Technology and Other Trends

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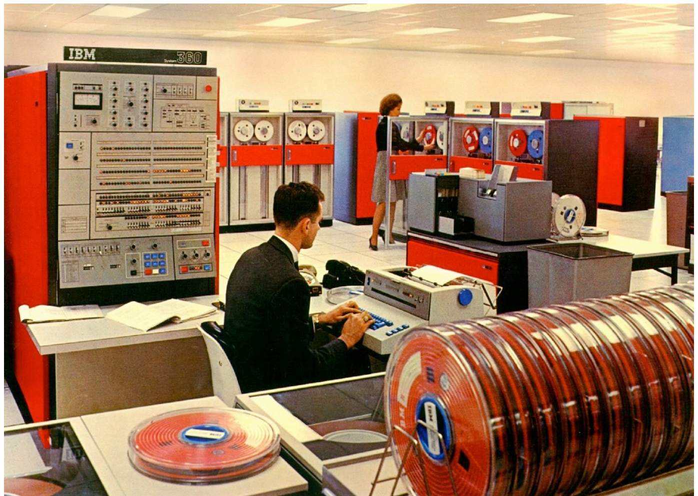
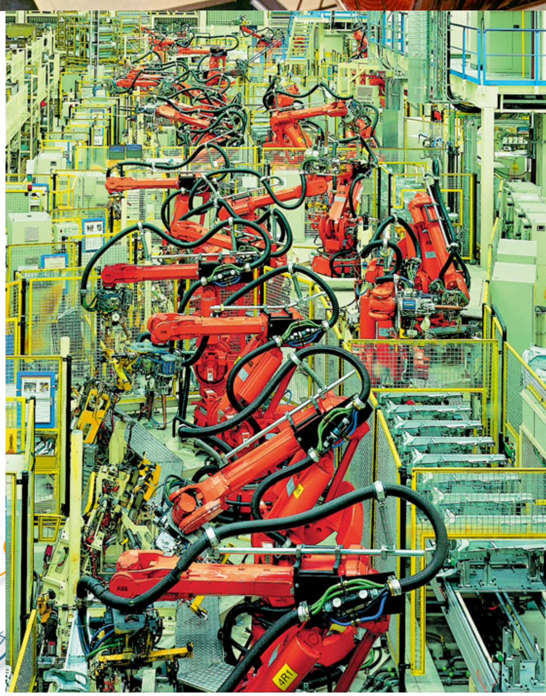
Two Revolutions



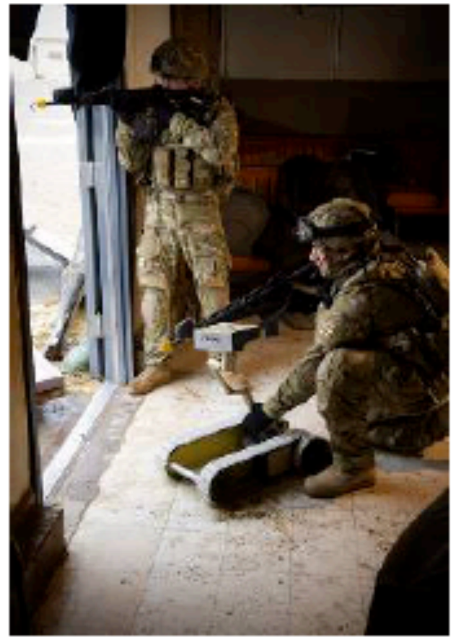
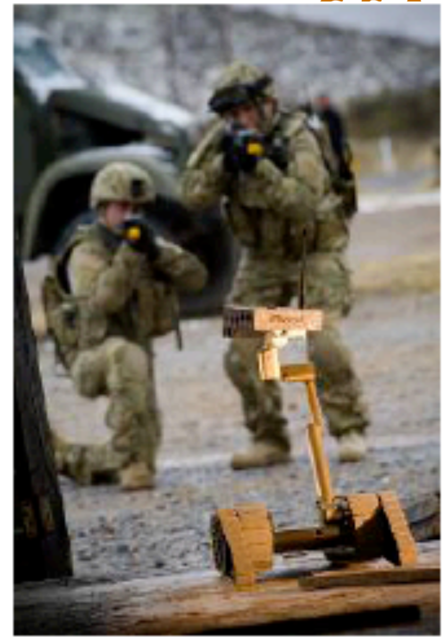


???

- Was
  - large corporate back room operation
  - automation slow and by specialized engineers
- Now
  - personal machines
  - office workers automate their own work and increase their own productivity

SUGV at Experiment 1.1




Big Trends for Robotics

- Technology exponentials driven by others
- First technology exponentials driven by robots

- Large scale military robot deployments

- Aging population
- Increased health costs
- Immigration backlash
- Globalization backlash
- Future of transportation
- Carbon neutral energy

The experts look ahead

Electronics, Volume 38, Number 8, April 19, 1965

Cramming more components onto integrated circuits

With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65,000 components on a single silicon chip

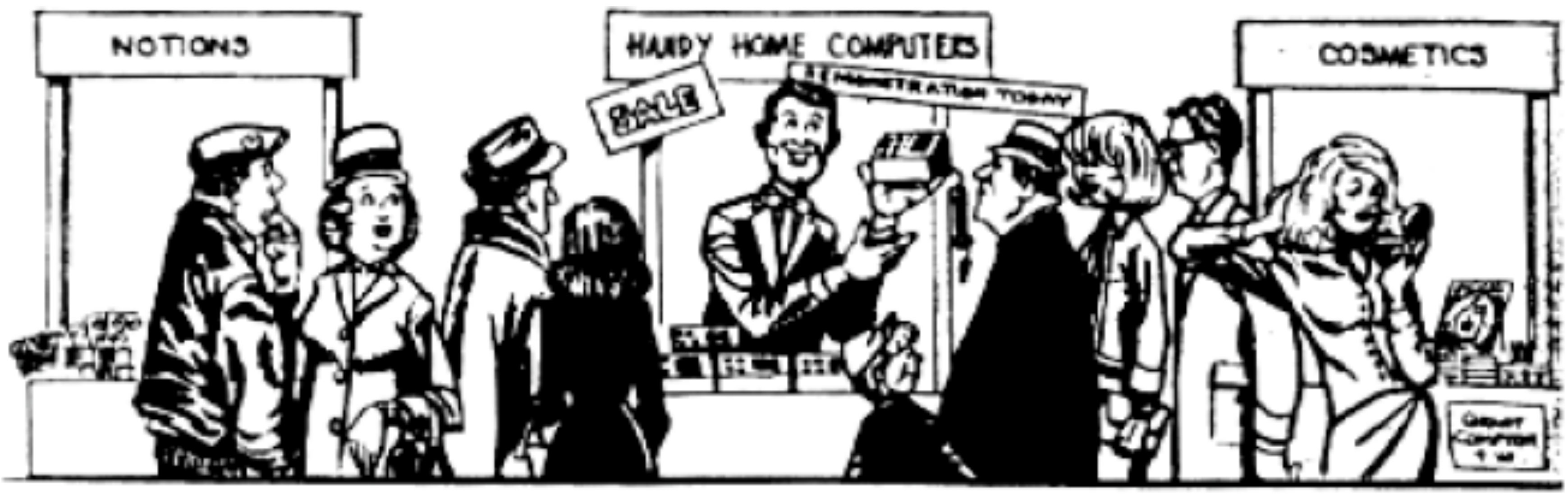
By Gordon E. Moore

Director, Research and Development Laboratories, Fairchild Semiconductor division of Fairchild Camera and Instrument Corp.

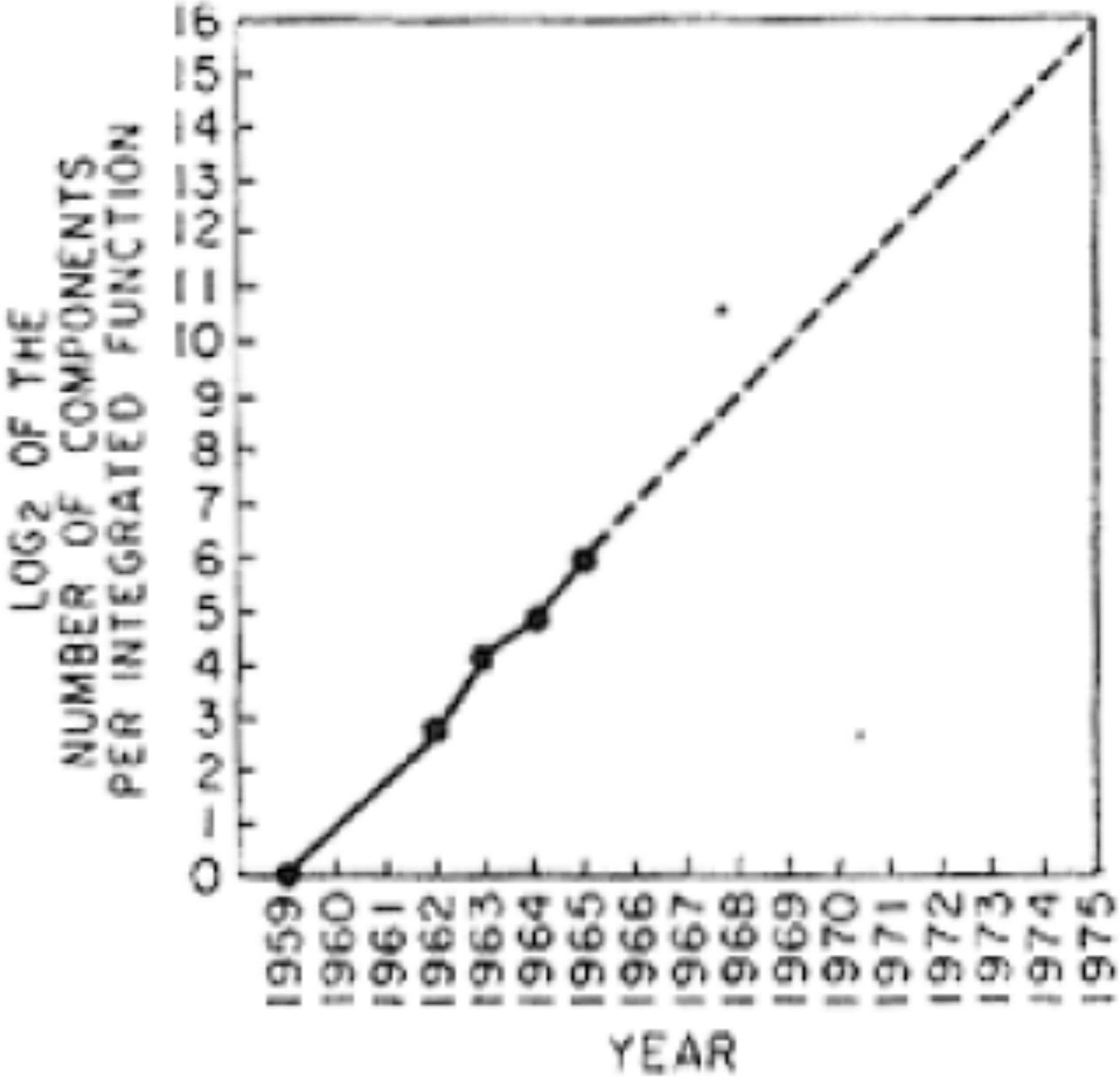
Radical Insights

The future of integrated electronics is the future of electronics itself. The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas.

Integrated circuits will lead to such wonders as home computers—or at least terminals connected to a central computer—automatic controls for automobiles, and personal portable communications equipment. The electronic wristwatch needs only a display to be feasible today.



The Key Graph

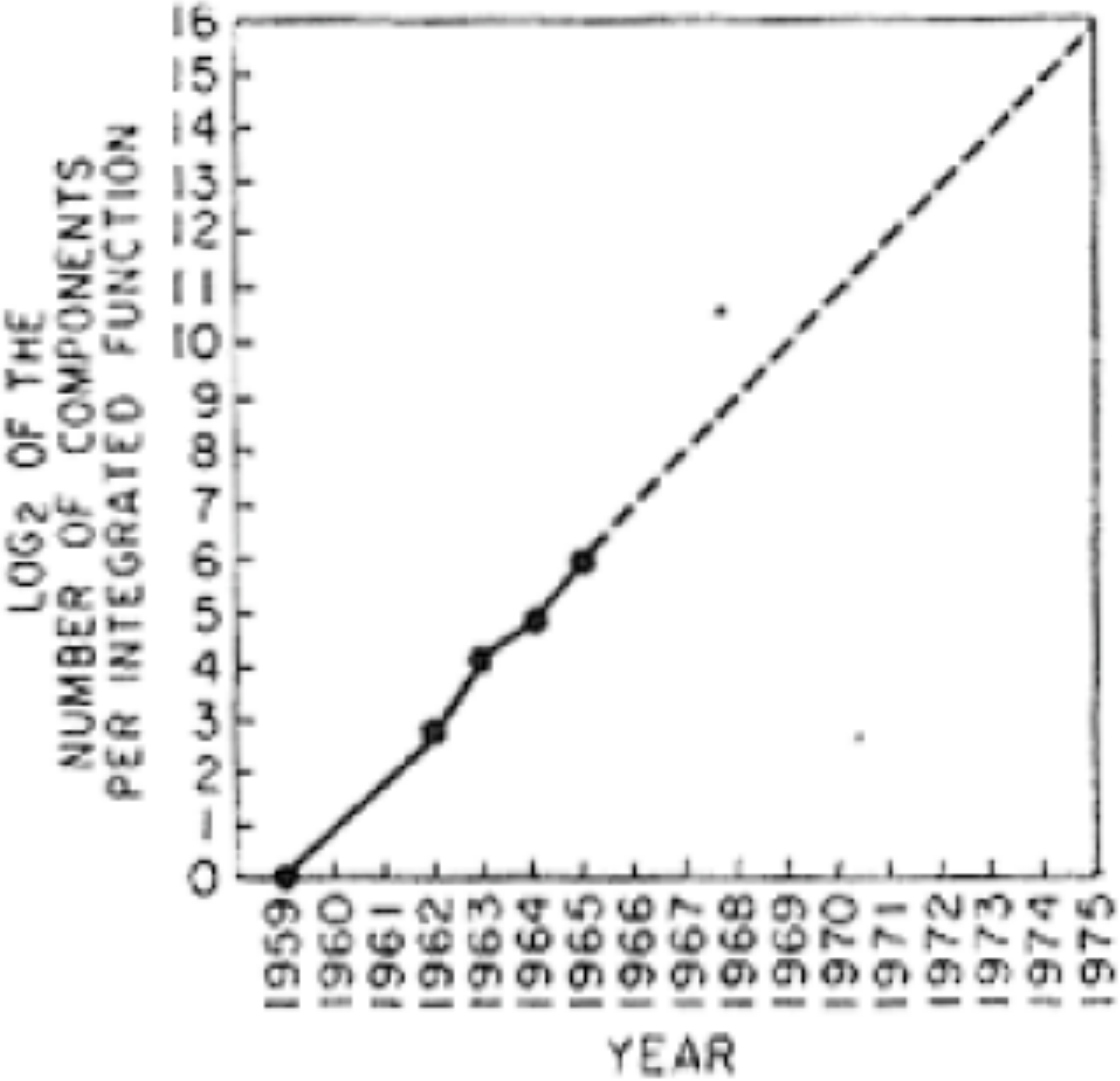


What Defines an Exponential?

$$\frac{ds}{dt} = \alpha s$$

- The rate of change of "stuff" is proportional to the instantaneous amount of "stuff" that is around already
- Is this the explanation for how computer power has been an exponential?
- Does the presence of computers of power P make it easier to build a computer of power wP, where w>1?

But Not in Play in 1965



Three Exponential Forms

1. Rate of improvement is proportional to the current level of adoption

2. The existence of the law tells everyone what level to aim for when

3. Someone else is driving an exponential and you get to hop on it for free

iPod as Current Storage Standard

- Mid 2003: 10 Gigabytes -- teenager price ($400), fits in pocket. Enough for most people's personal music collection.
- Mid 2004: 20 Gigabytes
- Mid 2005: (on Apple Web site):
  - 20 GB = $249
  - 30 GB = $349
  - 60 GB = $449 (sold as iPod Photo)
- Jan 2006 (on Apple Web site): 60 GB, $399 (thinner)
- Sept 2006 (finally): 80 GB, $349 [20,000 songs, 100 hrs video]
- Sept 2007: 160 GB, $349 (same March 4, 2008)
- Doubling every year

$\$400 = 2^{(\text{year}-2003)} \times 10 \text{ Gigabytes}$

- That means an iPod in 2025, $400, will have
  - 40,000,000 Gigabytes
  - or 40 Petabytes
- [iPod in 2015 will have 40,000 Gigabytes]
- [iPod in 2034 will have 2 Billion Gigabytes, i.e., 2 Exabytes]

The Million Book Project (Raj Reddy)

- Digitization centers in India, China, Egypt
- Aim is 1,000,000 books digitized and freely available (now subsumed by Google)
- 500 Gigabytes as text (= iPod in 2009) [only 320,000 books now]
- 50 Petabytes as image files
- Library of Congress has 20 million books
  - 10,000 Gigabytes as text (= iPod in 2013)
- Current [2007] iPod = 200 hours of video (= 100+ movies)
- 379,871 movies on IMDb (? 800K including Bollywood)
- An iPod in 2020 will store 819,200 movies…
- All the ones worth caring about: <2016

Exponential Consequence

Future robots, disconnected from the net, can have enormous onboard databases.

Costs of Mechanical Components

	1993	1999	2000	2001	2003	2005	2006
Linear Bearing	$9.69	$10.02	$10.42	$10.71	$10.71	$11.60	$12.00
Ball Screw / inch	$2.12	$2.26	$2.26	$2.34	$2.39	$2.75	$2.75
Ball Nut	$124.09	$131.84	$131.84	$136.72	$139.46	$153.35	$155.65
Flexible Coupling	$17.58	$21.75	$22.30	$22.85	$22.85	$22.85	$22.85
Miter Gear	$11.57	$15.06	$13.02	$13.02	$13.40	$15.05	$15.76
100 MIPS[4][1]	$47.62	$2.78	$1.72	$1.06	$0.41	$0.16	$0.10
Relative C.P.I.[2]	1.000	1.055	1.138	1.222	1.219	1.305	1.476

Table A.1: Price trend data of precise mechanical parts and computation over time.[2]

Name	Description	McMaster-Carr
Linear Bearing	1/4"x1/2"x3/4" Frelon Lined Linear Bearing	#5986K2
Ball Screw / inch	1/2" Ball Screw (0.5" lead, 4150 Steel)	#5966K25
Ball Nut	1/2" Ball Nut (Mates with #5966K25)	#5966K15
Flexible Coupling	1/4"x1/4" (7 degree max) precision coupling	#6208K22
Miter Gear	Steel 20 degree Miter Gear (12px15x1/2" bore)	#6529K15

Relative Mechanical Costs over Time

	1993	1999	2000	2001	2003	2005	2006
Linear Bearing	1.000	0.980	0.945	0.904	0.907	0.917	0.839
Ball Screw/inch	1.000	1.010	0.937	0.903	0.925	0.994	0.879
Ball Nut	1.000	1.007	0.934	0.902	0.922	0.947	0.850
Flexible Coupling	1.000	1.173	1.115	1.064	1.066	0.996	0.881
Miter Gear	1.000	1.234	0.989	0.921	0.950	0.997	0.923

Moore's Law

- Even Gordon Moore is worried there is only another 10 years left
- "Solution" is multi-cores
  - BUT, parallel programming is not solved
- [At the same time handhelds are driving down power consumption]
- BUT, BUT, our robots can probably easily utilize 8 or so cores, without general parallel programming
  - dedication of individual cores to full blast processing (e.g., video comp., SLAM, etc.)
  - i.e., good days are here for robots

Yearly increase multiplier for [instructions executed/second/$]

- Based on 1950-2000 data; perhaps it is getting faster, but assume constant (consv.).
- Factor is 1.45/year. Doubles in 1.88 years.
- E.g., 1MIP/$ in 1998 ==> 1.45MIP/$ in 1999
- Compared to a robot in 2007 this is how much computer power we'll have for same priced robot if we spend the same portion of COGS on computation

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.00	1.45	2.09	3.02	4.37	6.31	9.12	13.2	19.1	27.5	39.8

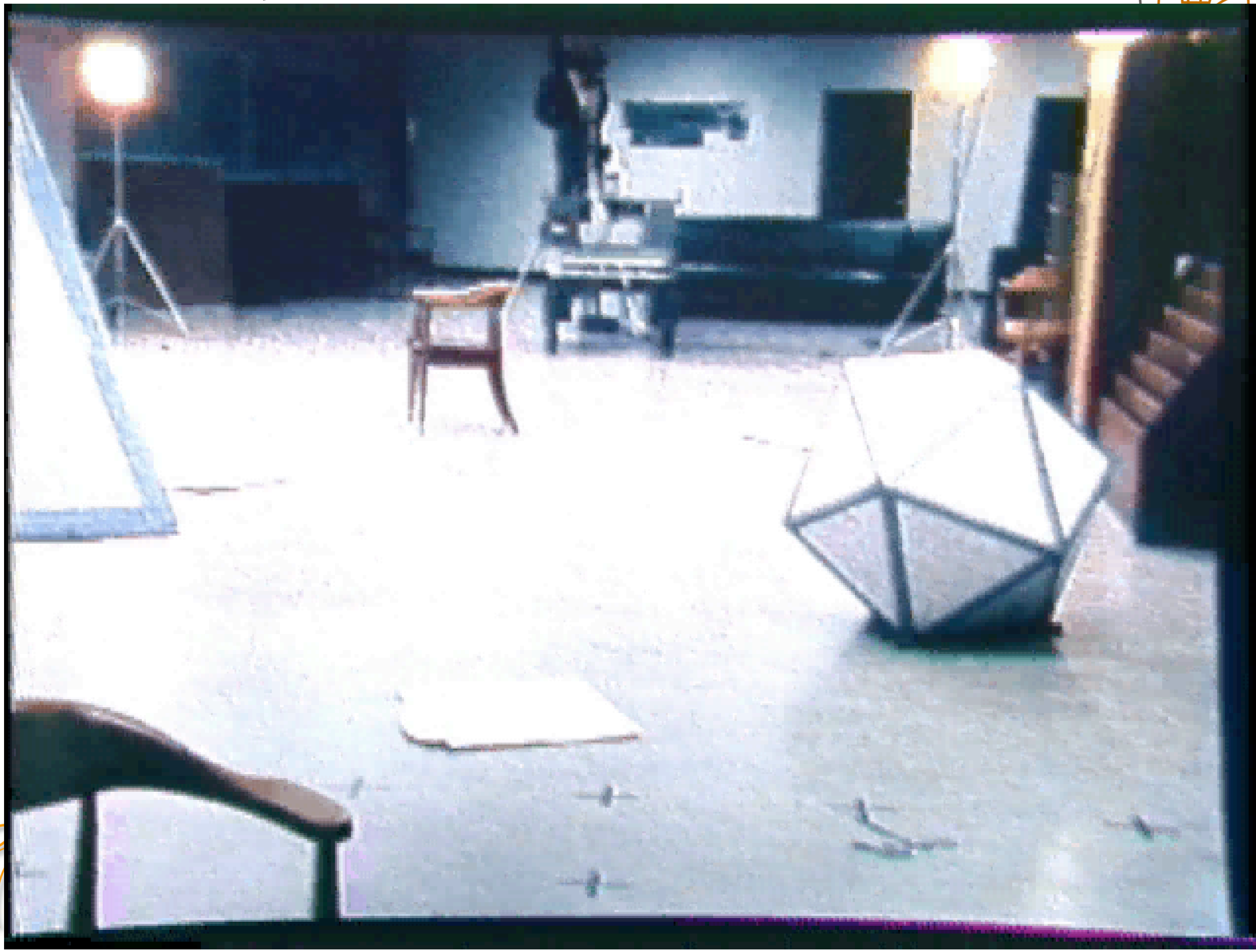
Exponential Consequence

When computation can be used to replace mechanical precision robots will get cheaper over time.

Exponentials and pseudo-E's for Robots

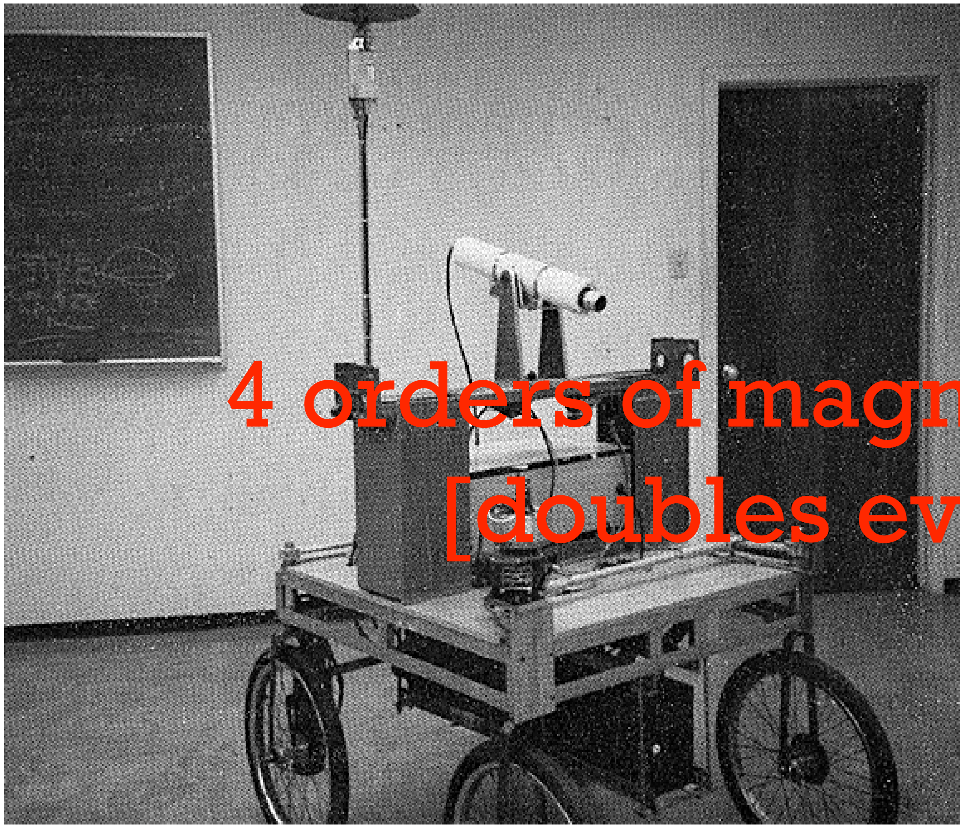
- Amount of computation
- # of cores on chip
- Onboard memory
- Pervasive wireless communication bandwidth
- Cost of sensors
  - cameras
  - auto collision sensors
  - nanotech-based sensors
- Installed base
  - user acceptance/familiarity
  - # of offerings
- Massive data sets on the WWW
  - machine learning
  - new vision algorithms
- Performance of speech systems
  - vocabulary, speaker independence, noise env.
- Smart automobiles
- Robots as teaching vehicles
  - college and high school

The Cart, in 1979



Stanford AI Lab

1979: 20 meters/6 hours



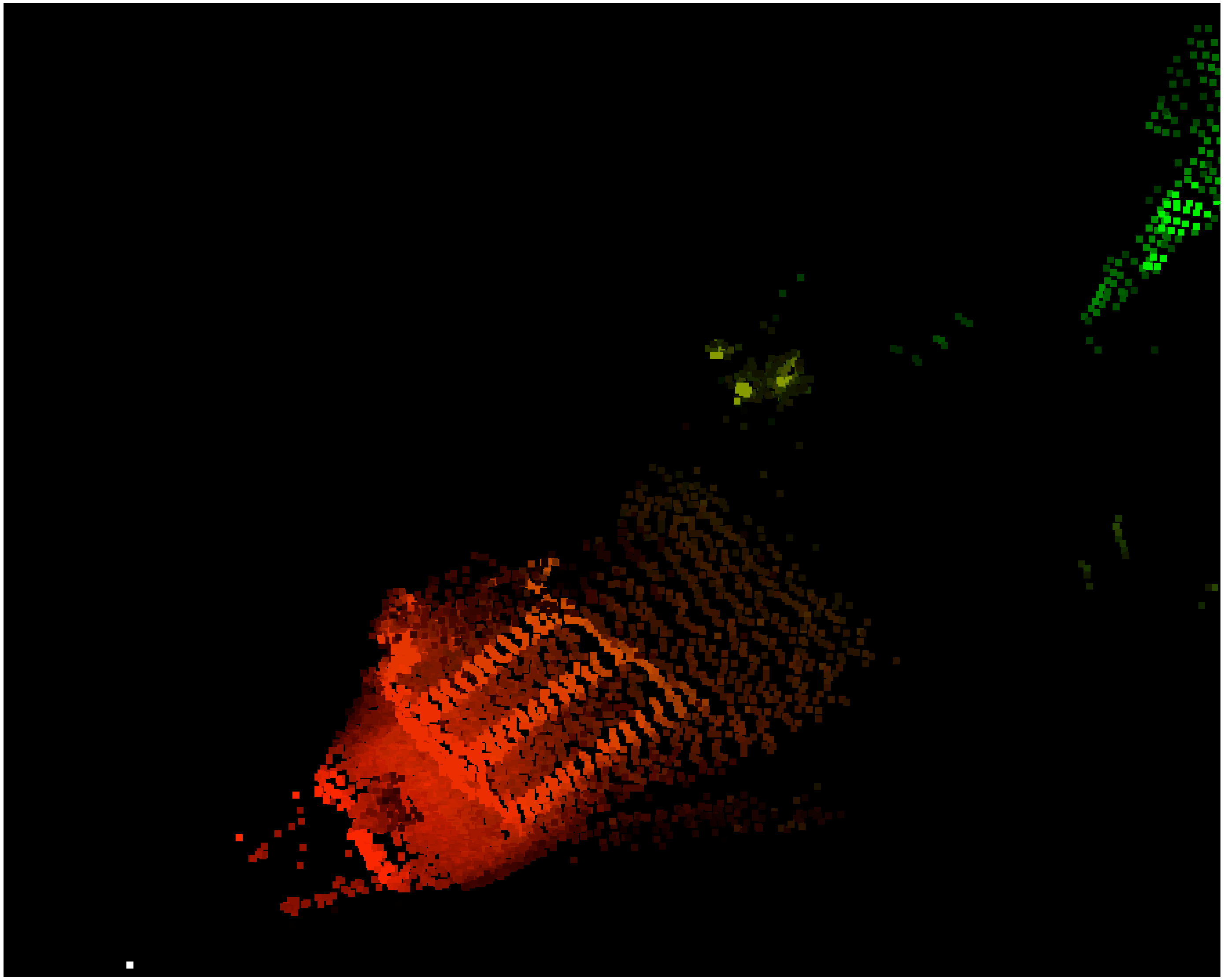
4 orders of magnitude in 26 years
[doubles every 2 years]

2005: 200 kilometers/6 hours

Robots As Drivers of Exponentials

CSAIL

Robots Requirements as Driver: ASC Sensor



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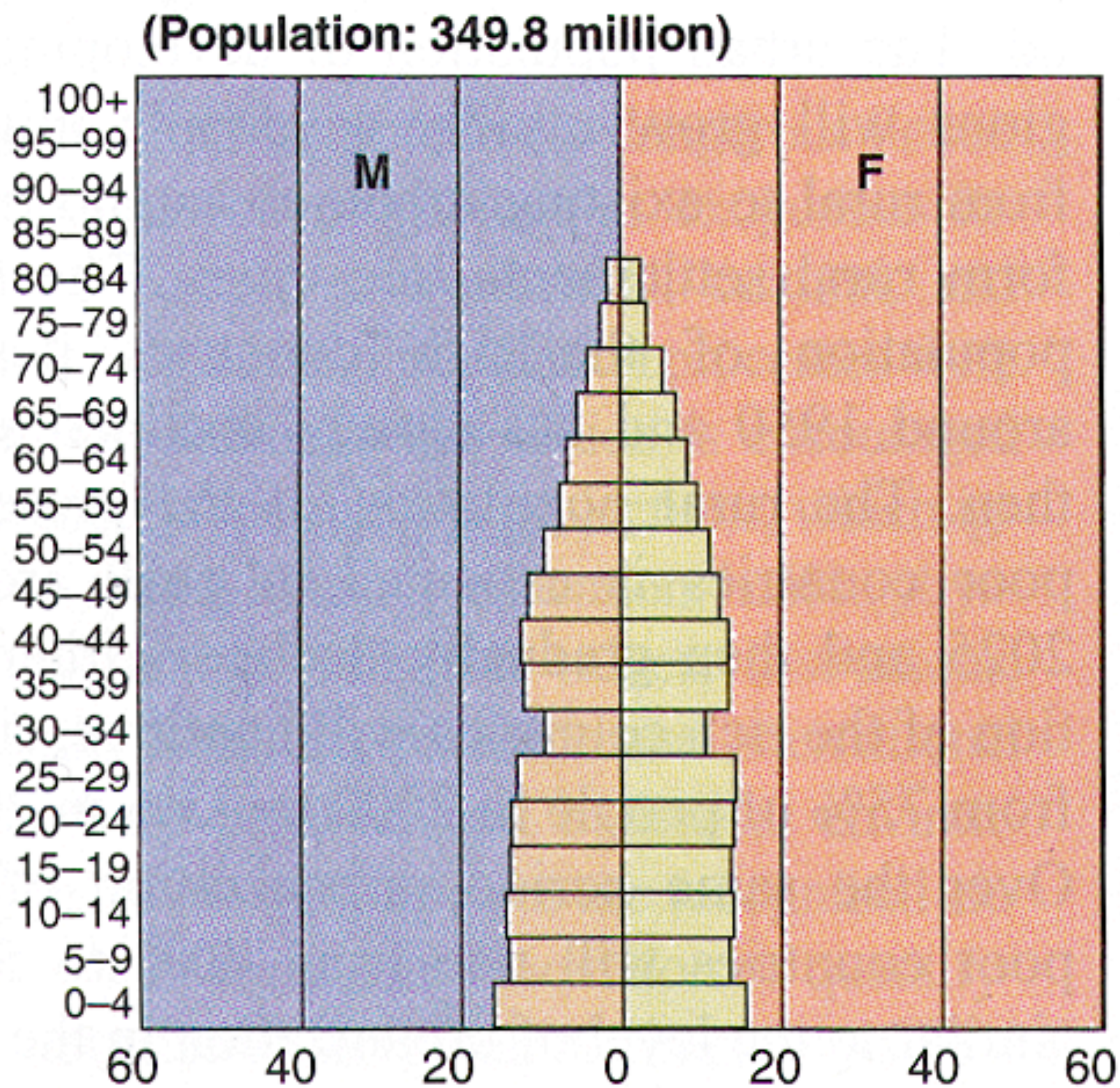
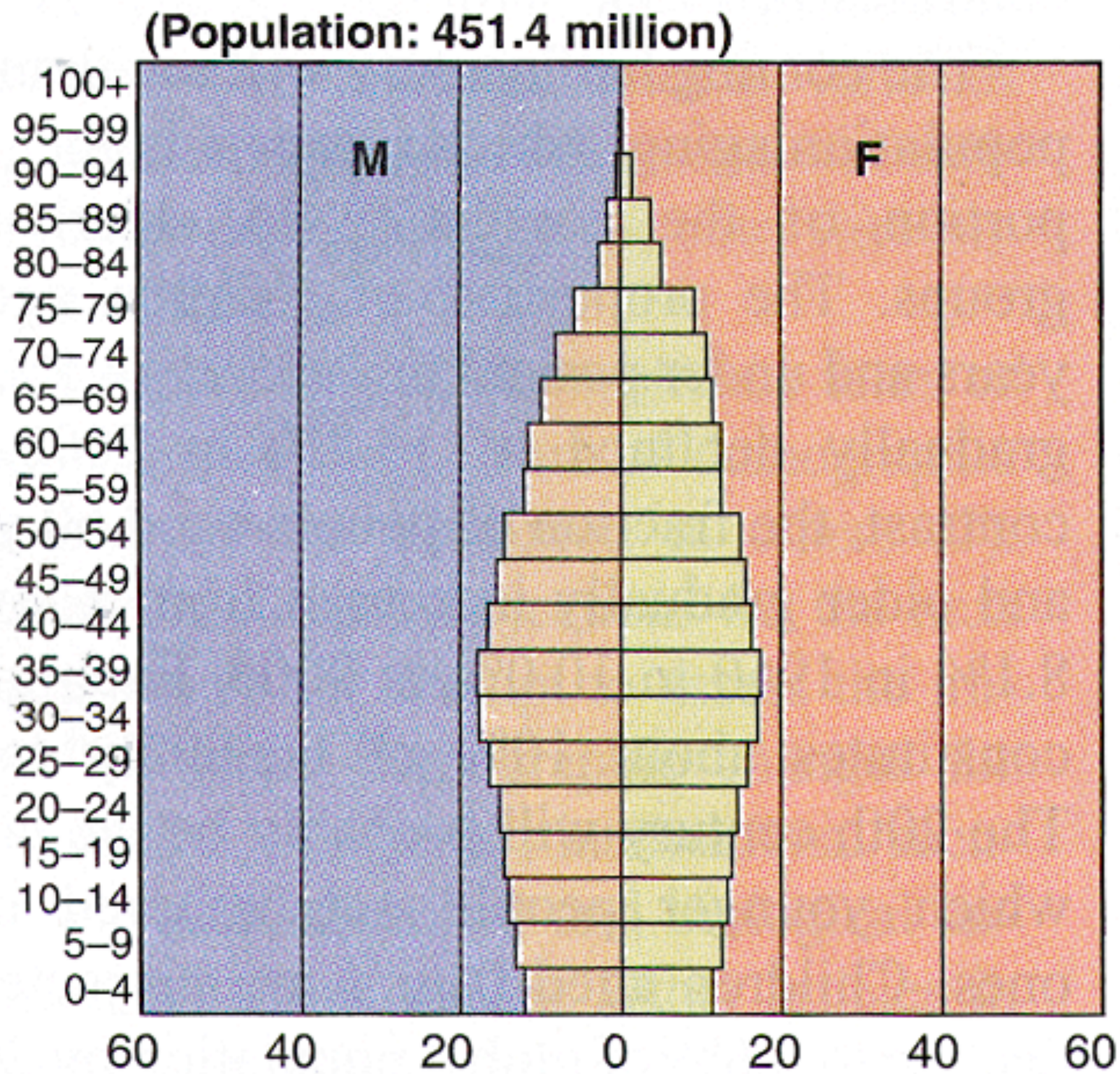
Europe - 1950



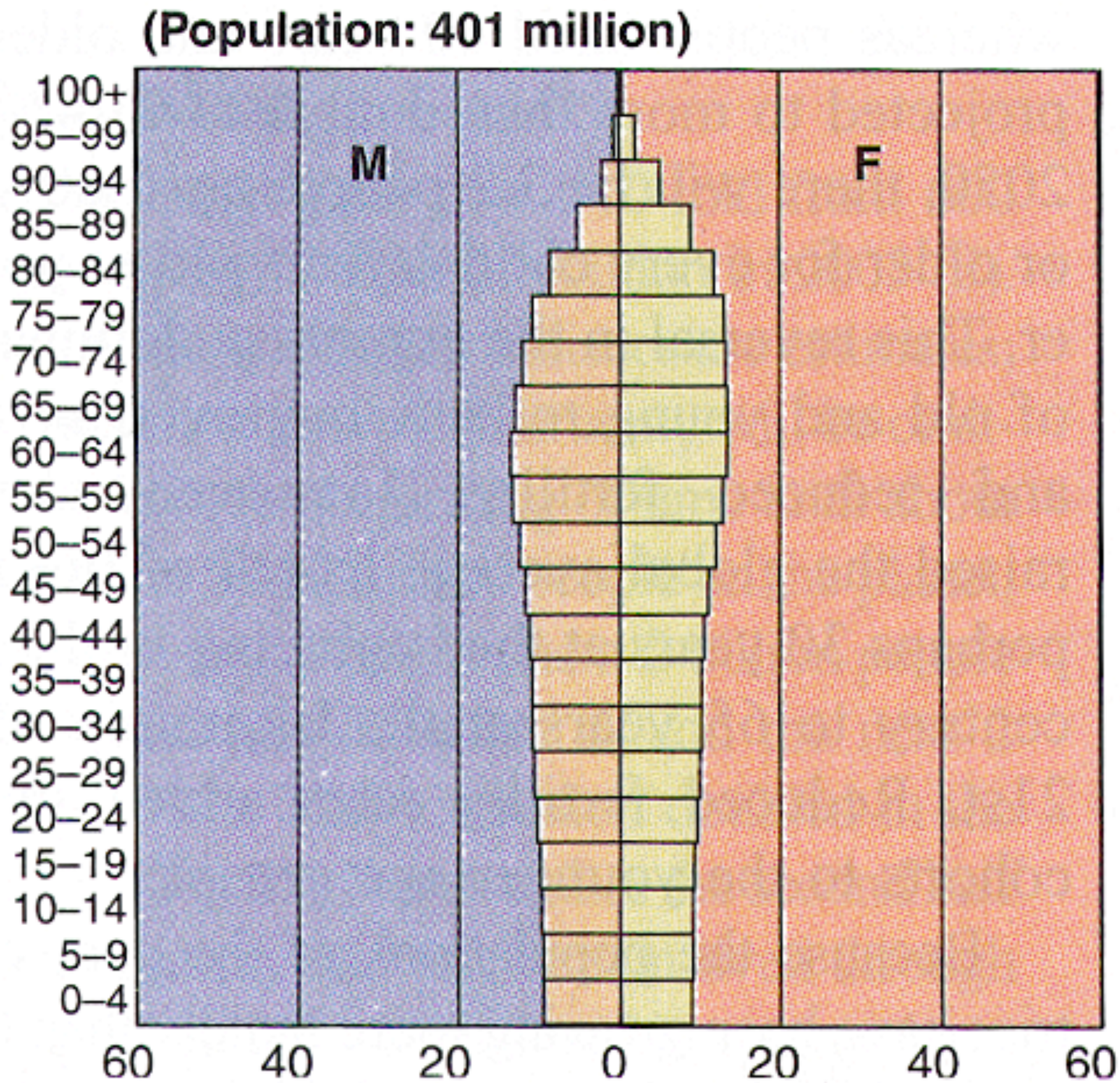
JE Cohen, Science 302, 1176 (2003)

Europe - 2000



JE Cohen, Science 302, 1176 (2003)

Europe - 2050



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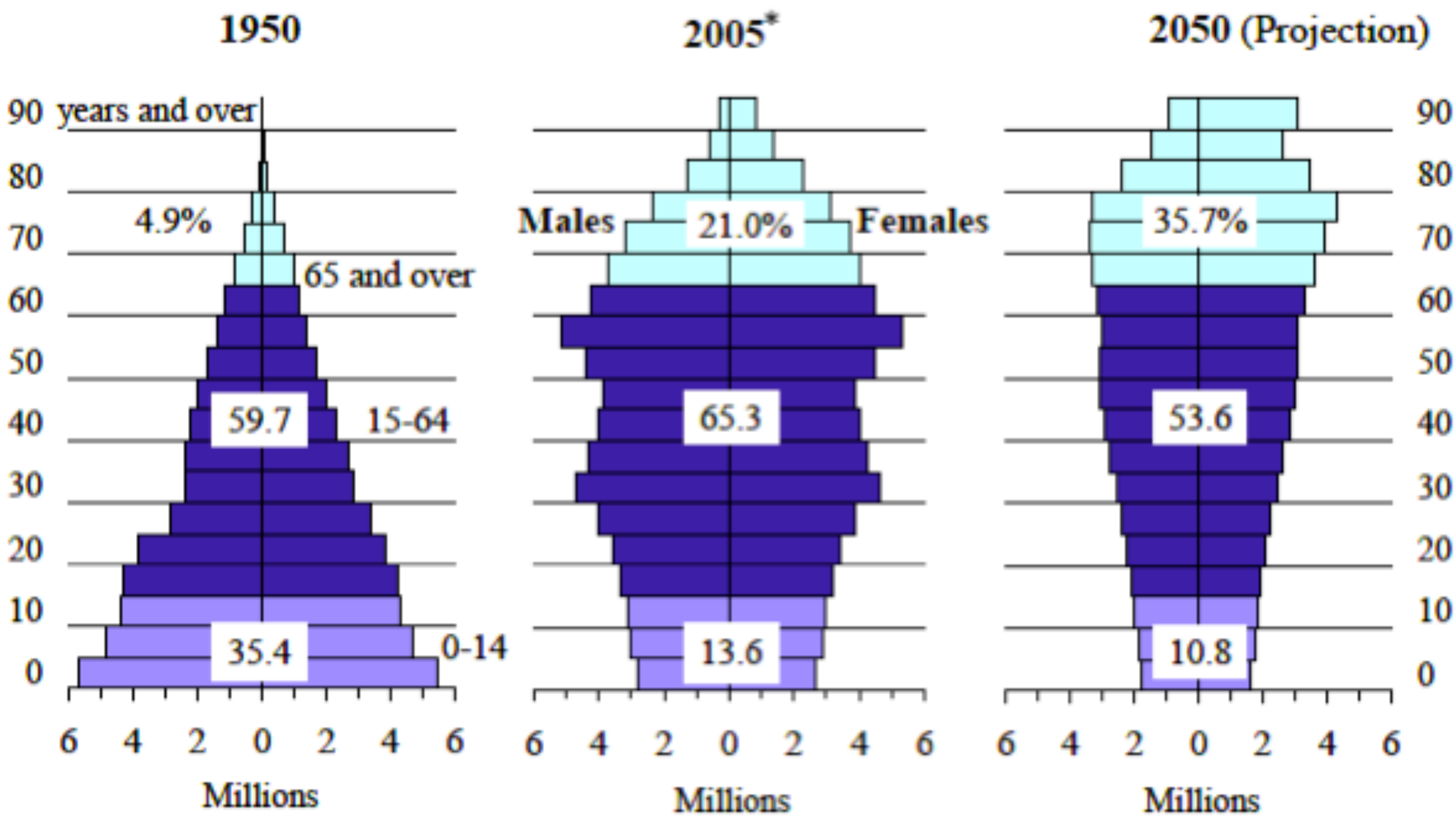
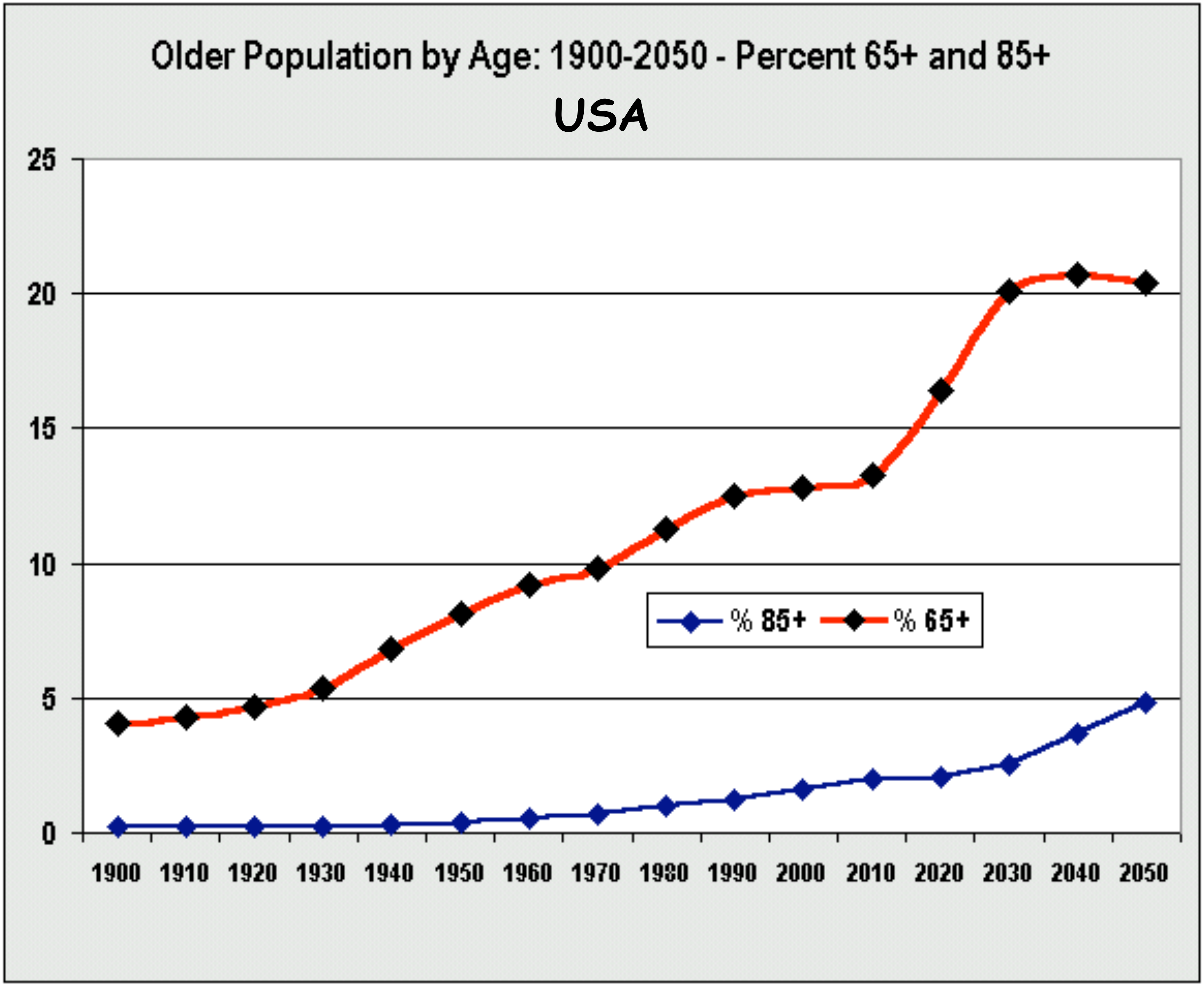
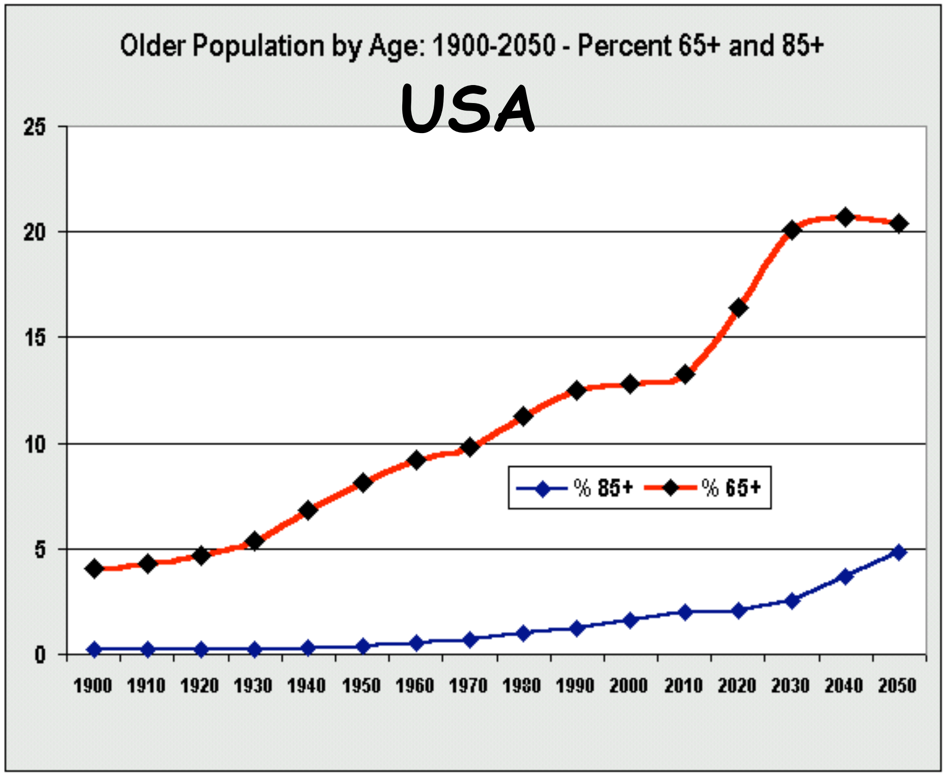
Japan: 1950 to 2050



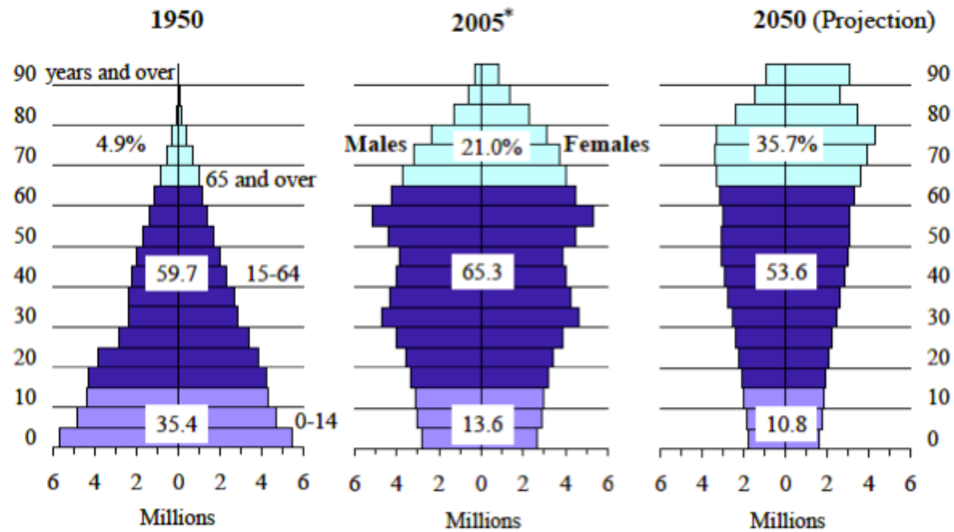
Statistics Bureau, Japan Ministry of Health, Labor, and Welfare



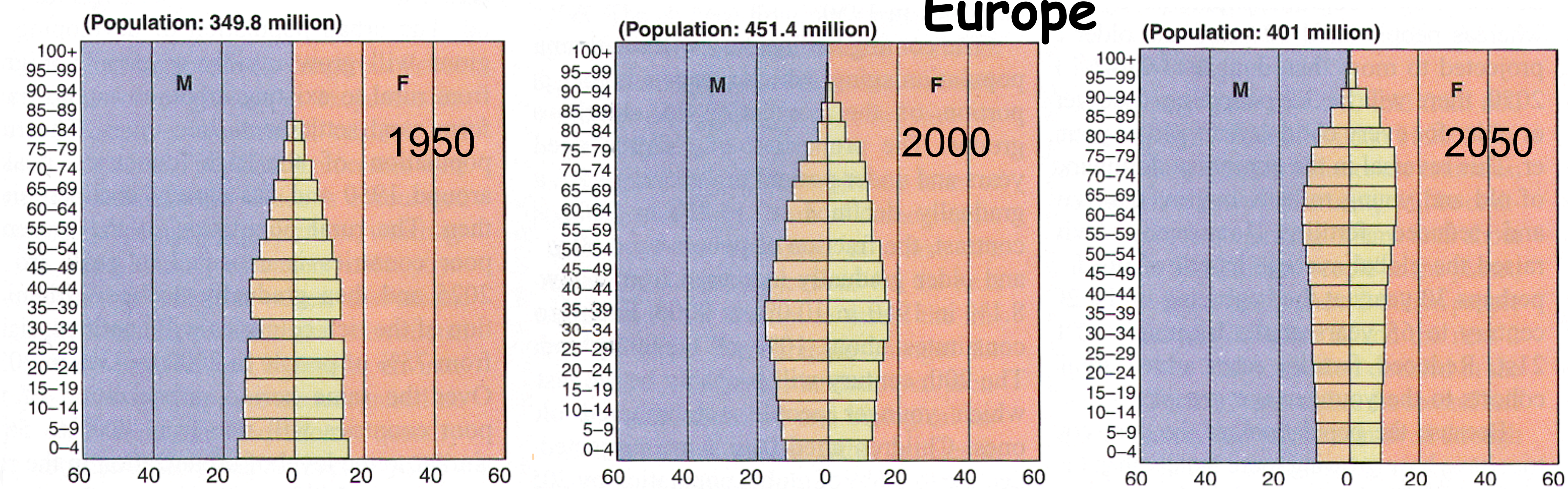
Older Population by Age: 1900-2050 - Percent 65+ and 85+
USA
25
20
15
10
5
0
% 85+
% 65+
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050



Japan



Europe



IDG News, Dec 6, 2007

At a Tokyo news conference held to unveil the two new robots, Toyota also showed its Robina robot, which made its first public appearance in the middle of this year. The Robina is designed for face-to-face communication with humans. In that role, the robot served as a guide at the Toyota Kaikan Exhibition Hall in Toyota City in August this year.

The robot can automatically navigate a route through obstacles and, by holding a pen in one hand and a piece of card in the other, sign its signature on the card.

Toyota is one of many Japanese companies actively investigating robotics and the areas that go hand-in-hand with the technology, such as artificial intelligence. While violin playing and autograph signing may appear to be nothing more than whimsical tricks they require a high level of mechanical and electrical control and are the kind of tasks that engineers need to perfect before they take the next step towards human assistance.

Japan's rapidly aging society is providing the push behind all these projects.

Immigration Backlash

- Both a legal and an illegal issue
- Some industries are suffering due to loss of illegal immigrants (e.g., OK, CO, CA)
- Some places are suffering due to legal immigrants getting too rich (e.g., lack of Polish workers in UK and Germany)

- Some work just has to take place in-situ, and not even immigrants want to work there

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.

Globalization Backlash

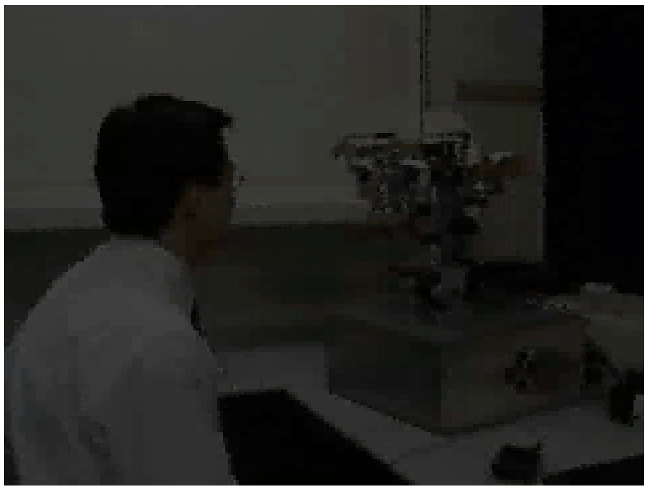
- Worries about product quality when built in unregulated environments
- Cost of transportation
- Anger at perceived loss of jobs
- Worry about loss of US capability

- Can robots increase the productivity of US manual workers?

But, Also Need Research…

- Visual object recognition capabilities of a two year old child
- Language capabilities of a four year old child
- Manual dexterity of a six year old child
- Social sophistication of an eight year old child

Two examples from my students



Kismet, by Cynthia Breazeal, 2000

Domo, by Aaron Edsinger, 2007

My Messages:

- A new class of robots just gotten here
- Defense robots are at the vanguard of a transformation of human society
- There are lots of technologies that are enablers
- There is going to be strong pull from many future user communities