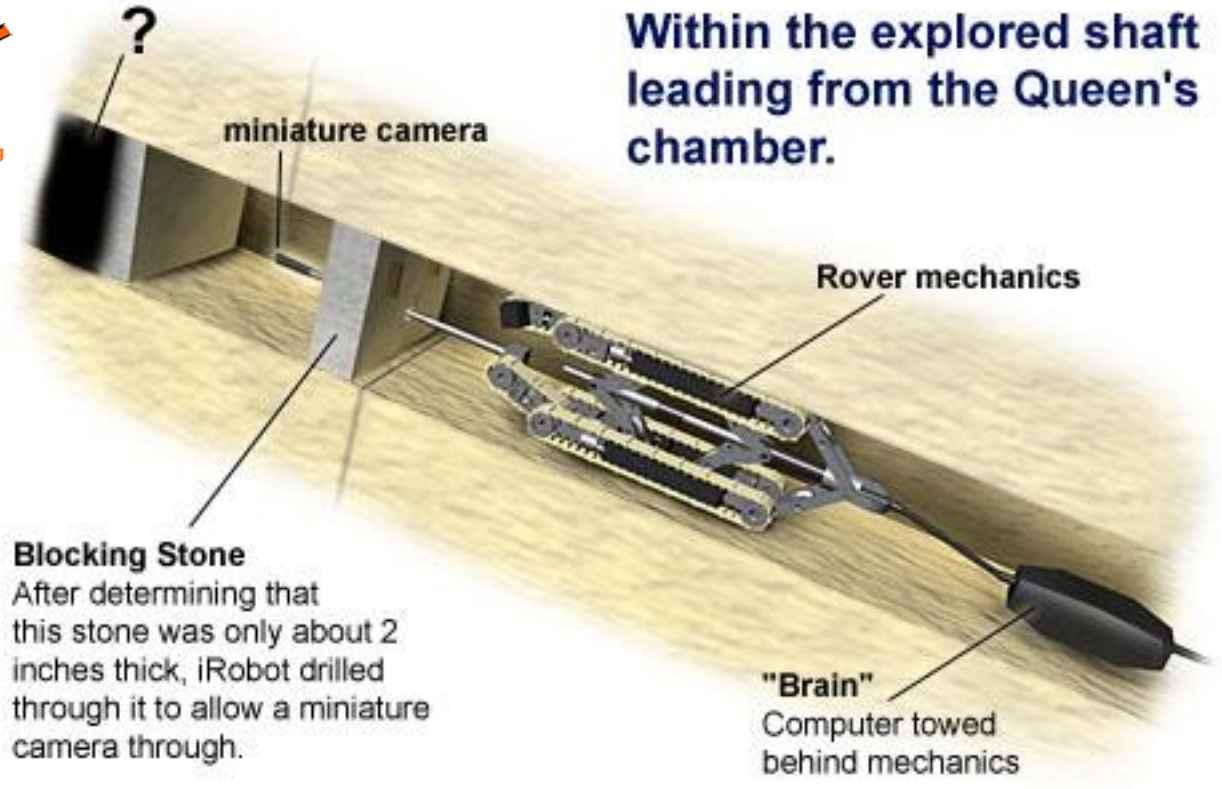
Curiosity



Robots Today

- **Exploration Robots**





Robots Today

- **Military Robots**

"Future Combat System is a major program for an entire System of Systems to transform the U.S. Army to be strategically responsive and dominant at every point on the spectrum of operations, through real-time network-centric communications and systems for a family of manned vehicles and unmanned platforms by the next decade".

R-Gator: Autonomous Unmanned Ground Vehicle

Robots Today

- **Unmanned Vehicles**

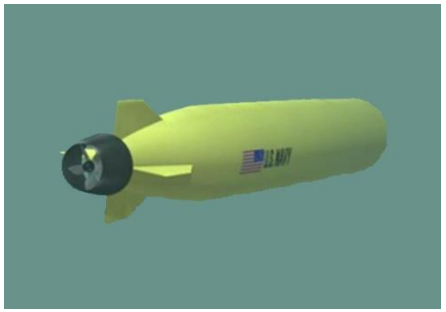
UXVs

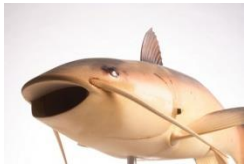
Unmanned Ground Vehicles (UGV)

Unmanned Aerial Vehicles (UAV) & Micro Aerial Vehicles (MAV)

Unmanned Surface Vehicles (USV)

Unmanned Underwater Vehicles (UUV)





Robots Today

- **Unmanned Ground Vehicles (UGVs)**

Boston Dynamics BigDog
Robot The Army mule
YouTube

Boston Dynamics
RHex
YouTube

Robots Today

- **Unmanned Aerial Vehicles (UAVs or Drones)**
  - There are 17,300 drones in the US army inventory.
  - These drones can carry up to 3000 pounds of weapons.
  - Fabricated by Boeing

UAV carrying Viper Strike Weapon System

A forward looking infrared (FLIR) camera mounted on the side of an UAV

Robots Today

- **Unmanned Aerial Vehicles (UAVs or Drones)**

AH-64 (25)
39,805 Hours

(43) UH-60
28,460 Hours

CH-47(26)
31,688 Hours

(4) Fixed Wing
7,483 Hours

UAV (7 Raven)
685 Hours

(0) OH-58*
3,413 Hours

109,534 Total Hours: 01 Feb 03 – 15 OCT 05

Source: Brigadier General E.J. Sinclair, 2005 UAVS Symposium

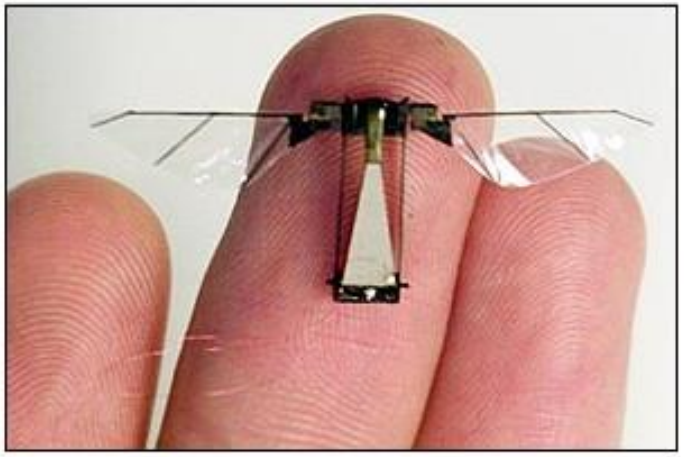
Robots Today

- **Micro Aerial Vehicles (MAVs)**

Micro Aerial Vehicles (MAV) are used in **spying missions**, where they quite literally serve as a "**fly on the wall**" - recording and transmitting audio-visual information.

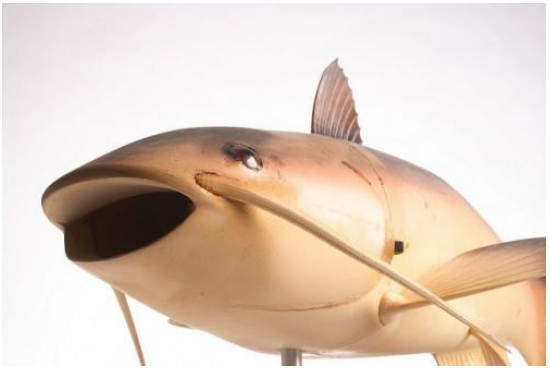
An individual robot is equipped with **miniature cameras, microphones, modem** and **GPS**.

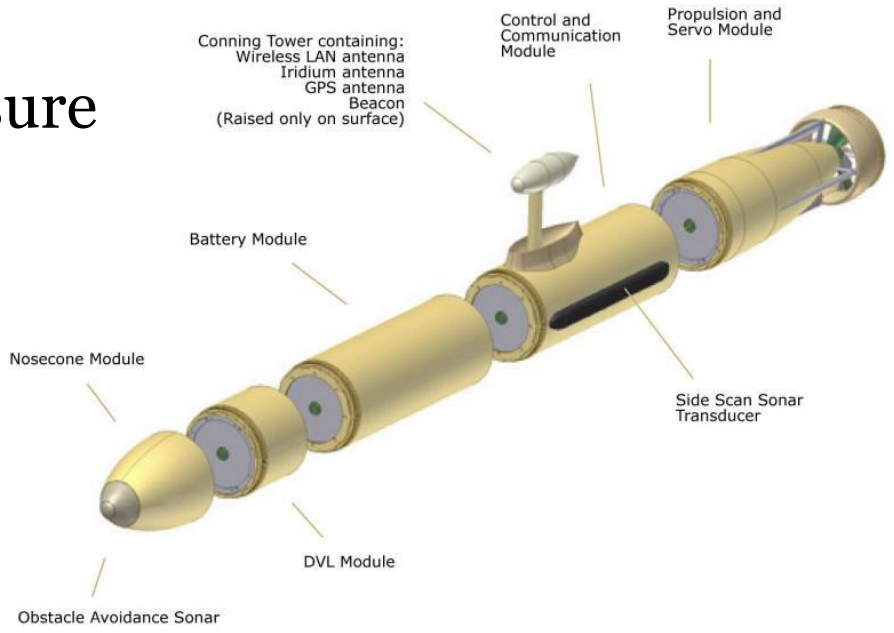
A number of terrorist cells are being infiltrated thanks to this new technology.



Robots Today

- **Unmanned Underwater Vehicles (UUVs)**
  - CIA's Office of Advanced Technologies and Programs developed the Unmanned Underwater Vehicle (UUV) **fish** to study aquatic robot technology.
  - The **UUV fish** contains a pressure hull, ballast system, and communications system in the body and a propulsion system in the tail.



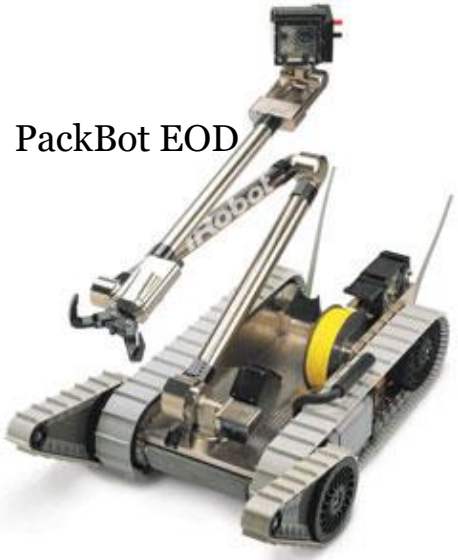


Robots Today

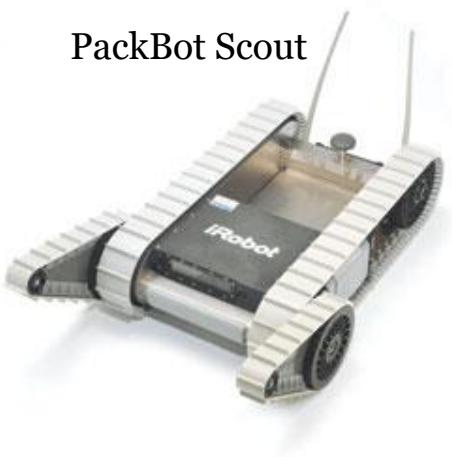
- **Surveillance and Reconnaissance Robots** iRobot

PackBot Explorer

PackBot EOD

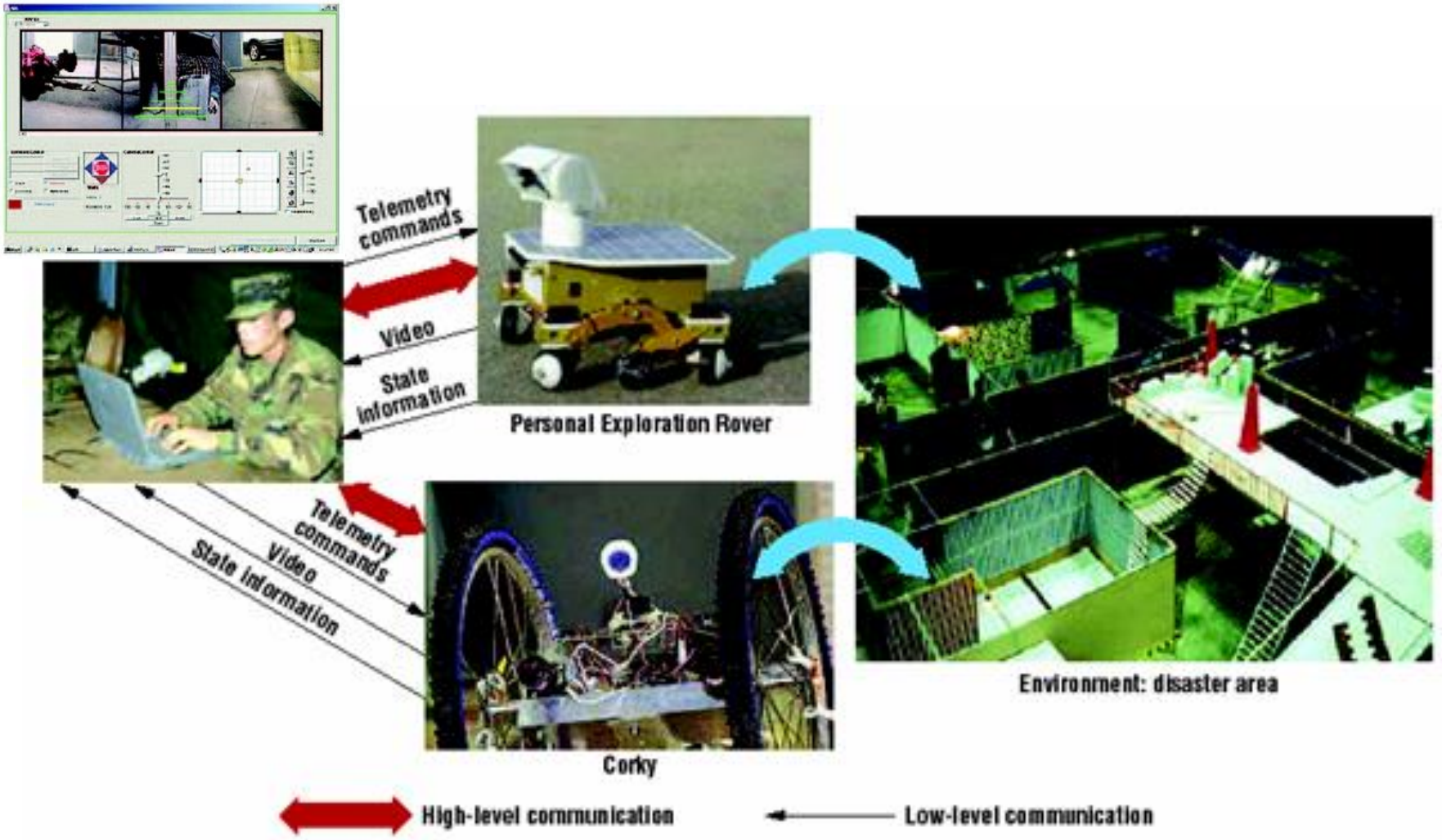


PackBot Scout



Robots Today

- **Search and Rescue**



Robots Today

- **Fire Fighting Robots**

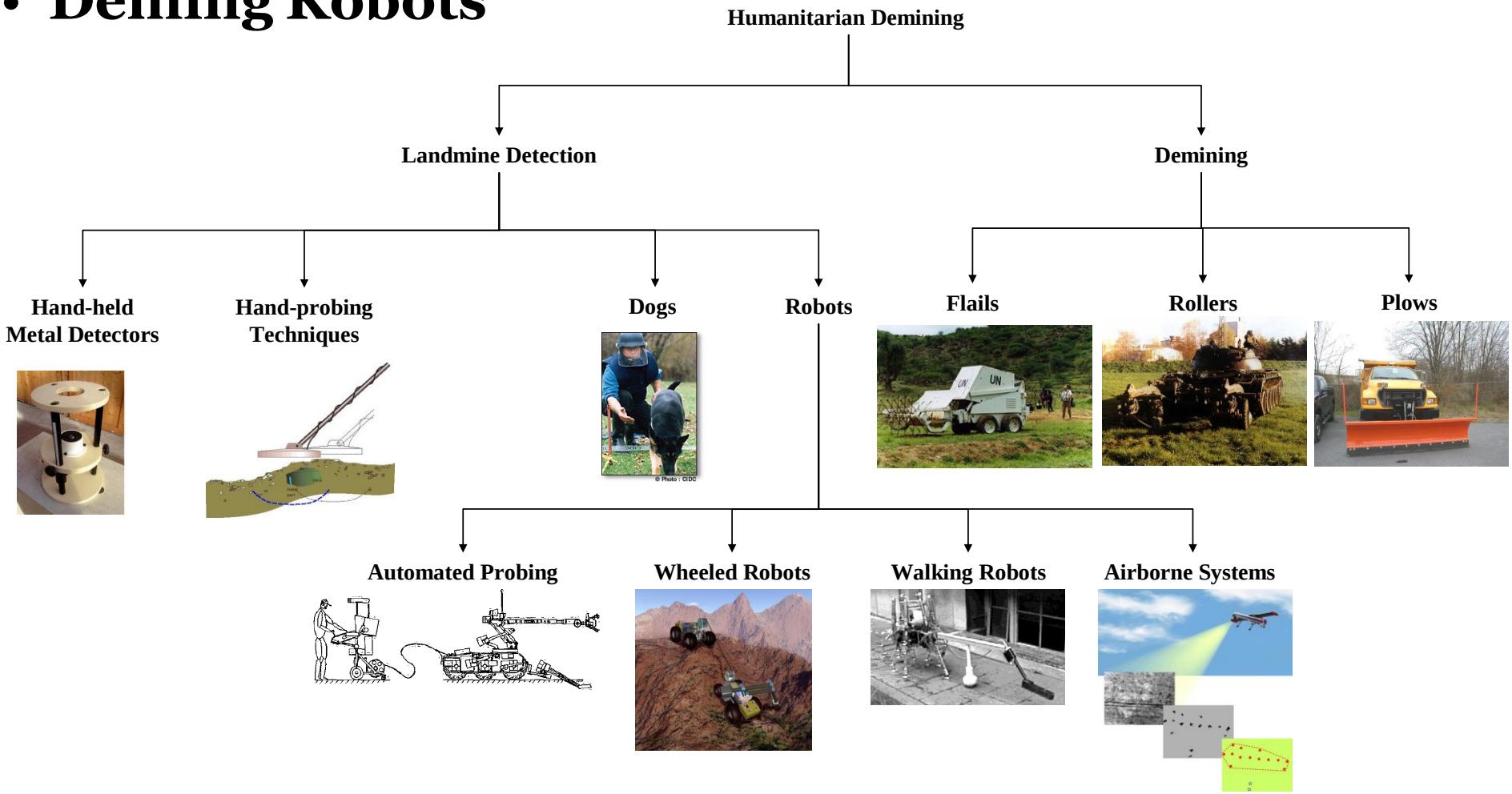
SACI 2.0 is a firefighting robot presented in July 2006 with the following features:

-It has Fault Tolerant Architecture with redundancy in its moving system;

-It has lighting system; -It is modular; -It has at least 100% more autonomy, with a full load capacity up to a minimum of six hours; - It can have infrared or common video cameras and be controlled by wireless remote control.

Robots Today

- **Deming Robots**



Egypt, Angola, and Iran account for more than 85 per cent of the total number of mine-related casualties in the world each year.
Egypt has 23 million mines mostly in border regions.

Robots Today

- **Deming Robots**


Mini Flail


Tempset


Mini-Deminer


Mini Flail -TECHNOPOL


Bozena


TODS


AARDVARK MK4


UOS-155 BELARTY


ARMTRAC-325


HYDREMA 910 MCV


RA-140 DS

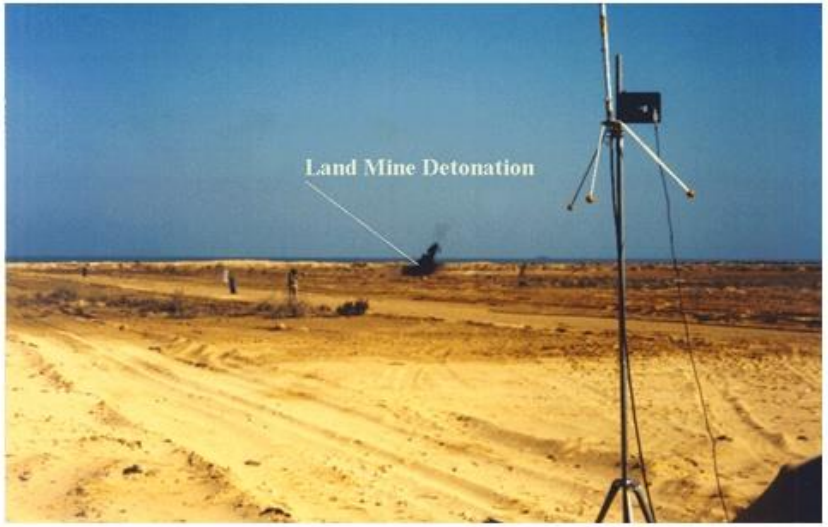

ARMTRAC-100

Robots Today

- **Deming Robots**

  Teleoperated Ordnance Disposal System (TODS) provides safe, effective and efficient delivery of tools necessary for the clearance of landmines. TODS was developed for and tested by the US DoD Humanitarian Demining Research and Development Program.

The ETODS system was developed by the US Department of Defense to Egypt during the month of September 1999. This was an effort supported by OAO Robotics to demonstrate the mine clearance capabilities of the ETODS system to the Egyptian Ministry of Defense.



ETODS at Work near the Red Sea

Source: http://www.manitgroup.com/oao.htm

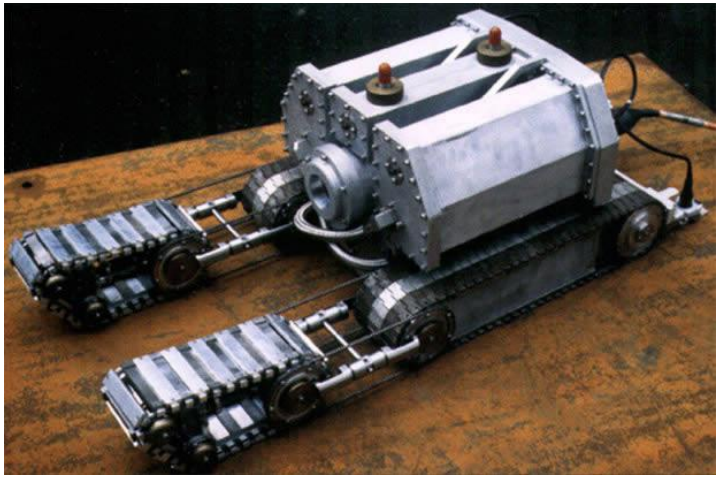
Robots Today

- **Inspection Robots**

Pipeline Inspection

Pioneer

Neptune: A Robotic Inspection System for Oil Storage Tanks



Robots Today

- **Agriculture Robots**

Ag-robots Farm Robots

National Robotics Engineering Consortium

feldt-electronics : http://www.feldt-electronics.de/

Robots Today

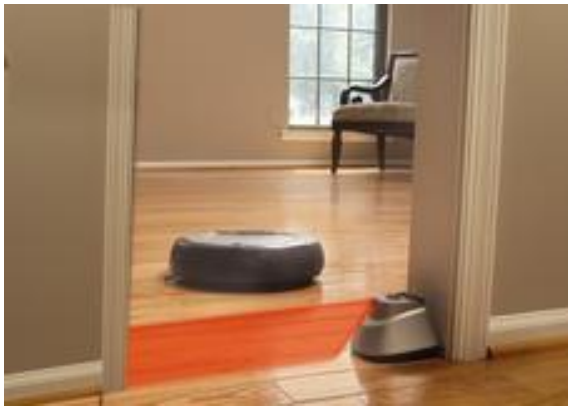
- **Cleaning and Mowing Robots**

Roomba - Making money with autonomous robots

Since the Roomba retails for about $300 in 2003, it's been able to sell 1.5 million of them in three years.

Price now is about $120

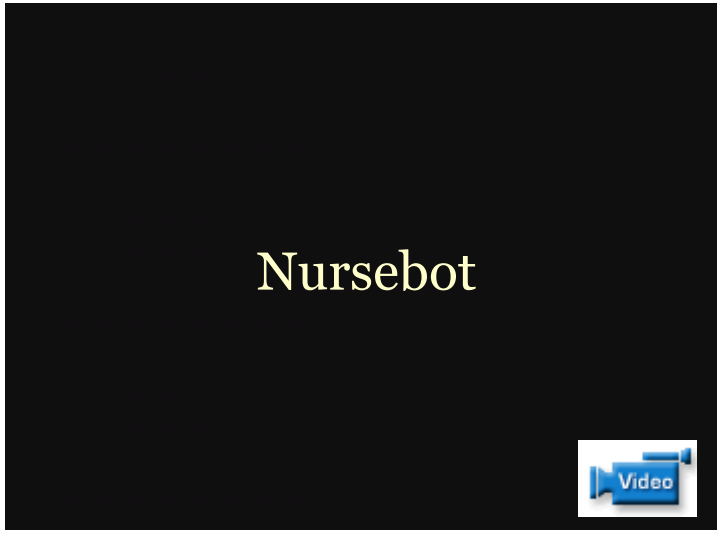
iRobot

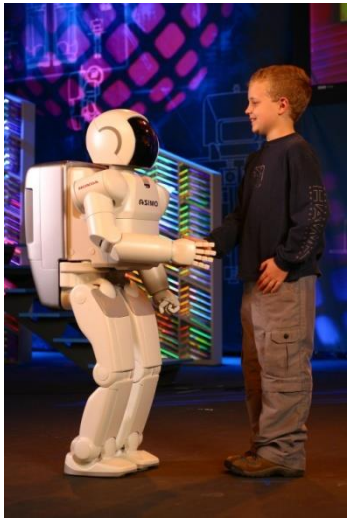


Robots Today

- **Personal Assistant Robots**

Nursebot





ASIMO

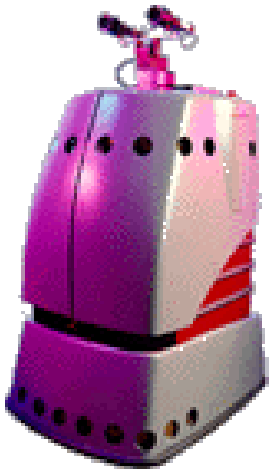
Maggie (UC3M)

Wakamaru

RI-MAN

Robots Today

- **Interactive Tour-Guide Robots**



Minerva is an autonomous robot that moves daily through crowds at the Smithsonian's National Museum of American History.

Robots Today

- **Entertainment Robots**

Anaconda

AIBO

QRIO

Robots Today

- **Soccer Robots**

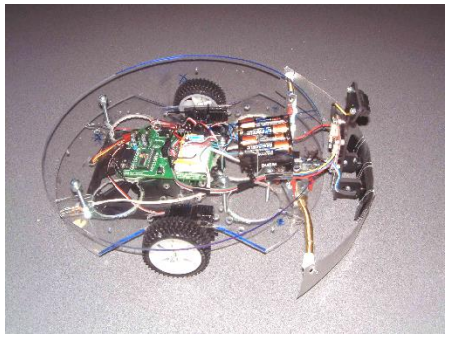
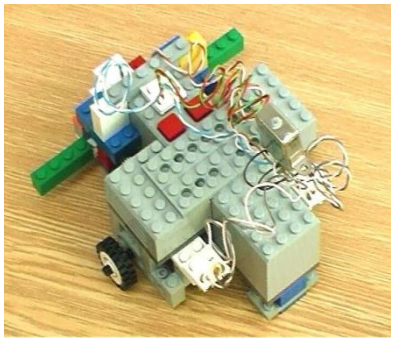
Robots Today

- **Hobby Robots**







http://www.eurobot.org/

http://www.handson.org.tw/

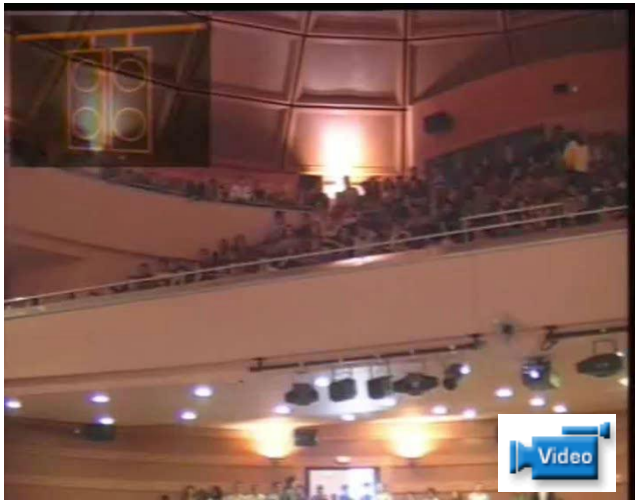
http://www.usfirst.org/robotics/

http://www.worldskills.org/

http://www.depeca.uah.es/alcabot/hispabot/index.html

Robots Today

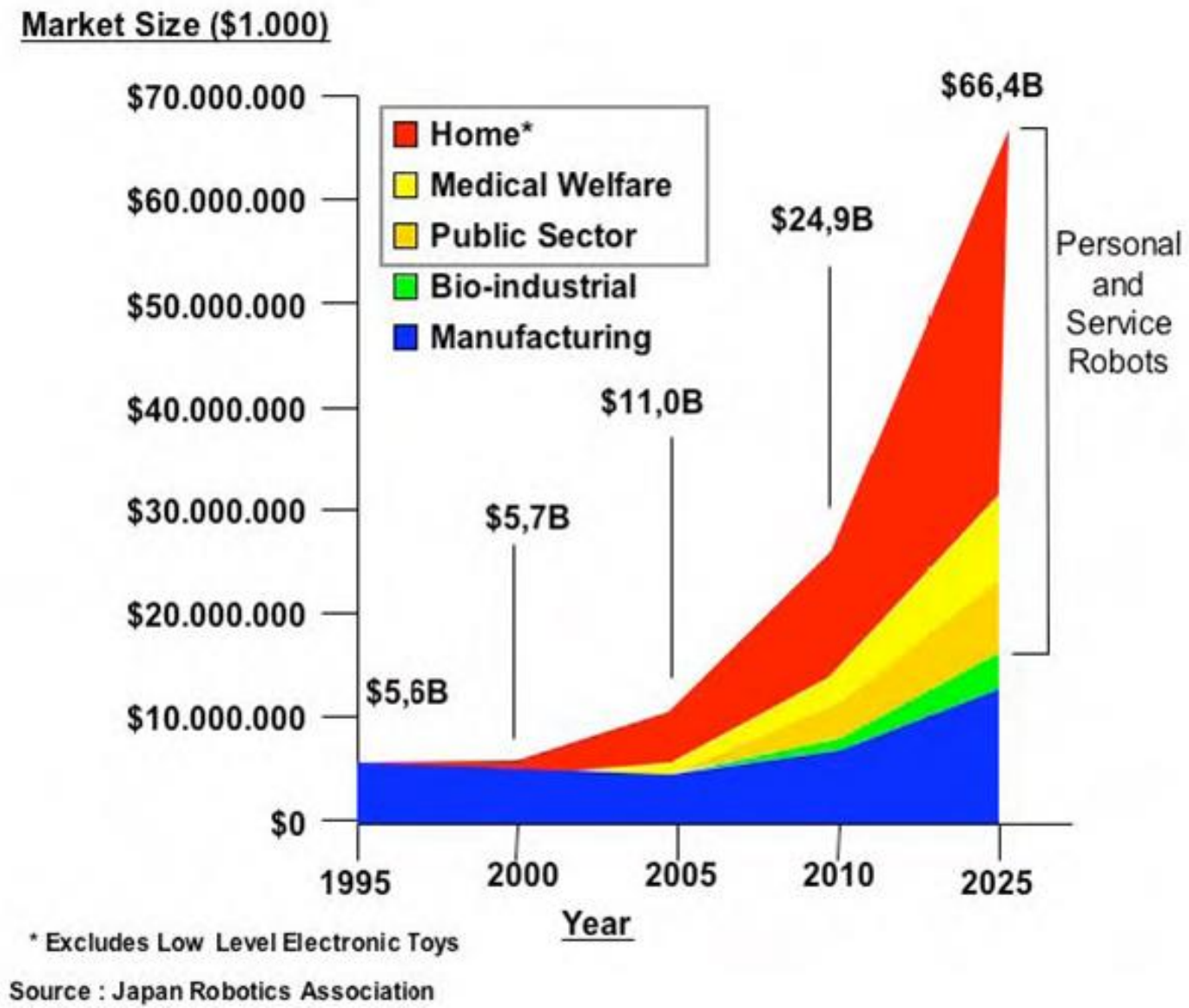
- **Hobby Robots: Hispabot**



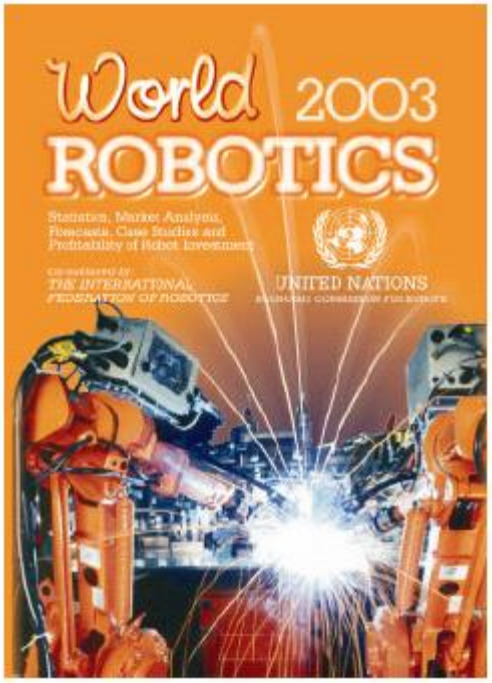
Outline

- What is a Robot?
- What is Robotics?
- Science Fiction
- Science Facts
- Robots Today
- **Robot Statistics**
- Robots' Future
- Summary

Robots Statistics



Robots Statistics

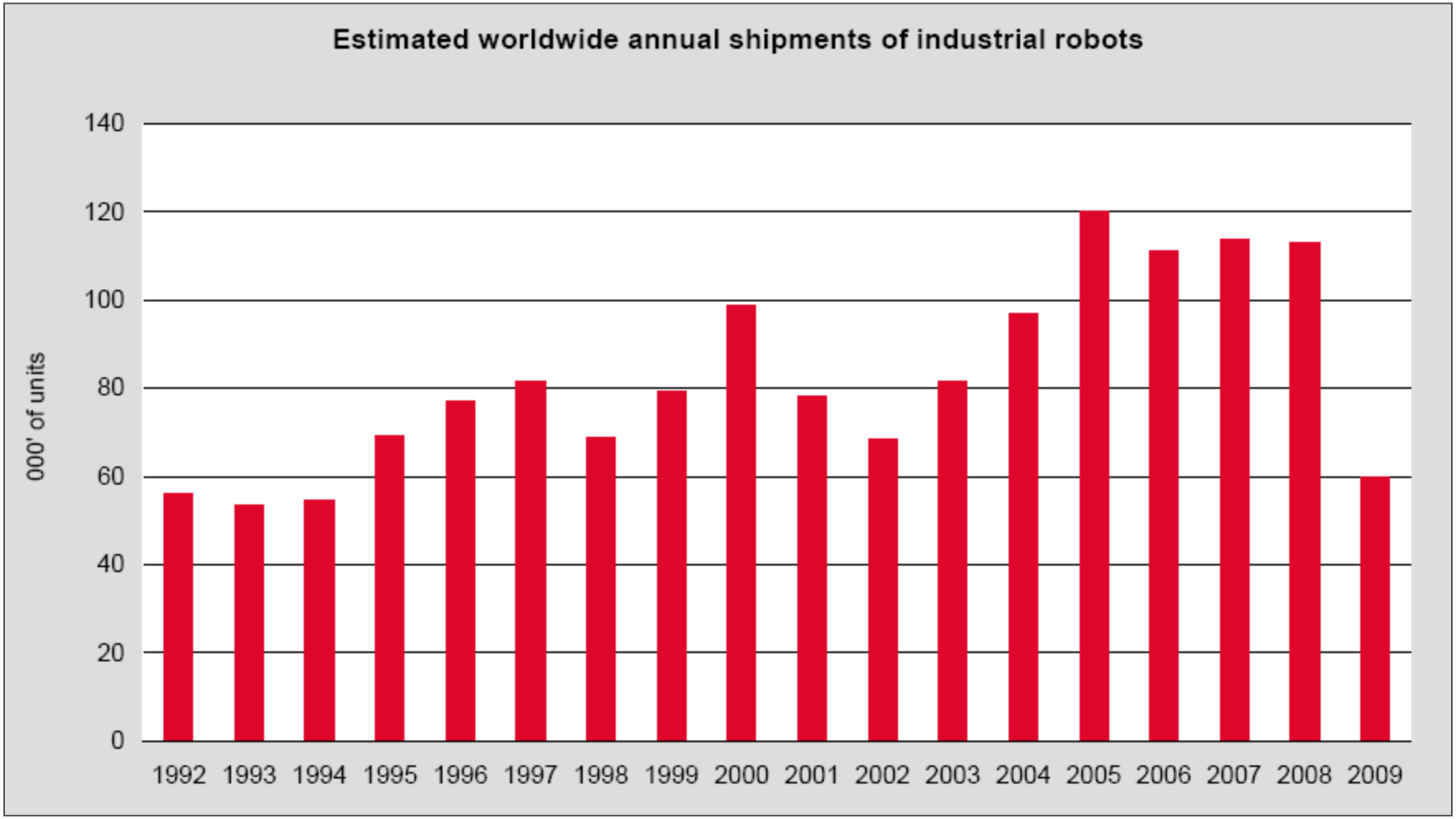


Installations and operational stock of multipurpose industrial robots in 2001 and 2002 and forecasts for 2003-2006.

Country	Yearly installations				Operational stock at year-end			
	2001	2002	2003	2006	2001	2002	2003	2006
Japan	28,369	25,373	27,300	33,900	361,232	350,169	344,000	333,400
United States	10,813	9,955	11,400	14,500	97,257	103,515	111,100	135,200
European Union	30,735	25,866	26,600	31,800	219,515	233,139	248,100	303,500
Germany	12,706	11,867	12,000	13,900	99,195	105,217	111,300	136,400
Italy	6,373	5,470	5,700	6,600	43,911	46,881	50,500	62,000
France	3,484	3,012	2,900	3,300	22,753	24,277	25,900	31,700
United Kingdom	1,941	750	800	1,100	13,411	13,651	13,700	14,400
Austria a/	330	670			3,153	3,521		
Benelux a/	620	620			8,590	8,674		
Denmark	330	249			1,683	1,853		
Finland	406	248			2,927	3,023		
Portugal	100	100			800	844		
Spain	3,584	2,420			16,378	18,352		
Sweden	859	460			6,714	6,846		
Other Europe	698	744	800	1,100	11,002	11,013	10,500	12,100
Czech Rep. a/	70	90			985	1,025		
Hungary	27	64			120	176		
Norway	98	80			618	664		
Poland	20	150			520	644		
Russian Fed. a/	150	190			5,000	5,000		
Slovakia b/								
Slovenia b/								
Switzerland a/	333	170			3,759	3,504		
Asia/Australia	5,310	5,108	5,600	7,500	56,997	60,412	64,300	73,300
Australia	270	510			2,953	3,310		
Rep. of Korea (all types of industrial robots)	4,080	3,998			41,267	44,265		
Singapore a/	300	100			5,458	5,346		
Taiwan, Province of China	660	500			7,319	7,491		
Other countries a/	2,250	1,520	1,700	2,300	10,374	11,640	12,900	17,800
Subtotal, excl. Japan and Rep. of Korea	45,726	39,195	41,800	51,900	353,878	375,454	446,900	541,900
Total, including Japan and Rep. of Korea	78,175	68,566	73,400	91,100	756,377	769,888	838,400	875,300

Sources: UNECE, IFR and national robot associations.

Robots Statistics

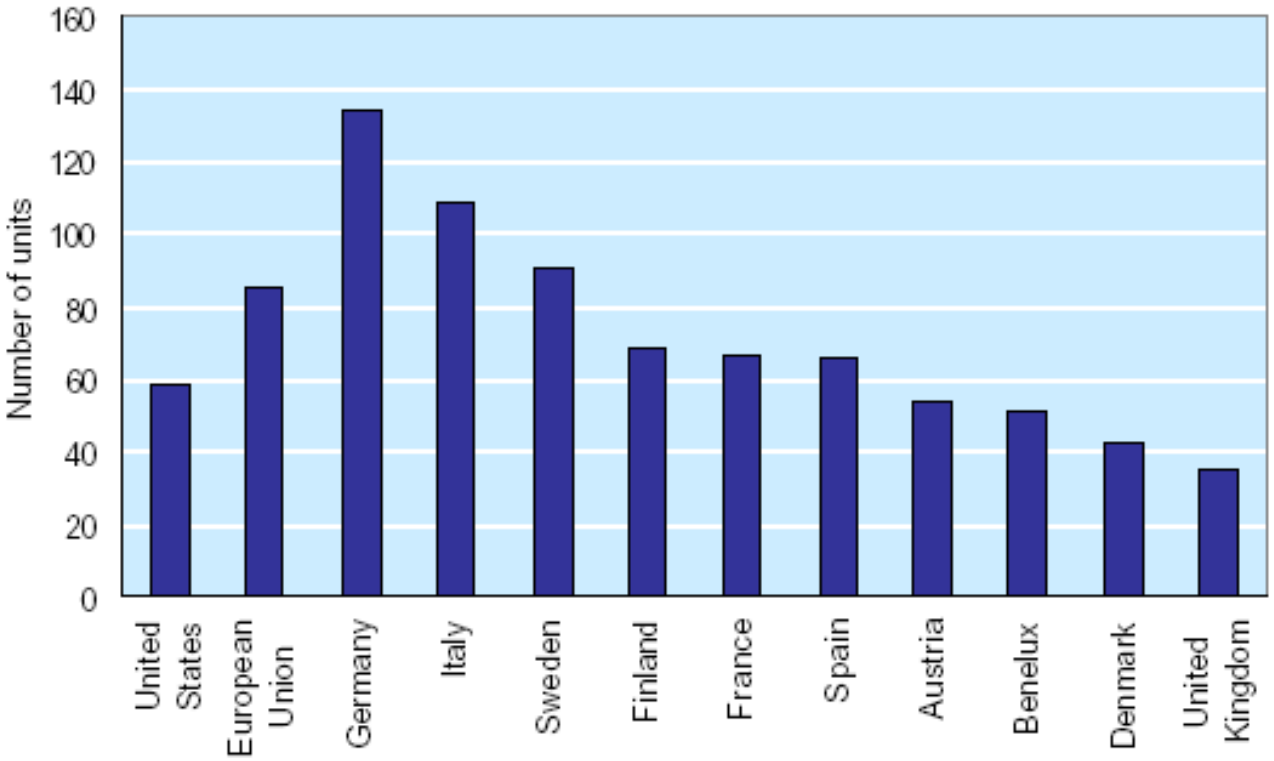


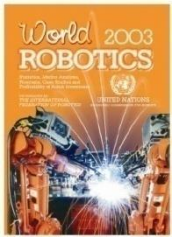
Source: IFR Statistical Department

Robots Statistics

Robot Density

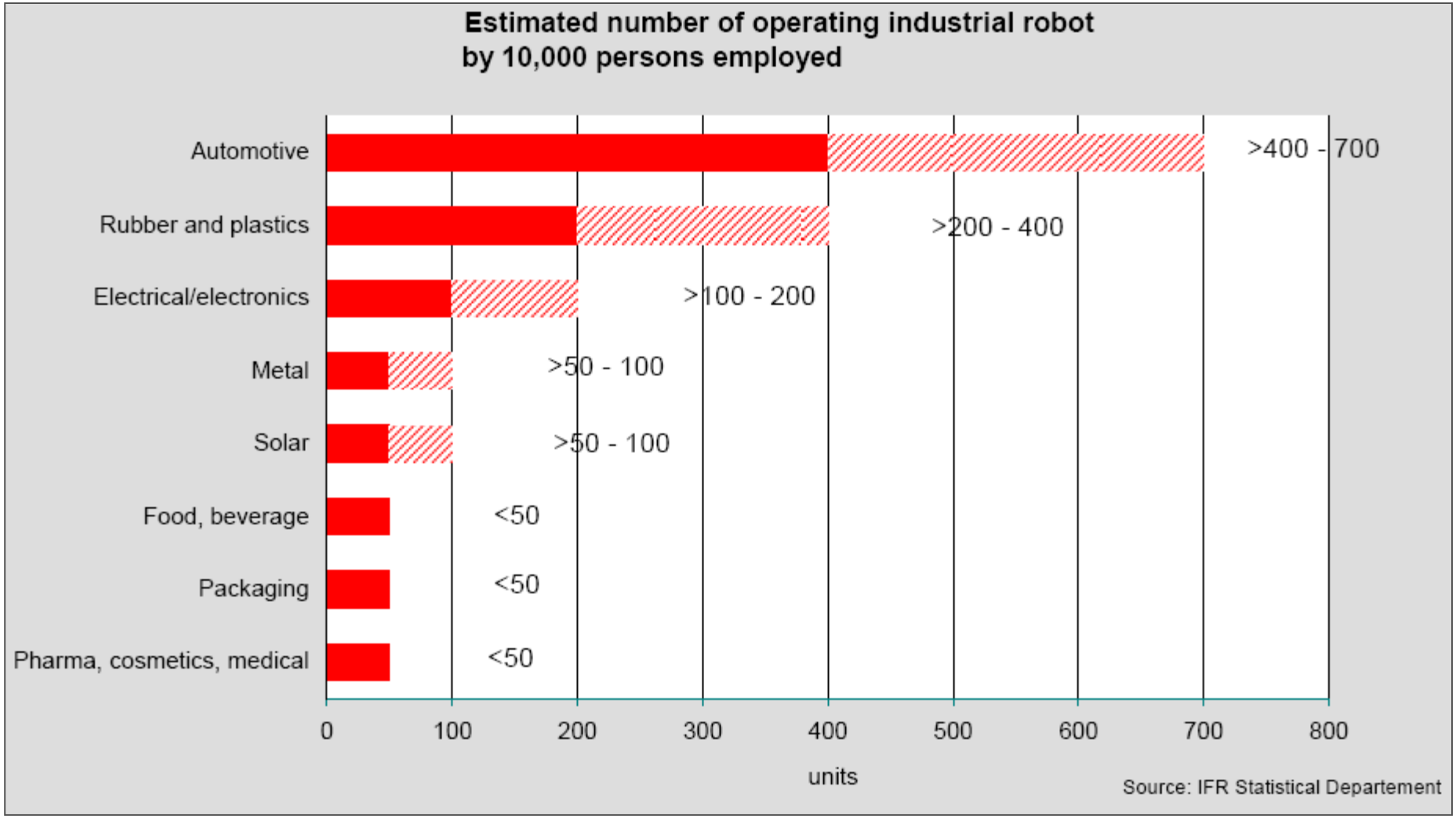
	2002
Japan a/	308
Rep. of Korea b/	128
United States	**58**
European Union	**86**
Germany	135
Italy	109
Sweden	91
Finland	68
France	67
Spain	66
Austria	54
Benelux	51
Denmark	43
United Kingdom	36
Australia	33
Norway	21
Portugal	9
Czech Rep.	8



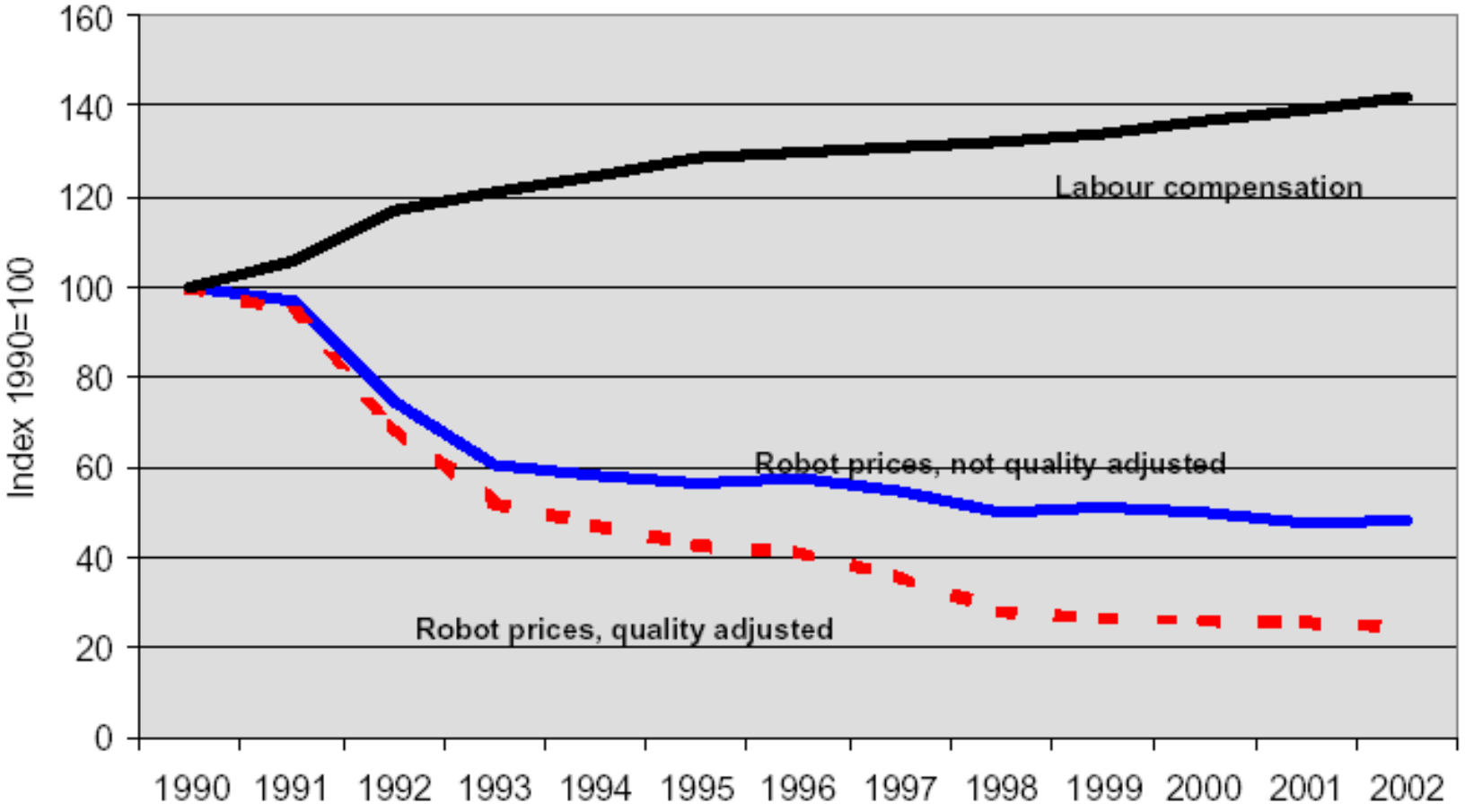


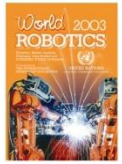
Robot density is the number of robots per 10,000 persons employed in the manufacturing industry

Robots Statistics



Robots Statistics





Price index of industrial robots in **Germany**, with and without quality adjustment. Index of labour compensation in the German business sector

Robots Statistics

More details about robot statistics and market penetration in the world and in Egypt are to be provided in:

Self-study: A-Robot Report: Robot Statistics and Market Penetration

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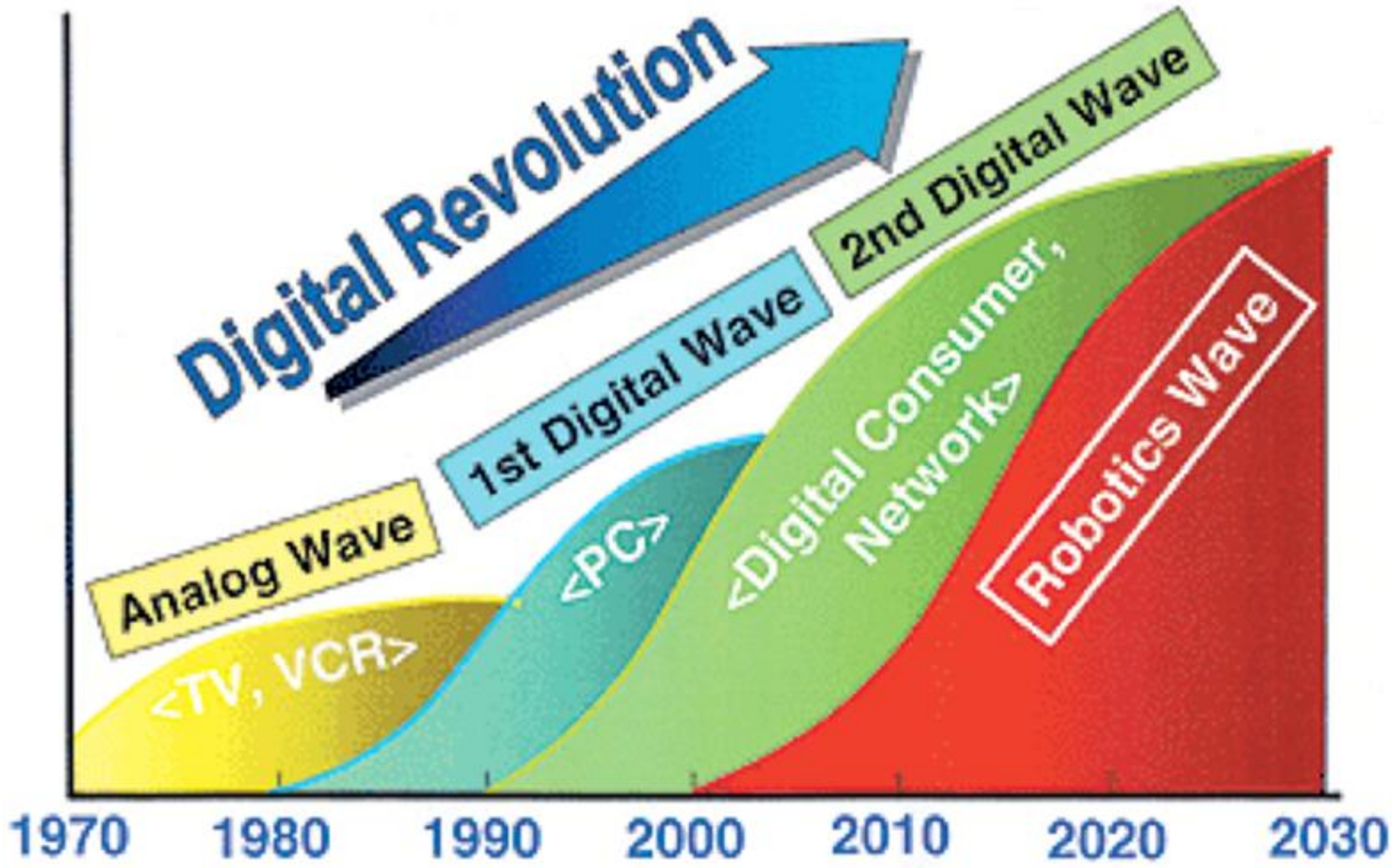
Robot's Future



Source: Bruno Siciliano. Robots Moving Closer to Humans. IEEE Distinguished Ambassador Seminar. Available at: http://ras-egypt.org/activities.html

Robot's Future

The Evolutionary Stages

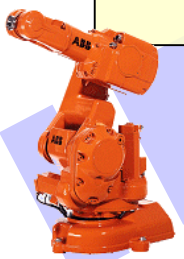
Service Robots for Personal Use

Service Robots for Professional Use

Personal Robotics

Service Robotics

Industrial Robotics



Robot's Future

- **A robot in every home**

"As I look at the trends that are now starting to converge, I can envision a future in which robotic devices will become a nearly ubiquitous part of our day-to-day lives. The challenges facing the robotics industry are similar to those we tackled in computing three decades ago."

Bill Gates, 2007
Scientific American

Robot's Future

- **Service Robots**

  Service robots assist human beings, typically by performing a job that is dirty, dull, distant or dangerous.

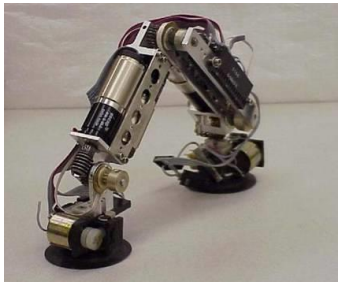
Service Robots

Service Robots for Professional Use

(Construction robots, demolition, medical, space robots, underwater expoloration, cleaning, demining, inspection, fire fighting,...

Service Robots for Personal Use

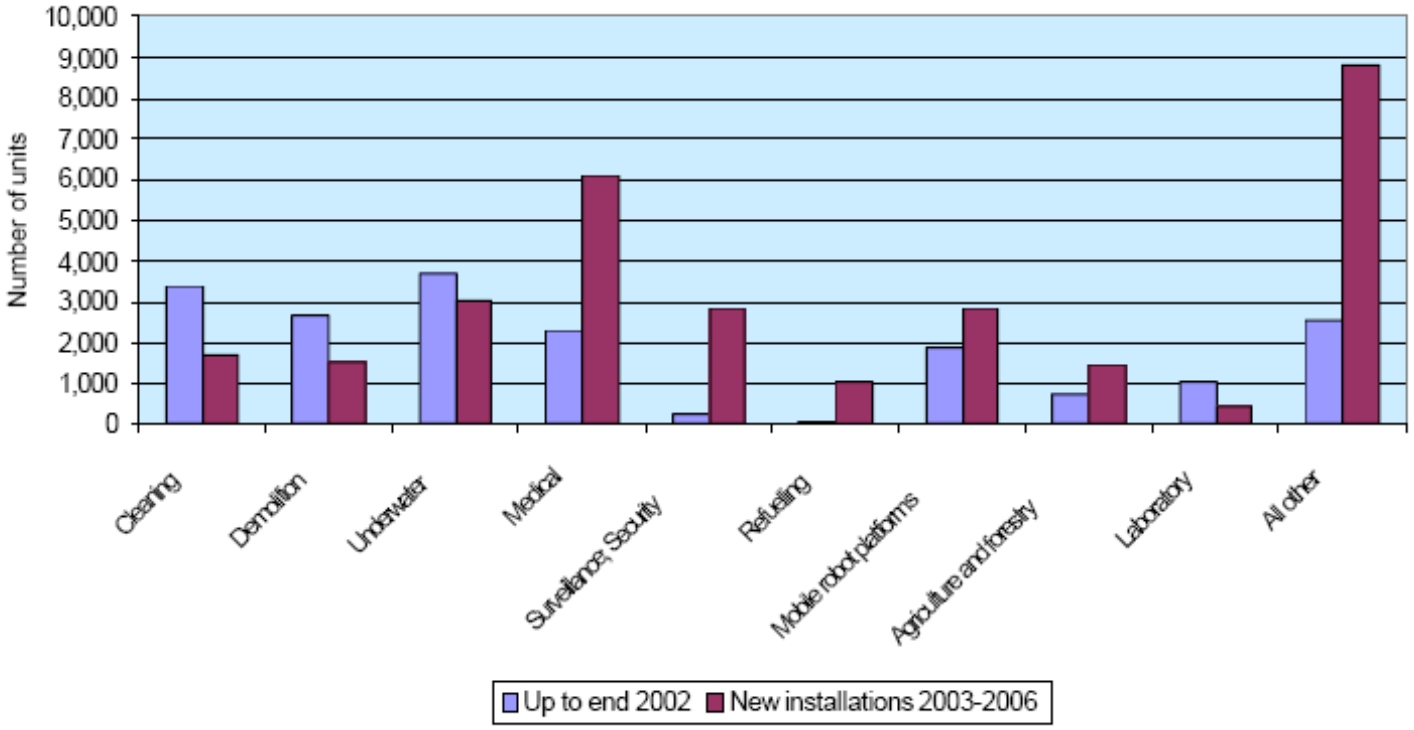
(domestic, personal assistant, entertainment robots, vacuum cleaners, etc.)

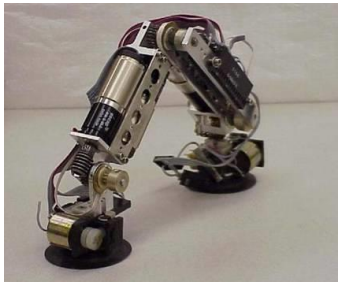


Robot's Future

- **Service Robots**

Service robots for professional use. Stock at the end of 2002 and projected installations in 2003-2006



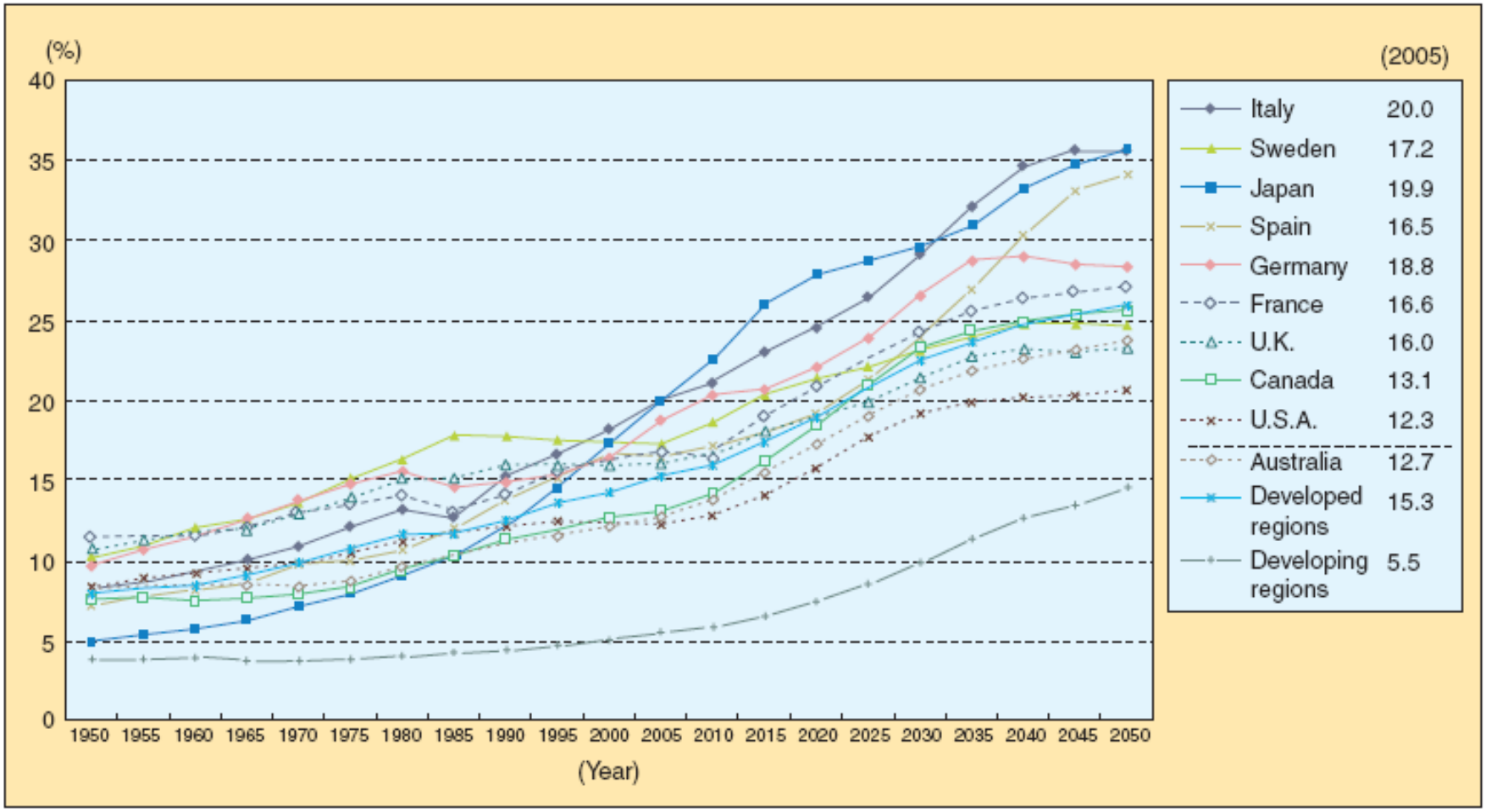


IFR, October 2002

Robot's Future

- **Service Robots**

Trends in percentage of the elderly (over age 85) in the world

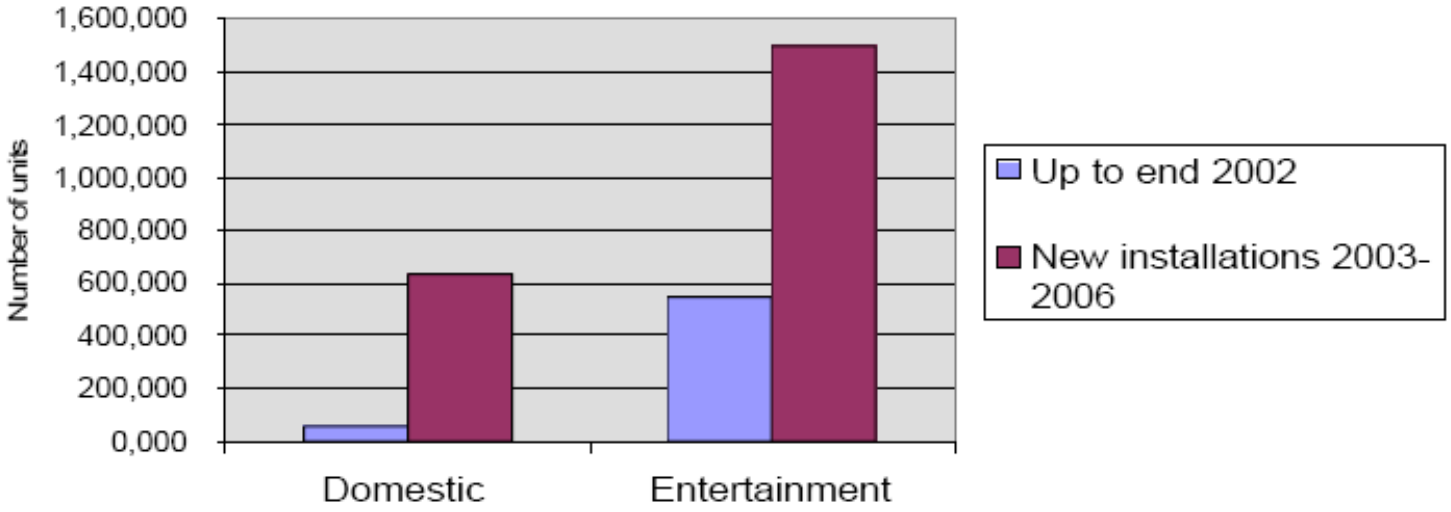


Source: ADRIANA TAPUS,MAJA J. MATARIC´, AND BRIAN SCASSELLATI, "Socially Assistive Robotics: The Grand Challenges in Helping Humans Through Social Interaction," IEEE Robotics & Automation Magazine, MARCH 2007

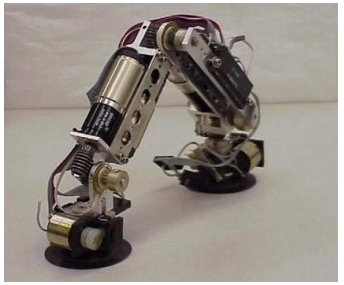
Robot's Future

- **Service Robots**

Service robots for private use. Stock at end 2002 and projected installations 2003-2006



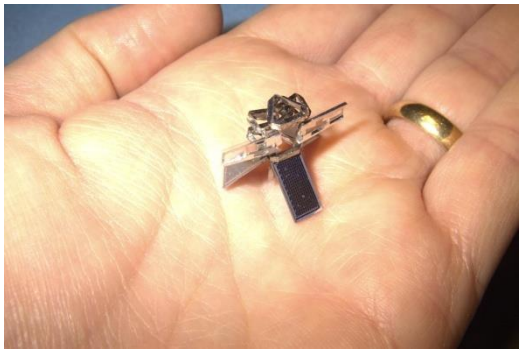
IFR, October 2002

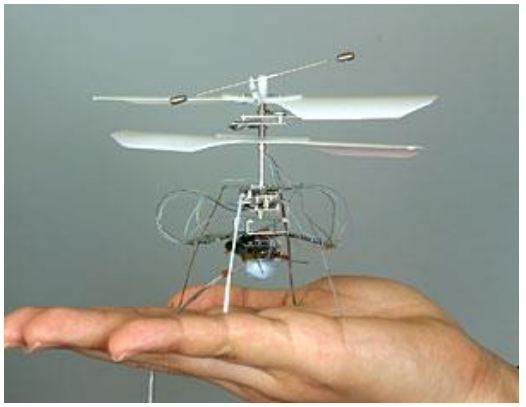


Robot's Future

- **Nanorobots or Nanobots**

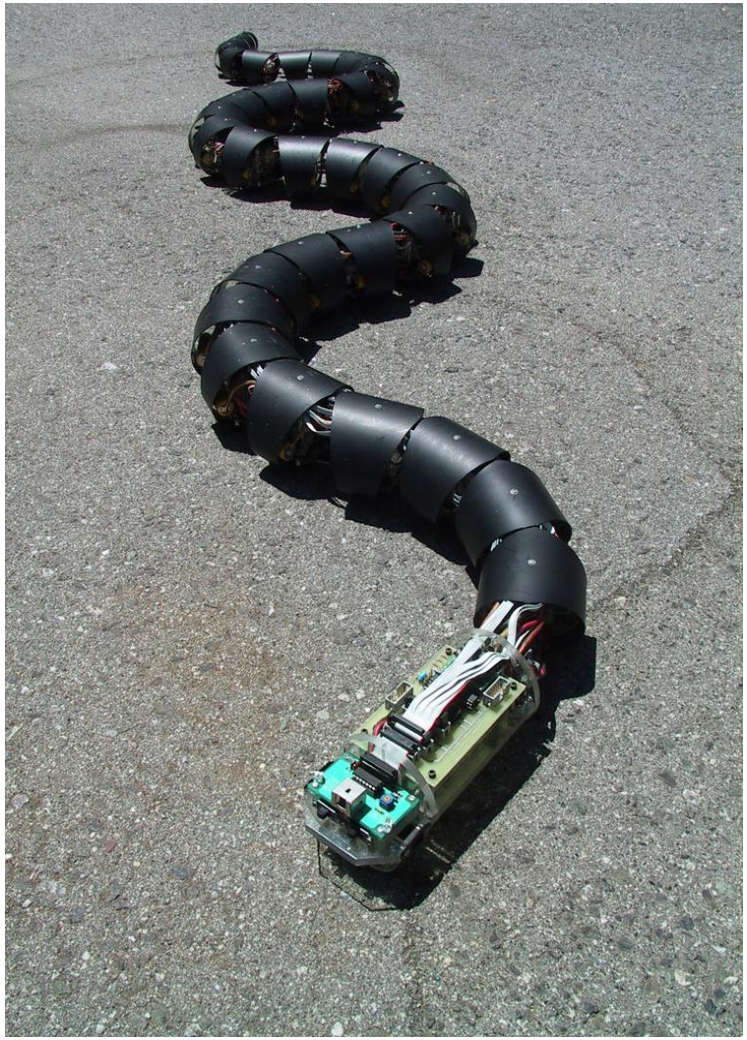
  Nanorobotics is the technology of creating robots at or close to the scale of a nanometre (10^{-9} metres). The first useful applications of nanorobots will likely be in medical technology. Another application is the detection of toxic chemicals, and the measurement of their concentrations, in the environment.

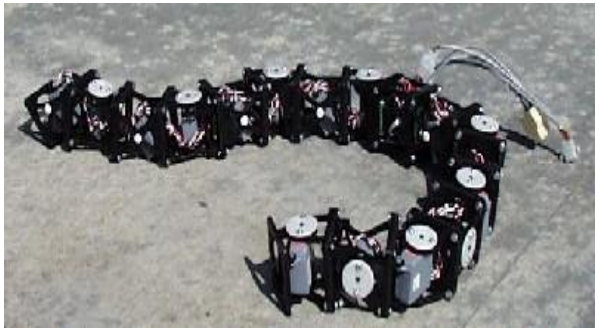


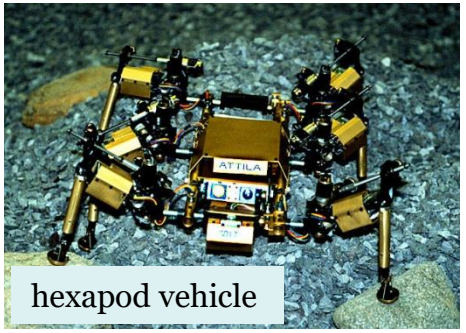


Robot's Future

- **Biologically-inspired Robots**







hexapod vehicle

OmniTread Robot

Genghis II

Cybor

Video

IEEE ICRA

2003 IEEE INTERNATIONAL CONFERENCE ON ROBOTICS AND AUTOMATION

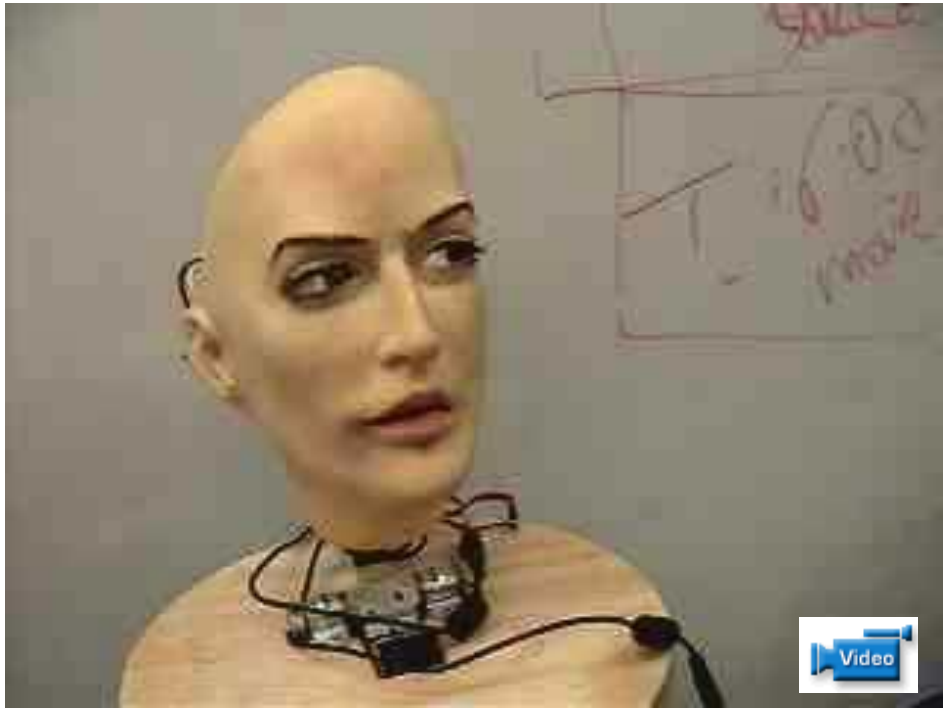
Robot's Future

- **Emotional Robots**

Albert HUBO – Hanson Robotics

Robot's Future

- **Emotional Robots**



Hanson-Robotics

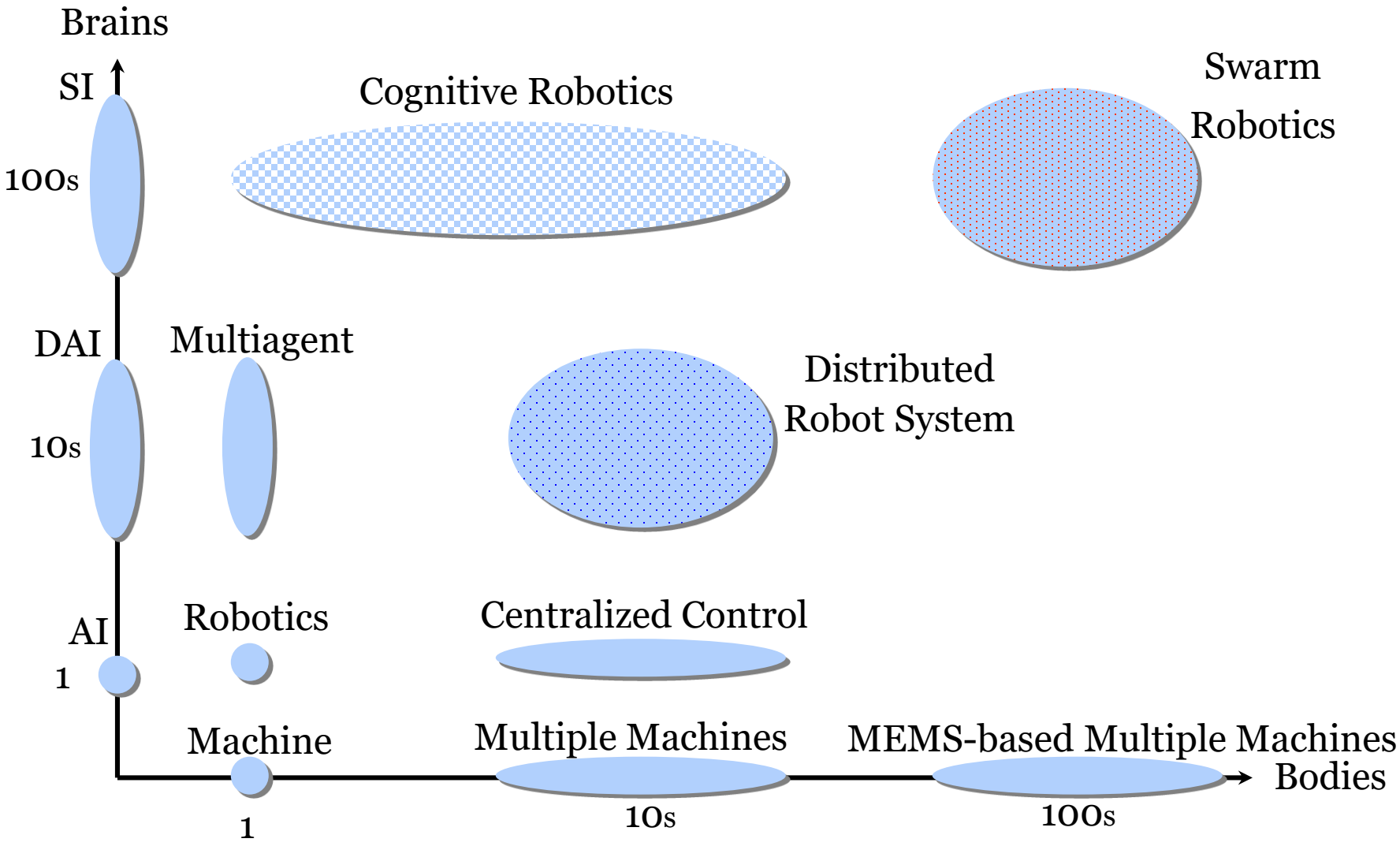
Ibn Sina Robot

Interactive Robots and Media Lab - UAE University

YouTube http://www.youtube.com/watch?v=OIOtOmyySQo

Robot's Future

- **Multirobot Systems**

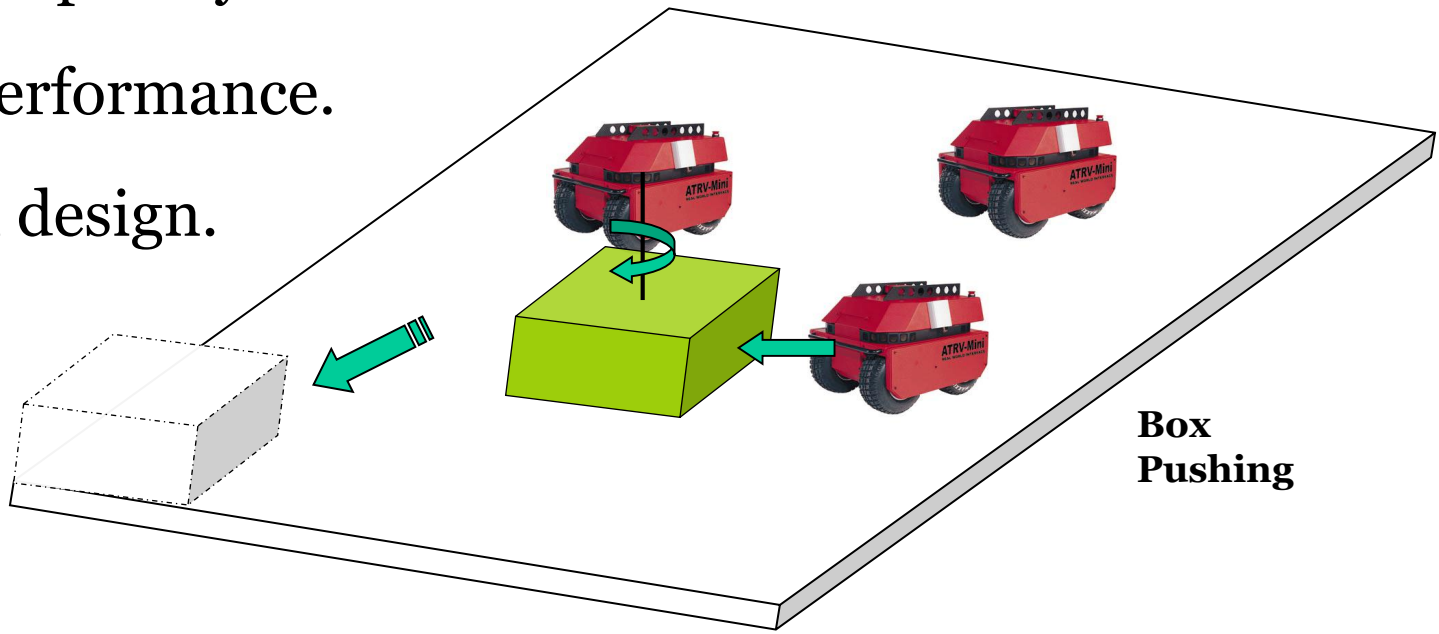


Robot's Future

- **Multirobot Systems**

Swarm robotics is the study of how large number of relatively simple physically embodied agents can be designed such that a desired collective behavior emerges from the local interactions among agents and between the agents and the environment.

- ❖ Resolving complexity.
- ❖ Increasing performance.
- ❖ Simplicity in design.
- ❖ Reliable.

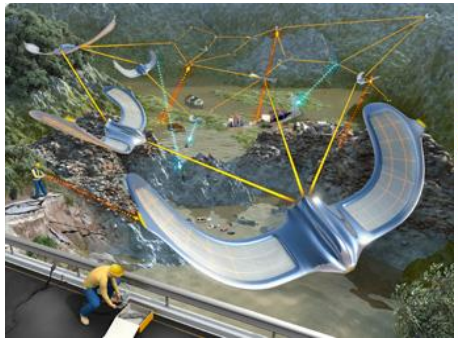


Robot's Future

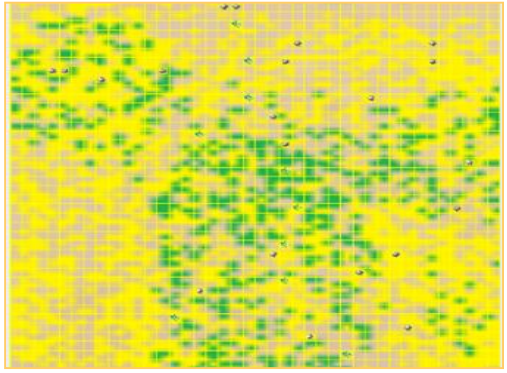
- **Multirobot Systems**

Urban Surveillance

Net-centric Warfare

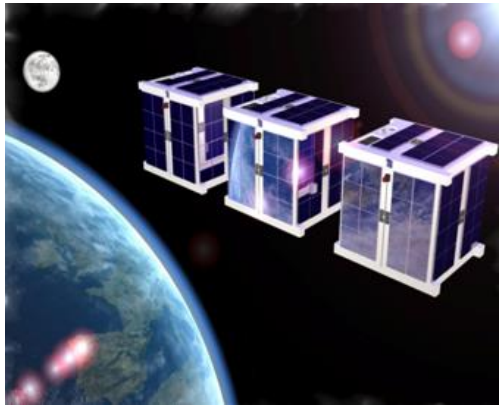


Search and Rescue



Minefield Mapping

Intelligent Carts



Nano and Pico Satellites

More info: Alaa Khamis, Cooperative Multirobot Systems. Available at: http://ras-egypt.org/activities.html

Outline

- What is a Robot?
- What is Robotics?
- Science Fiction
- Science Facts
- Robots Today
- Robot Statistics
- Robots' Future
- **Summary**

Summary

- A robot is a machine that imitates the actions and sometimes appearance of an intelligent creature, usually a human.
- New research and increasing applications have been the impetus behind the evolution of industrial robots into service robots.
- Personal robots derive from service robots as the latest step of this evolution by introducing the notion of personal use of the robot.