



# Robots Everywhere!

Rodney Brooks

Massachusetts Institute of Technology

iRobot Corporation

Heartland Robotics



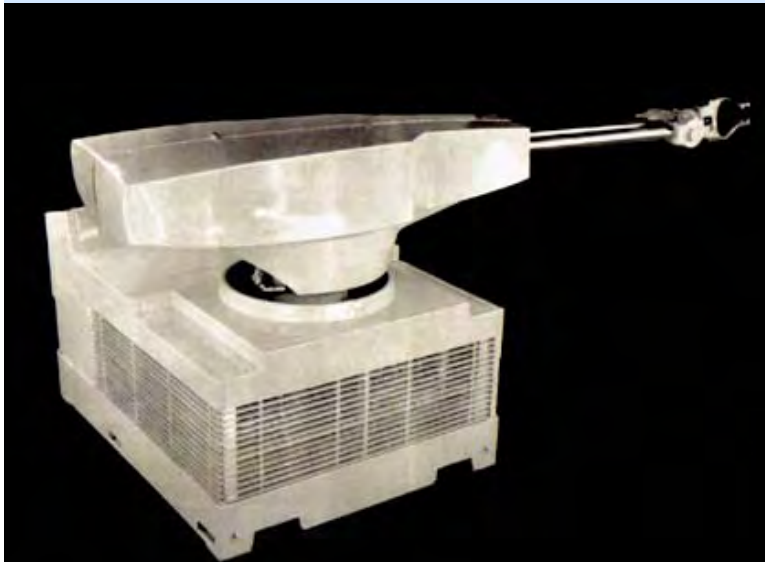
# My Messages

- The US invented and led in manufacturing robotics -- and then lost to Japan and the EU
- The US currently has the lead in a *new class of robots*, both in research and deployment
- World demographics are pulling on robotics for unstructured environments
- Japan, Korea, and the EU have made robotics for unstructured environments national priorities
- Investment in research at the intersection of computation and robotics is critical for success

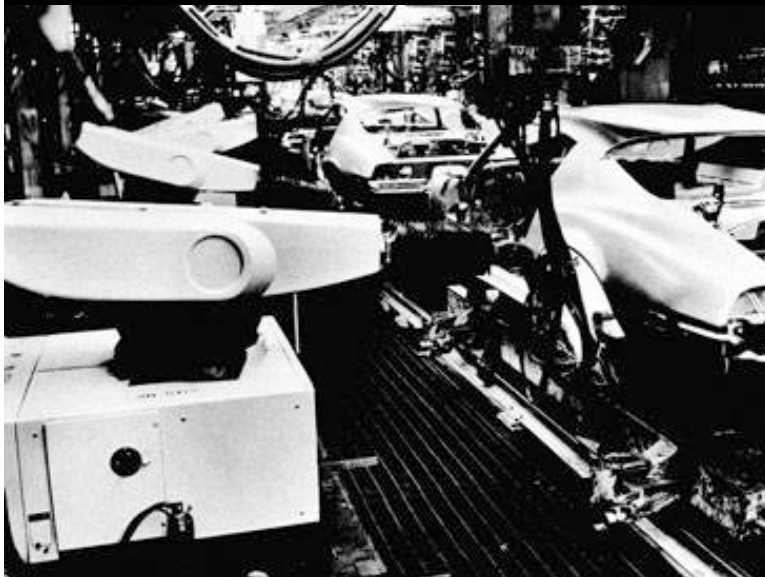
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# World's First Industrial Robot

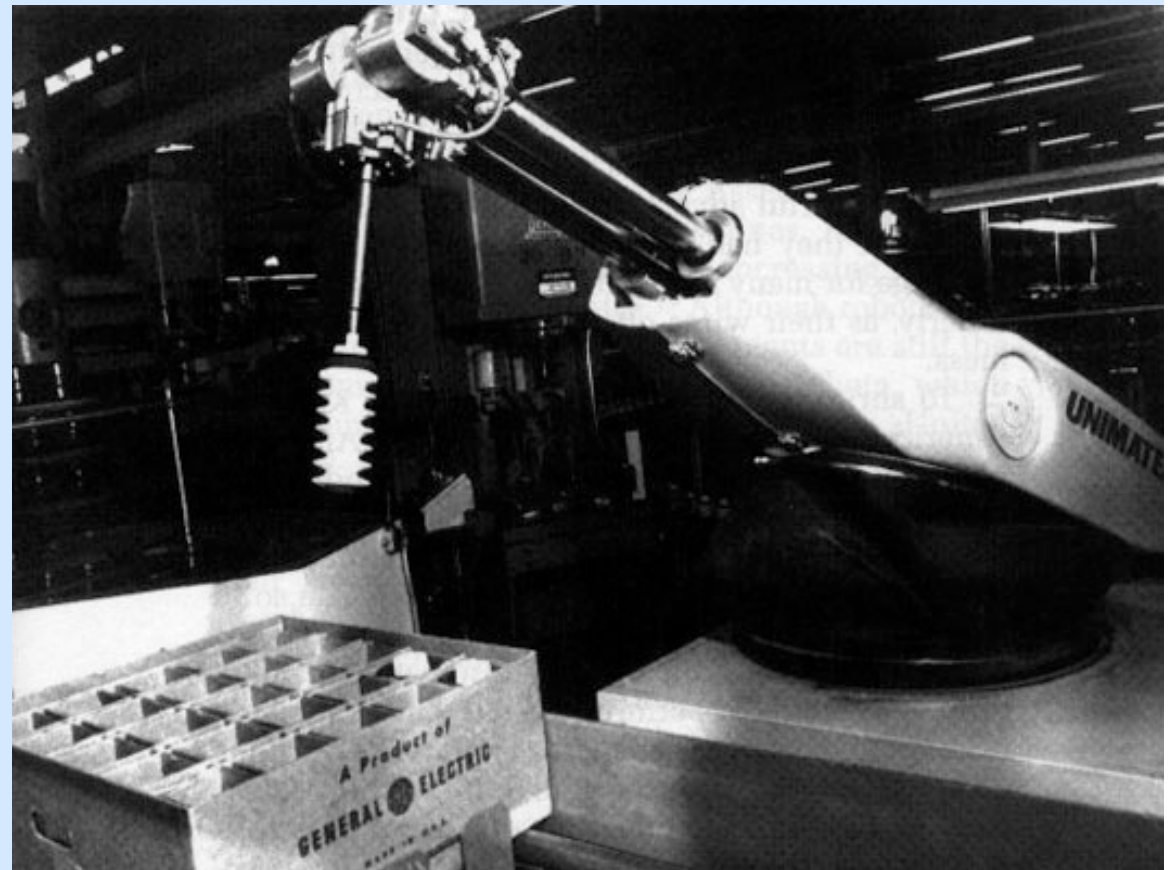


- The Unimate (Unimation)
  - by Joe Engelberger
- First installed in a GM factory
  - 1961
- Later bought by Westinghouse
  - then sold to Kawasaki



# Computation & Sensing Expensive

- No computer
- No sensors
- Same motions repetitively
- Cost of systems integration is 10 times robot cost



Today's industrial robots are much the same

# Today's Manufacturing Robots



- Unsafe for people to be around
- Engineered to be precise and repeatable, not adaptable
- Can only operate in very structured environments
- Their application is limited

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# Originally Ordinary People Couldn't Touch Computers



Now  
they  
can



What if ordinary people  
could touch robots?





# Now They Can



# 21st Century Revolution in Robots

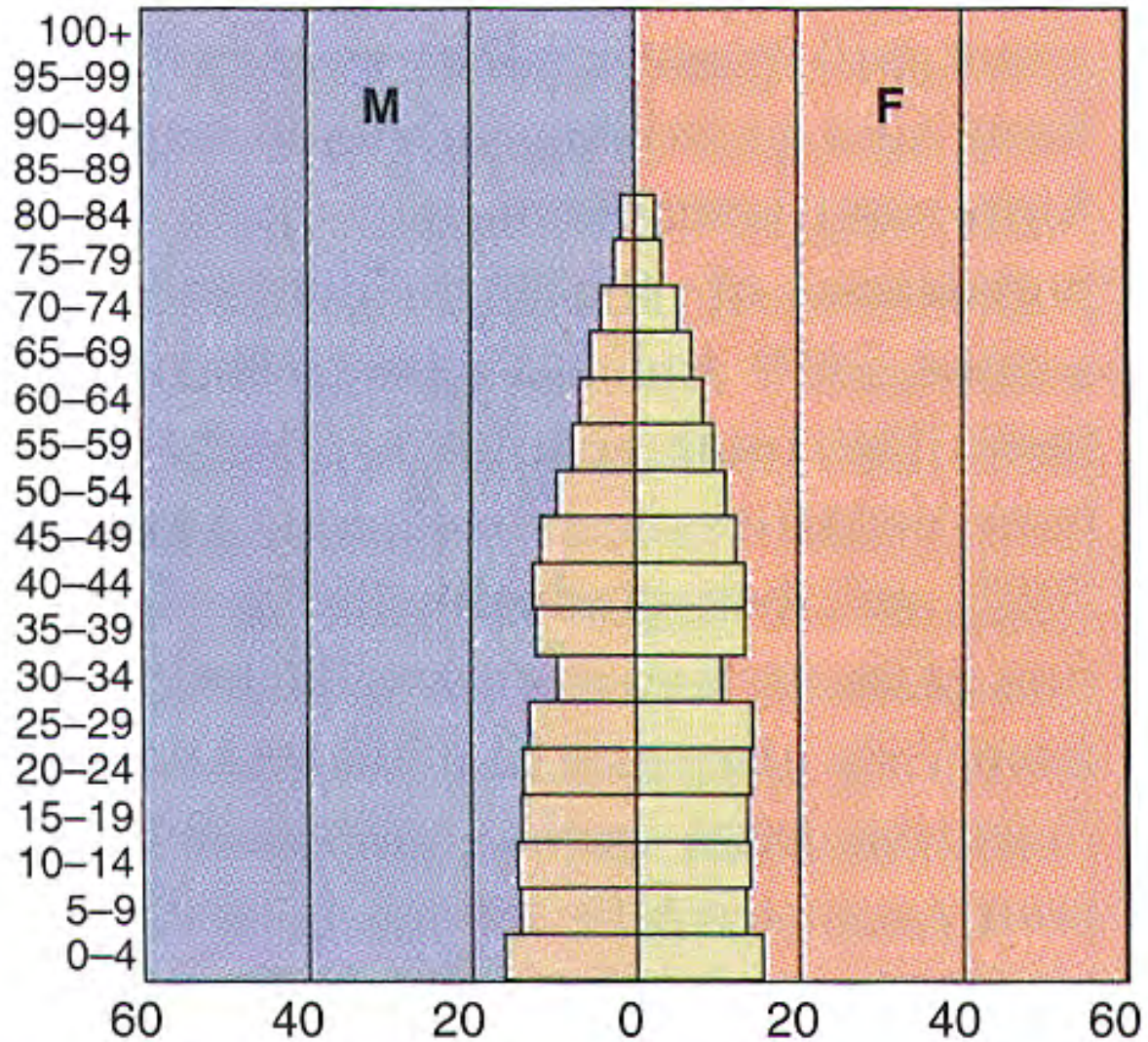
- Since 2002
  - four million robots deployed in people's homes
  - 10,000 ground robots deployed in Afghanistan and Iraq
- Almost every one is a US robot
- They operate in unstructured environments
  - i.e., environments not specially constructed for robots
- They rely on computation, sensing and perceptual algorithms, user interfaces, reasoning under uncertainty, video compression, networks, etc.

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# Europe 1950

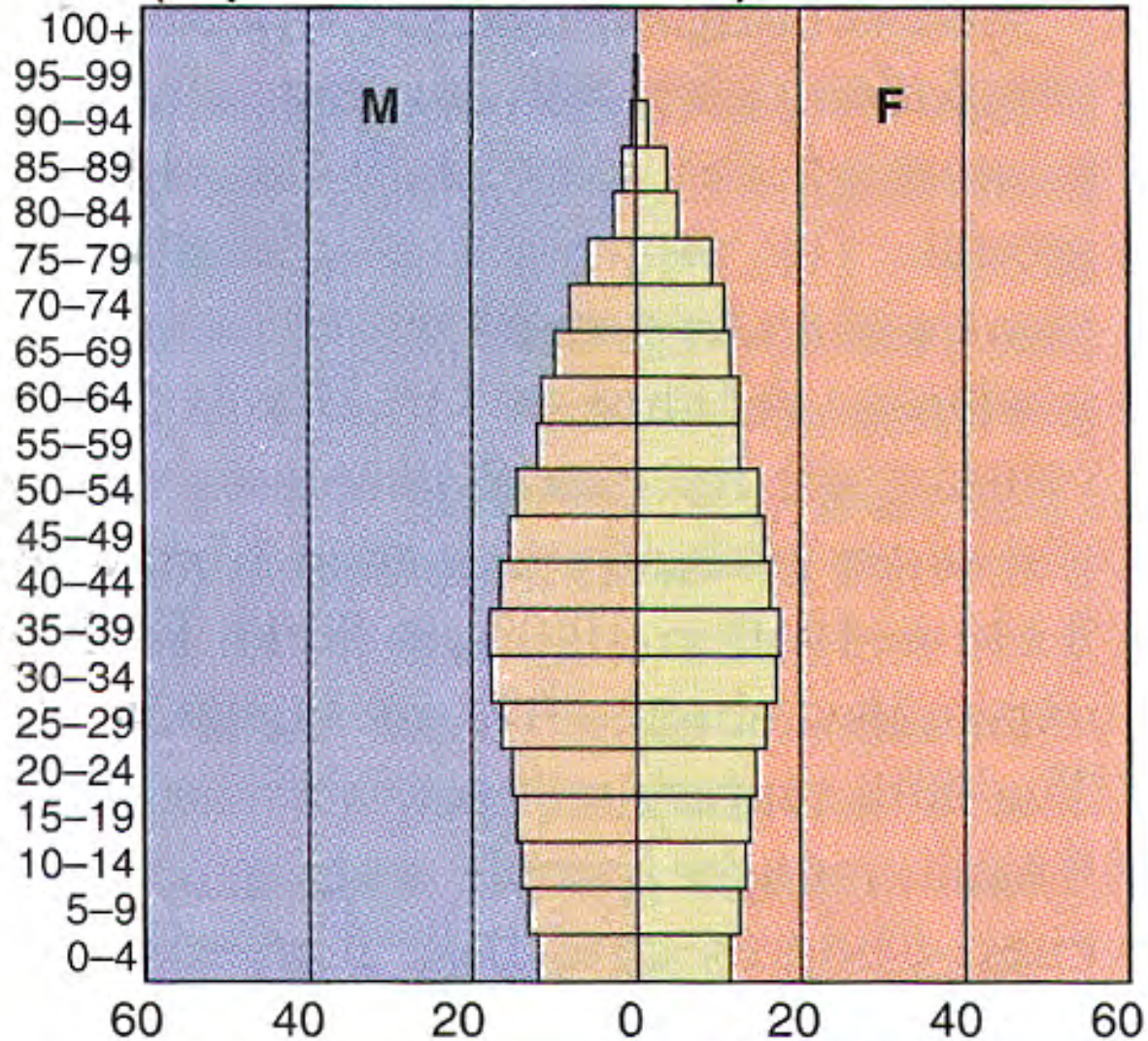
(Population: 349.8 million)



JE Cohen, *Science* 302, 1176 (2003)

# Europe - 2000

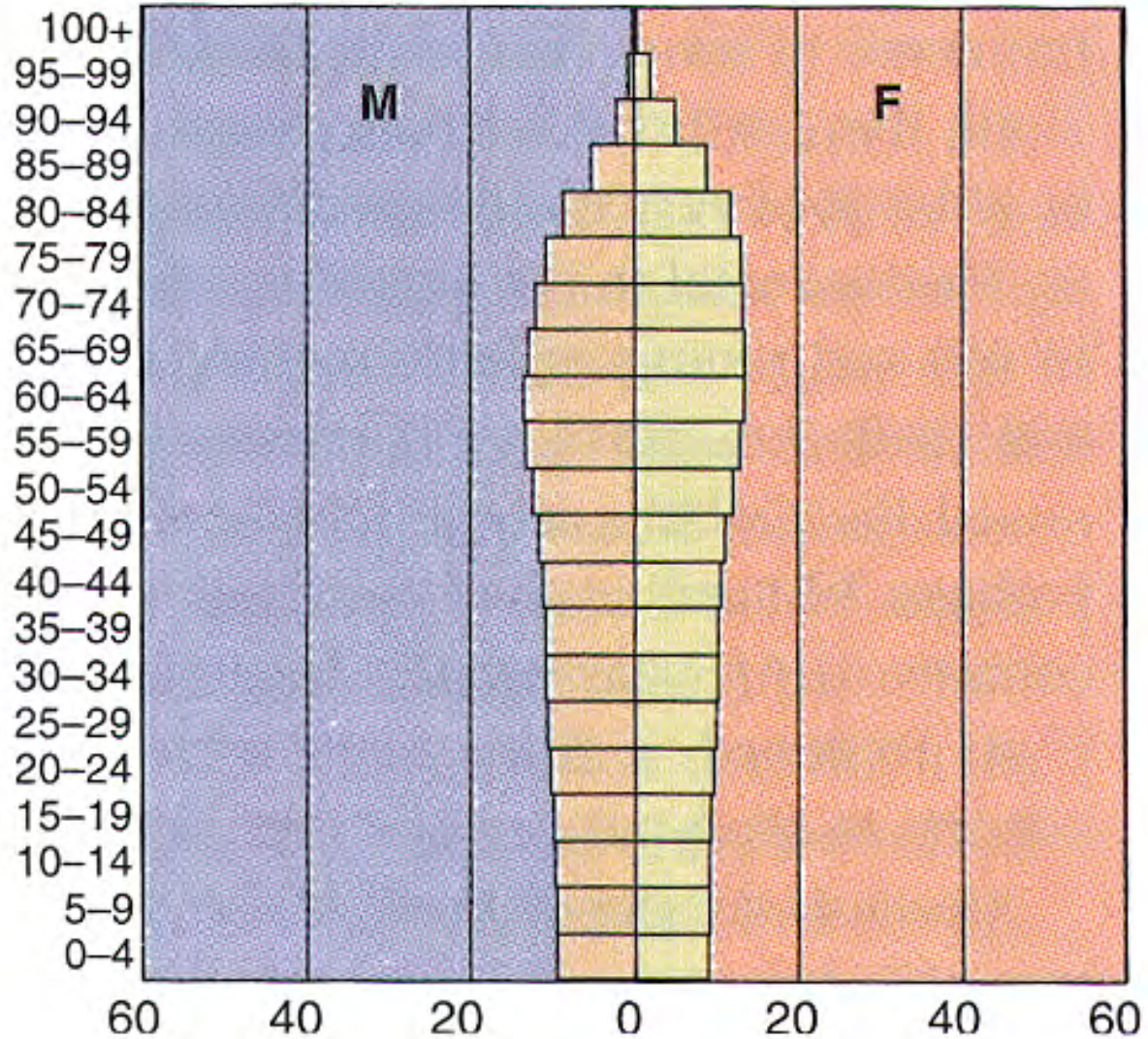
(Population: 451.4 million)



JE Cohen, *Science* 302, 1176 (2003)

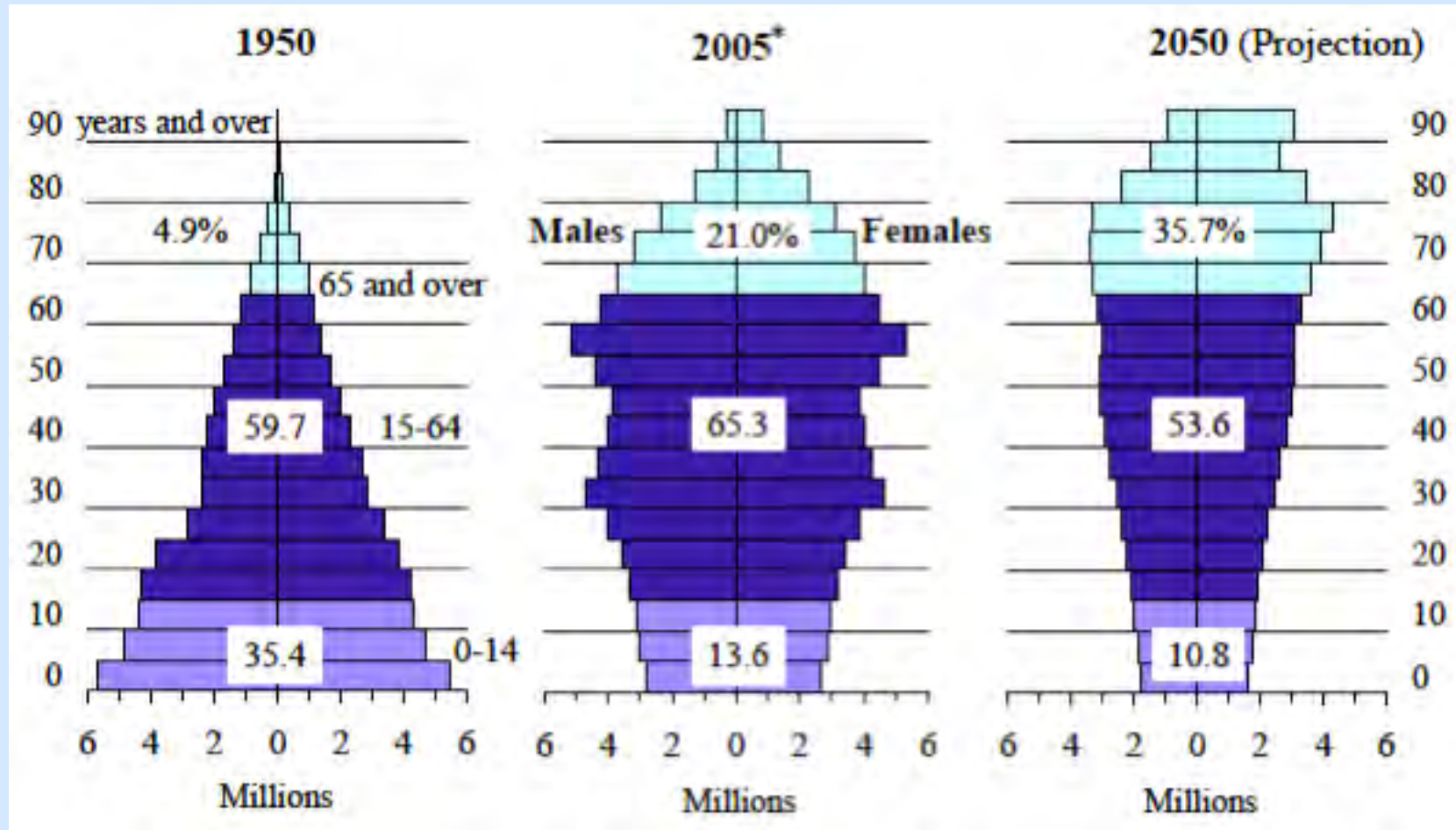
# Europe - 2050

(Population: 401 million)



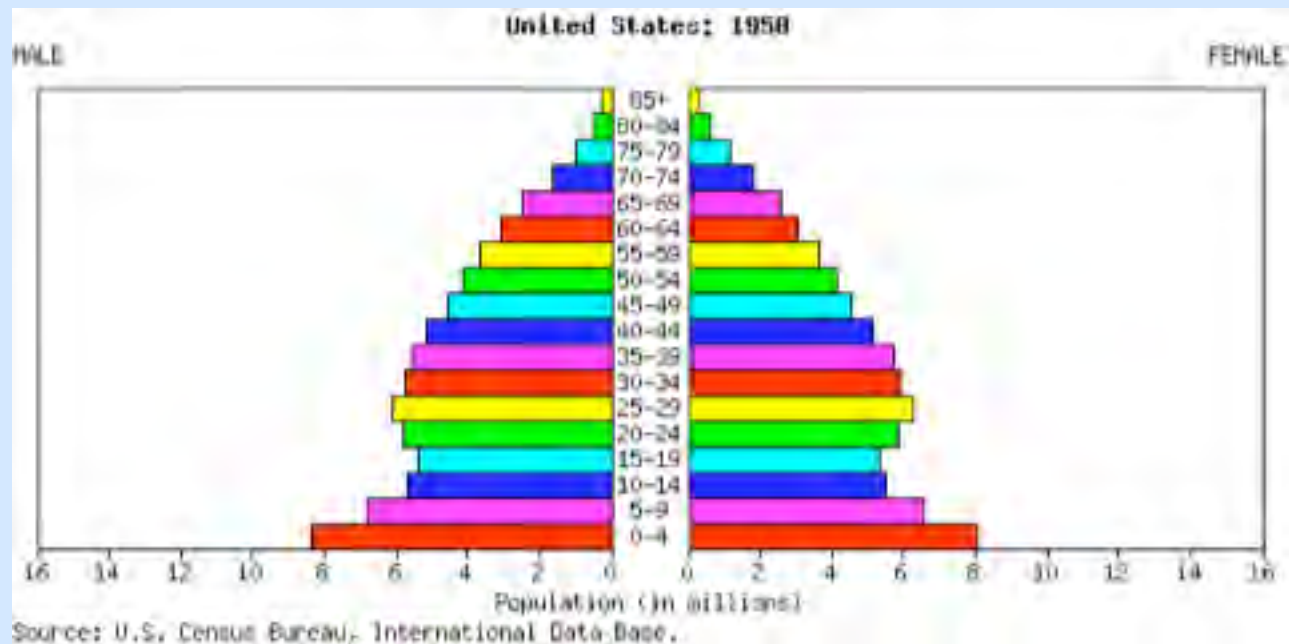
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# Japan: 1950 to 2050



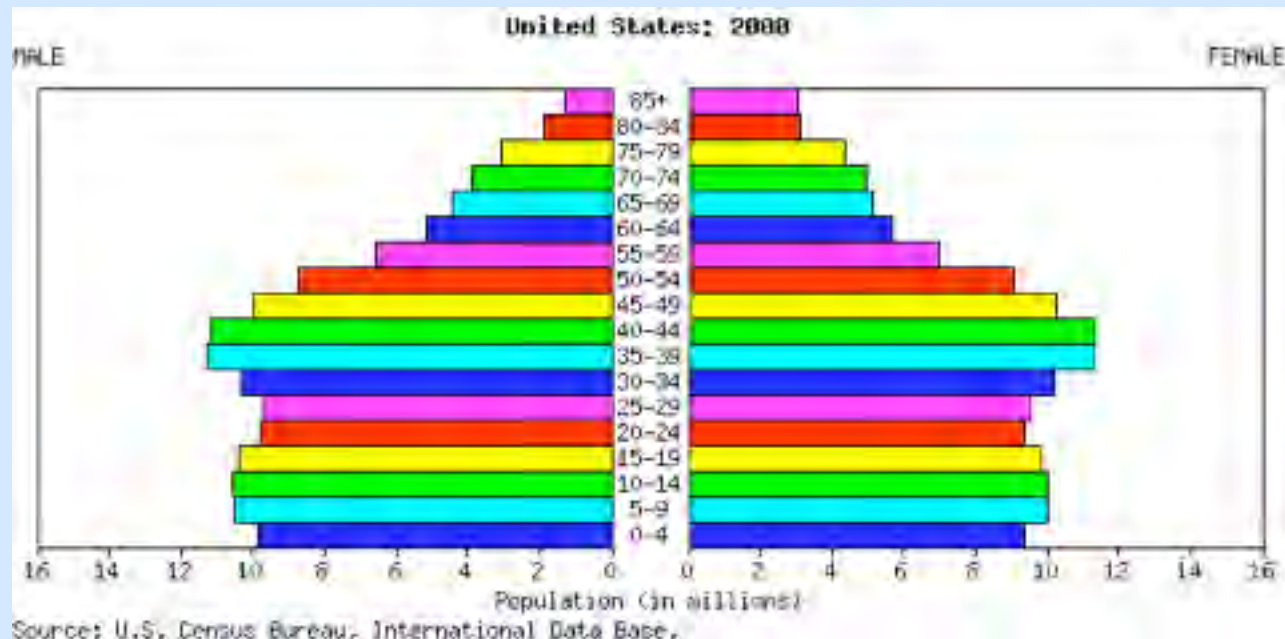
Statistics Bureau, Japan Ministry of Health, Labor, and Welfare

# United States: 1950

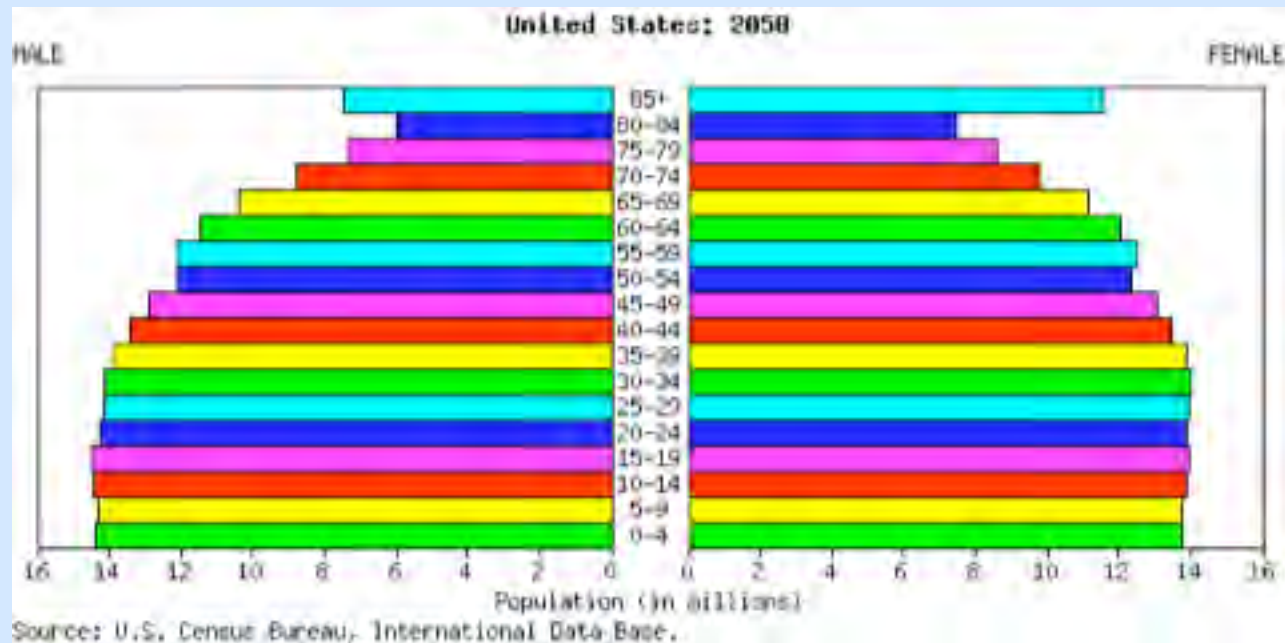




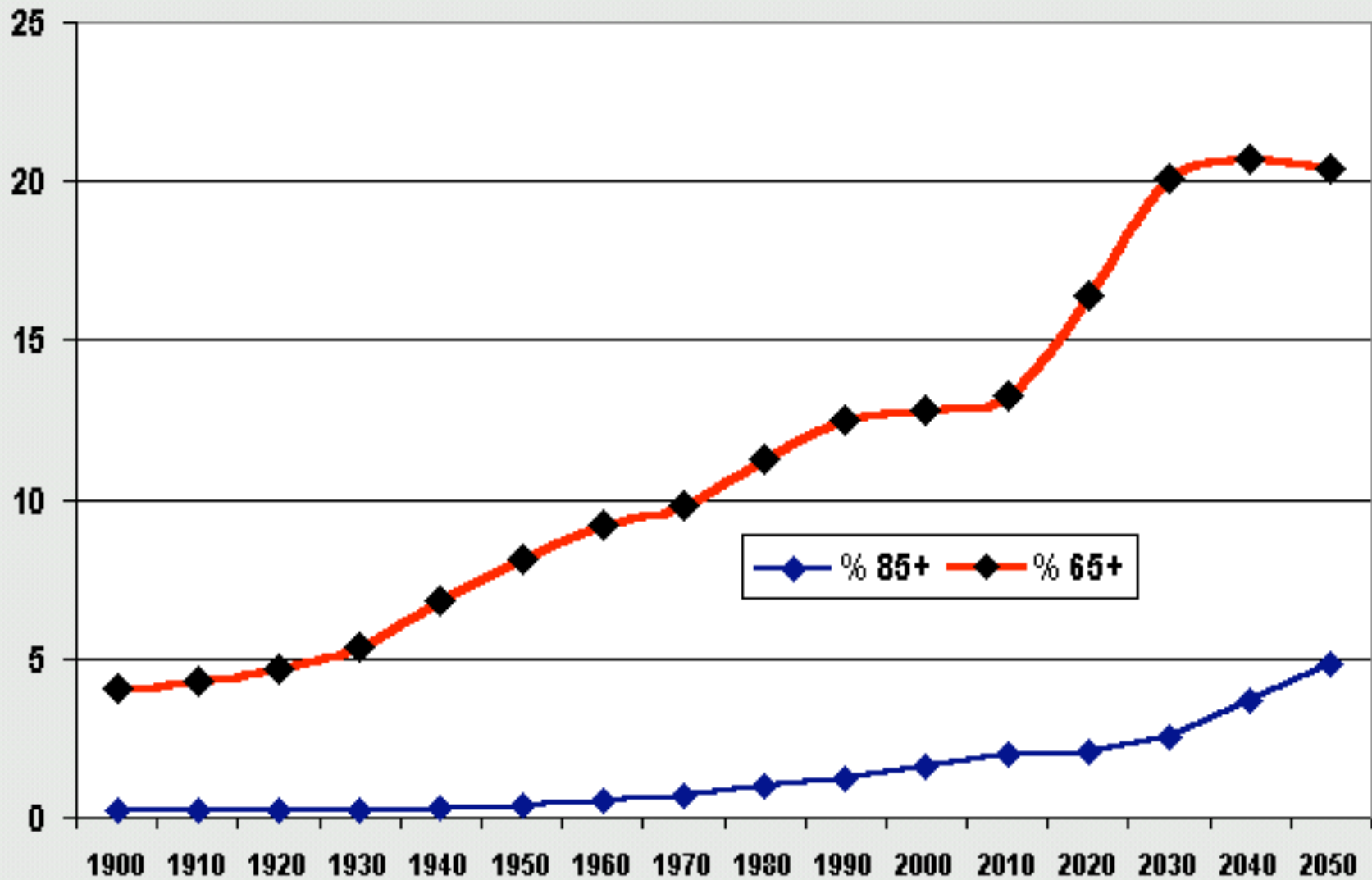
# United States: 2000



# United States: 2050



# Older Population by Age: 1900-2050 - Percent 65+ and 85+ USA





# Robots to rule at Rio Tinto

Ben Woodhead | January 18, 2008

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**RESOURCES giant Rio Tinto will replace humans with robots in its Western Australian mining operations over the next two years as it rolls out a fleet of automated vehicles including trucks, trains and drilling rigs.**



Rio Tinto chief Tom Albanese wants the resources giant to be global leaders in fully integrated, automated operations

The work is part of Rio Tinto's 'mine of the future' program, which has been underway for close to a decade and aims to radically transform mining by automating processes throughout the supply chain.

"We're aiming to be the global leaders in fully integrated, automated operations," Rio Tinto chief executive Tom Albanese said today as the miner unveiled its plans for robotic mining over the next two years.

"It will allow for more efficient operations and directly confront the escalating costs associated with basing employees at remote sites, giving us a competitive advantage as an employer along the way."

A number of new technologies including autonomous drilling rigs, trucks and trains will be deployed in Rio

Tinto's Iron Ore division in Western Australia's Pilbara region over the next two years.

The vehicles will be part of a two-year trial of autonomous technology and the company hopes to install robotic gear at other iron ore mines from 2010.

Printed May 17, 2008 02:11am AEST

## Crew shortage hits subs

Cameron Stewart | March 10, 2008

**ONLY half of Australia's submarine fleet can be sent to war, because of a critical shortage of qualified submariners.**

The crisis has left the Royal Australian Navy with only three full crews for its six Collins-class submarines, severely undermining the effectiveness of one of the nation's most vital and expensive defence assets.

"It's becoming a ghost fleet," said one submariner, who asked not to be named. "We are losing our crews - it feels like the Mary Celeste."

The Defence Department maintains that despite the "significant shortfall" in submarine crews, it still has enough to "meet operational requirements" for the submarines.

But Defence does not say if these operational tasks have been reduced in line with declining crew numbers.

Defence sources say the exodus of submariners - mostly to better-paid jobs in Western Australia's booming mining sector - has been stemmed in recent months, raising hopes that the worst may be over.

However, there is no sign of any recovery in crew numbers from current historical lows.

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# METI/Japan Dec '08 Press Release

METI has been advancing efforts to develop technologies required for the commercialization of robots and to ensure their safety, with an eye to fostering the robot industry to become a new world-leading industry.

# Korea; NYT April 2, 2006

If all goes according to plan, robots will be in every South Korean household between 2015 and 2020. That is the prediction, at least, of the Ministry of Information and Communication, which has grouped more than 30 companies, as well as 1,000 scientists from universities and research institutes, under its wing. Some want to move even faster.



# 108 Projects Under 1 EU Program

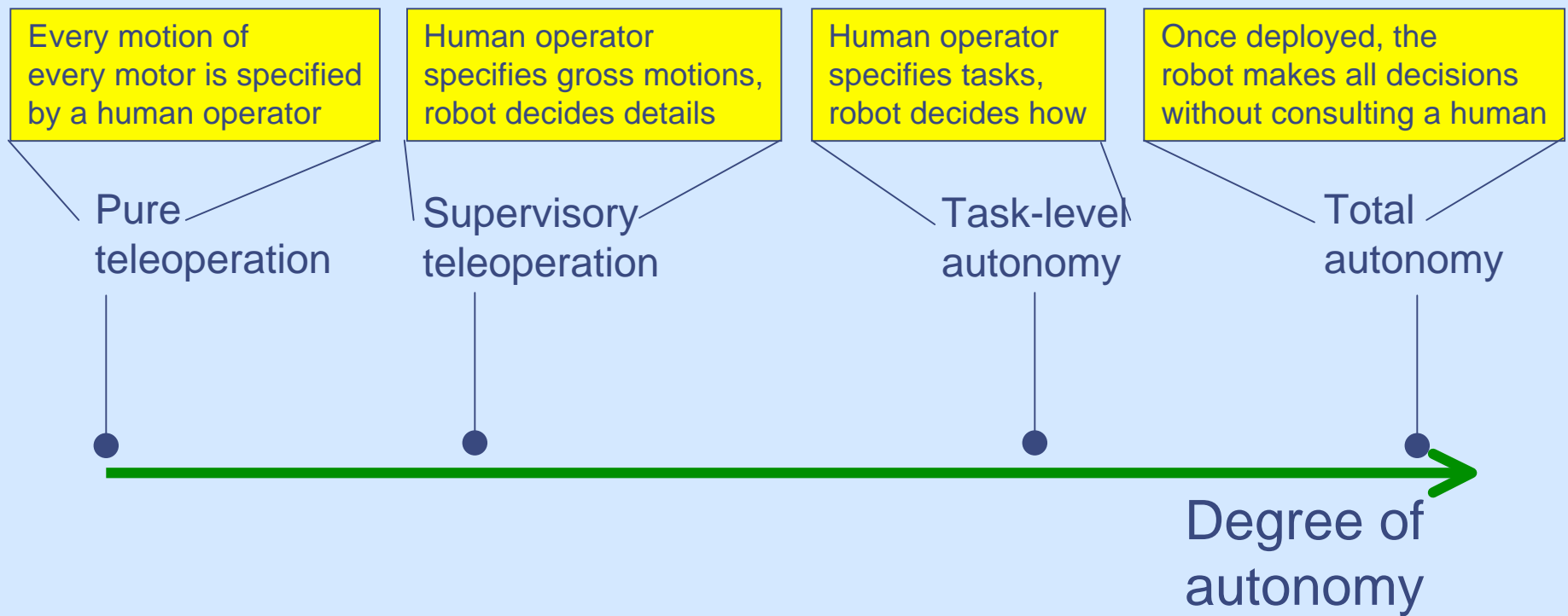




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# Autonomy for Robots



# Autonomy Levels



Pure  
teleoperation

Supervisory  
teleoperation

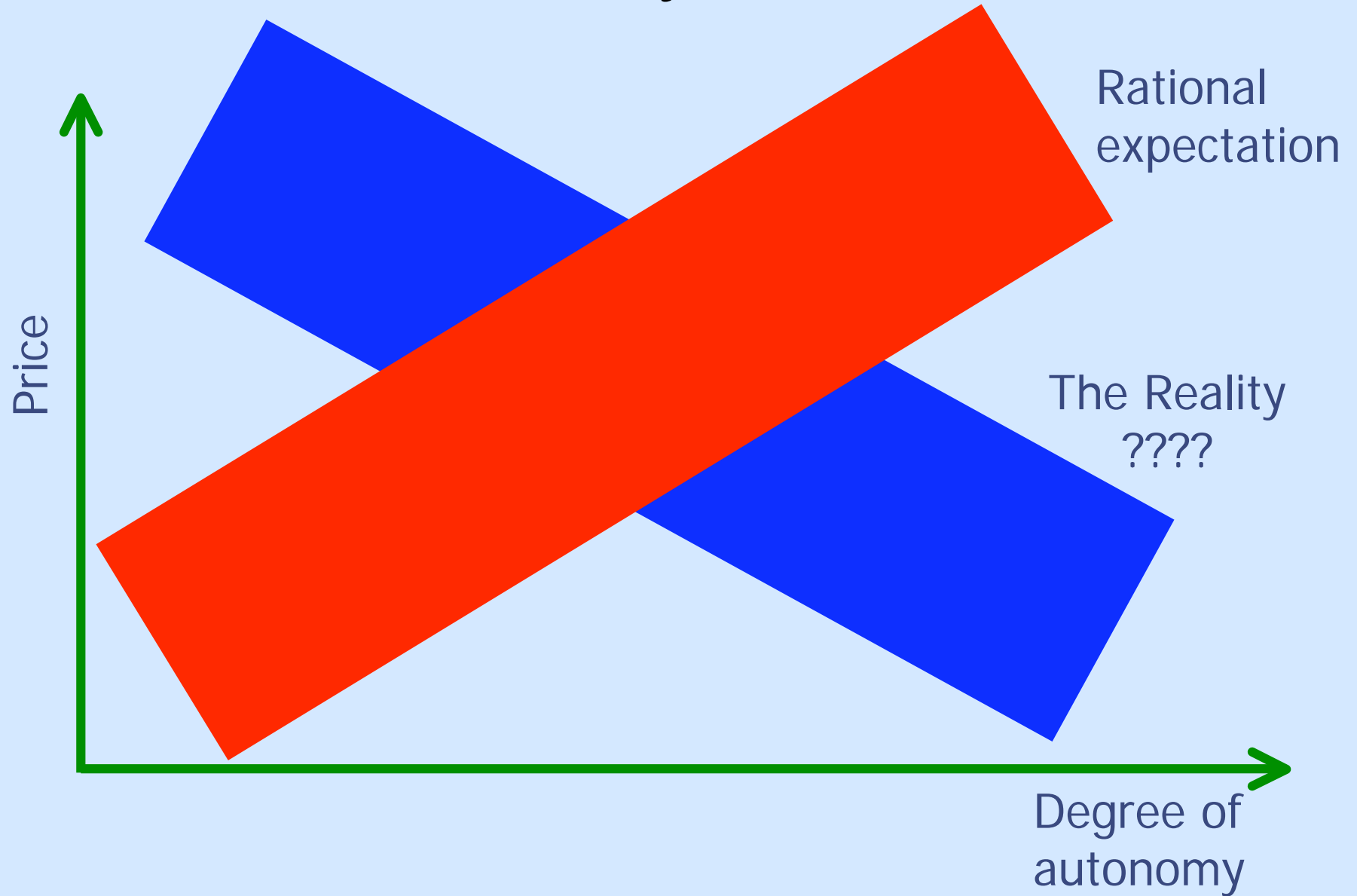
Task-level  
autonomy

Total  
autonomy

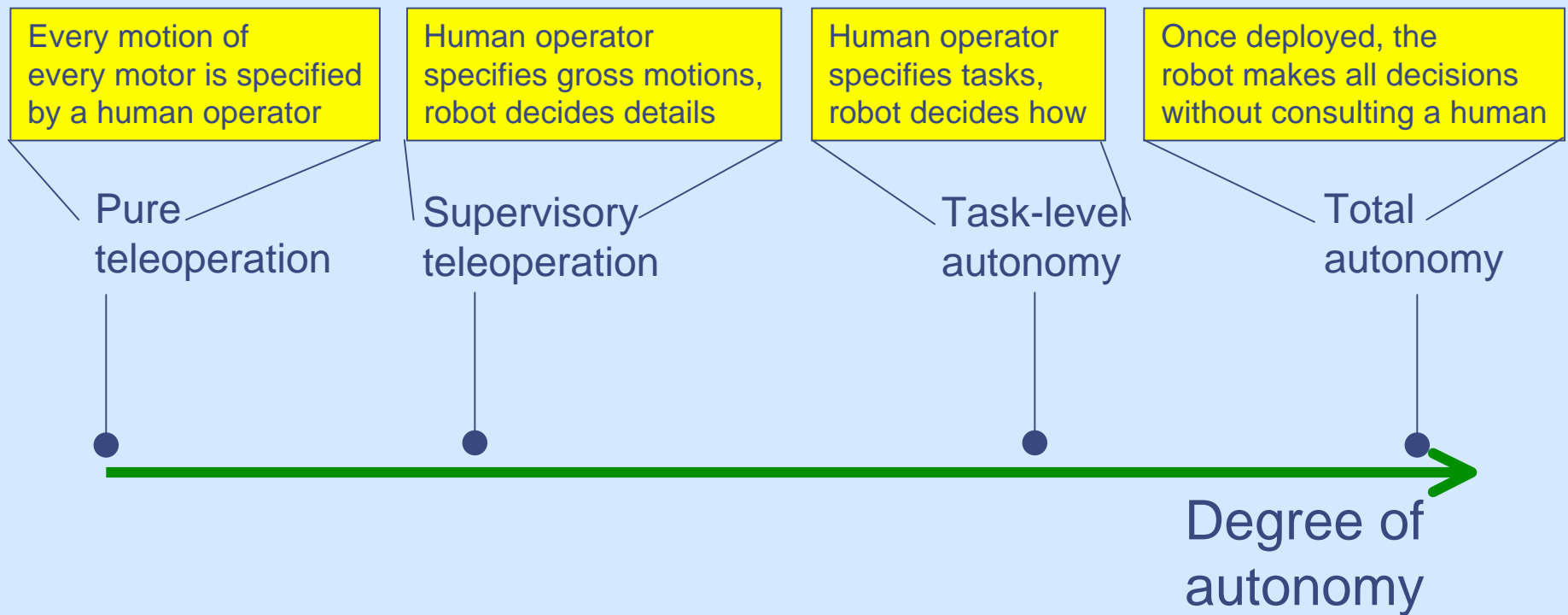


Degree of  
autonomy

# Autonomy vs. Price



# Autonomy for Robots



# Japanese Robot Autonomy

Honda



Pure teleoperation

Kawada HRP2



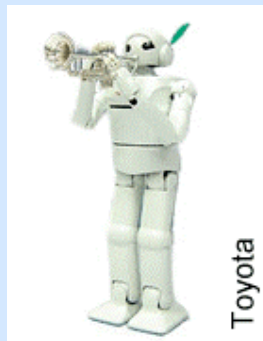
Supervisory teleoperation

Sony Aibo



Task-level autonomy

Total autonomy



Toyota



Sony QRIO

Degree of autonomy



# Space Robot Autonomy

Proposed Servicing



Pure teleoperation



Supervisory teleoperation



1997 Sojourner



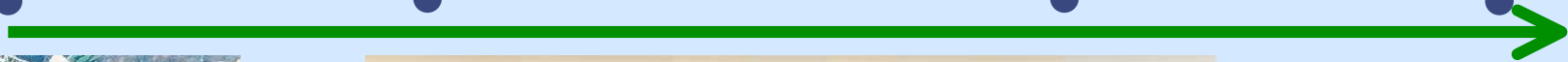
Task-level autonomy



1993 iRobot Star Wars

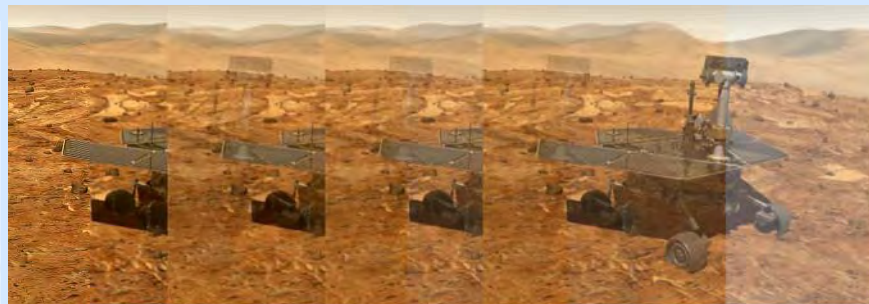


Total autonomy



Space Station

Toyota



Current Mars Rovers

Degree of autonomy

# Deployed Autonomy



Pure teleoperation



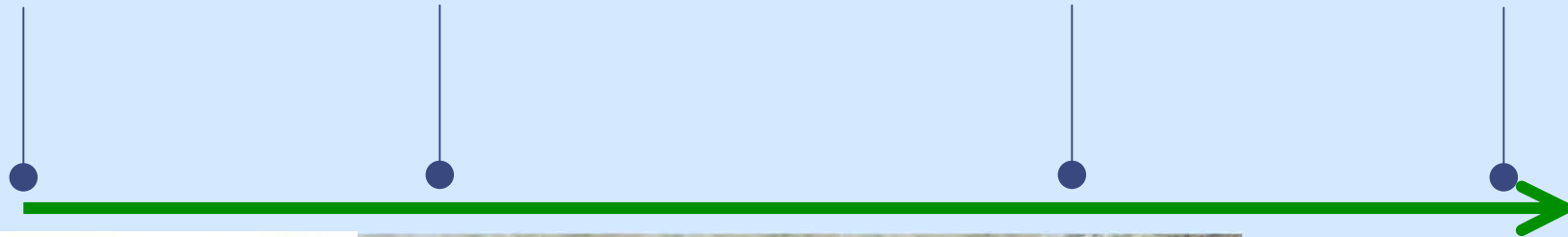
Supervisory teleoperation



Task-level autonomy



Total autonomy



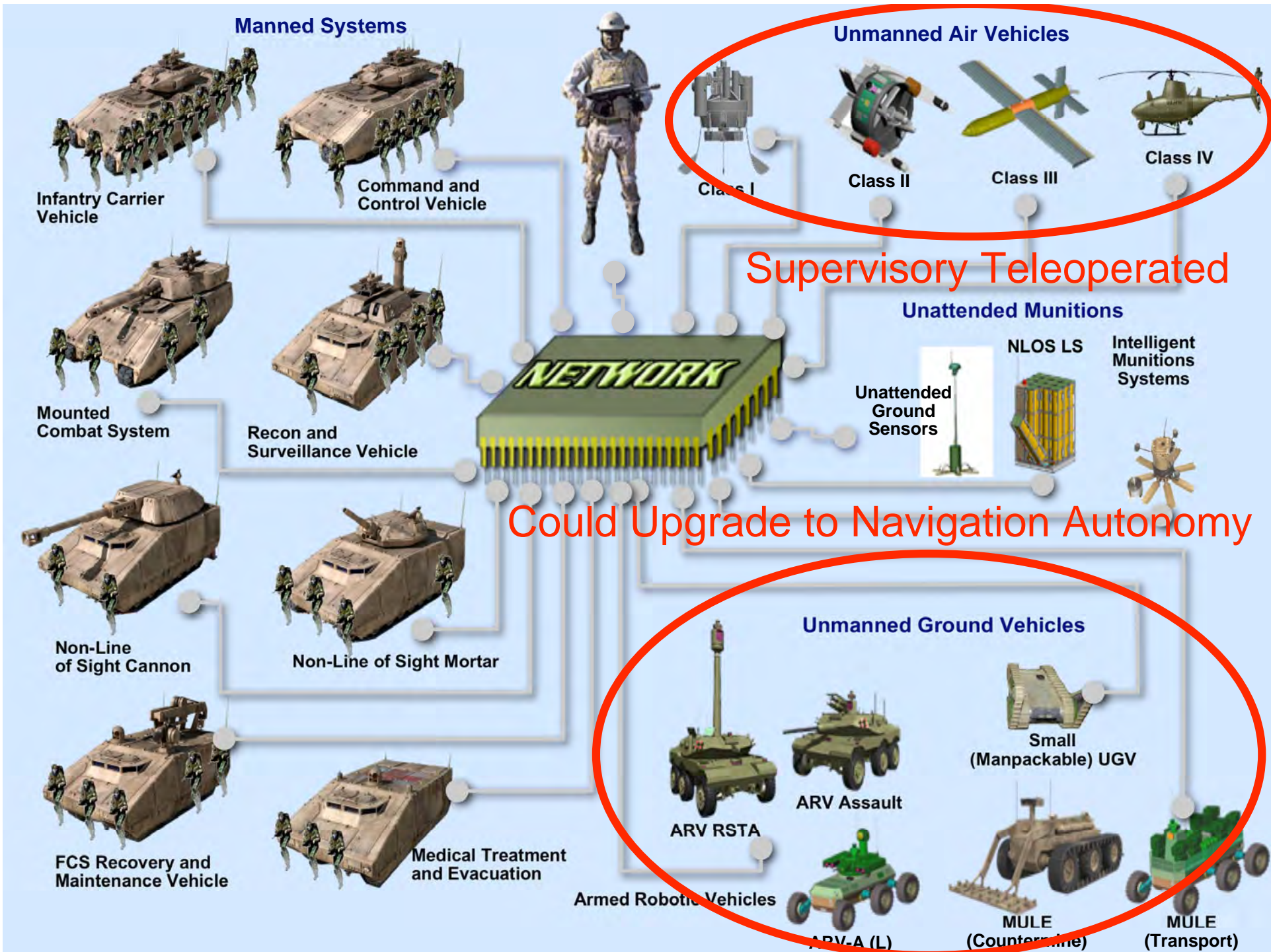
Degree of autonomy

# Why The Inverted Economics?

- It's not worth a person's time to operate a cheap robot
- In "must succeed" situations it's too risky not to have a person overseeing the robot
- The rationale for widespread deployment requires autonomy
  - our robots must get better at succeeding!

# DARPA Urban Grand Challenge





# Research Challenges

- Autonomy requires better contextual understanding:
  - generic visual object recognition
  - understanding of social context
  - understanding of spoken language (and sound!)
  - new sensors
- In order to do more things, robots need
  - ability to manipulate objects
  - to network into physical and virtual ad-hoc groups
  - ability to interact socially

# Further Reading

- <http://www.us-robotics.us> the CCC/CRA robotics roadmapping effort
- outlines challenges and opportunities for robotics in:
  - manufacturing
  - medical and healthcare
  - service industries