Technology, Jobs & Worker Health

John Howard
National Institute for Occupational Safety and Health
Washington, D.C.

29 November 2018

Annual NECOEM/MaAOHN Conference
Boston-Newton Marriott Hotel
Newton, Massachusetts

Industrial Revolutions

- **First Industrial Revolution**
  - Used water and steam power to mechanize production
- **Second Industrial Revolution**
  - Used electric power to create mass production
- **Third Industrial Revolution**
  - Used electronics & information technology to automate production
- **Fourth Industrial Revolution**
  - Using systems composed of physical entities controlled or monitored by digital algorithms, artificial intelligence

Drivers

- Economic
  - Fewer, Older Workers
  - Non-standard Work Arrangements
- Physical
  - Robotic Automation
  - Advanced Manufacturing
- Digital
  - Sensor-Driven Exposure Analytics
  - Artificial Intelligence

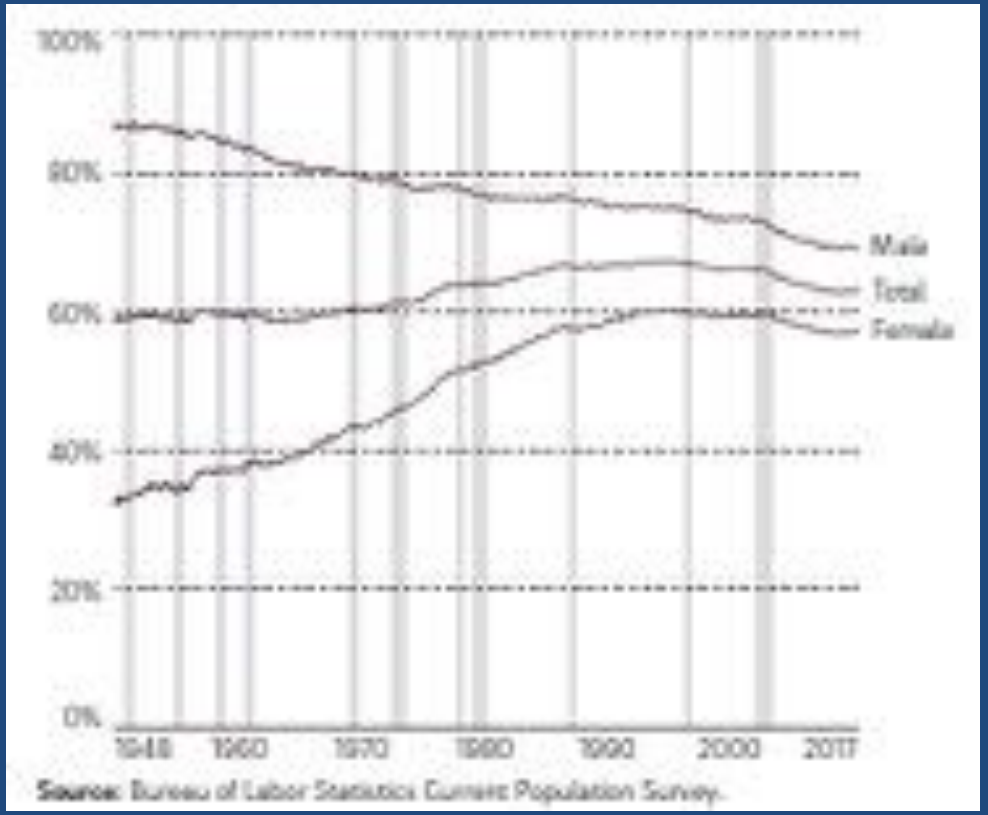
Economic

Participation Has Been Falling Since 2000

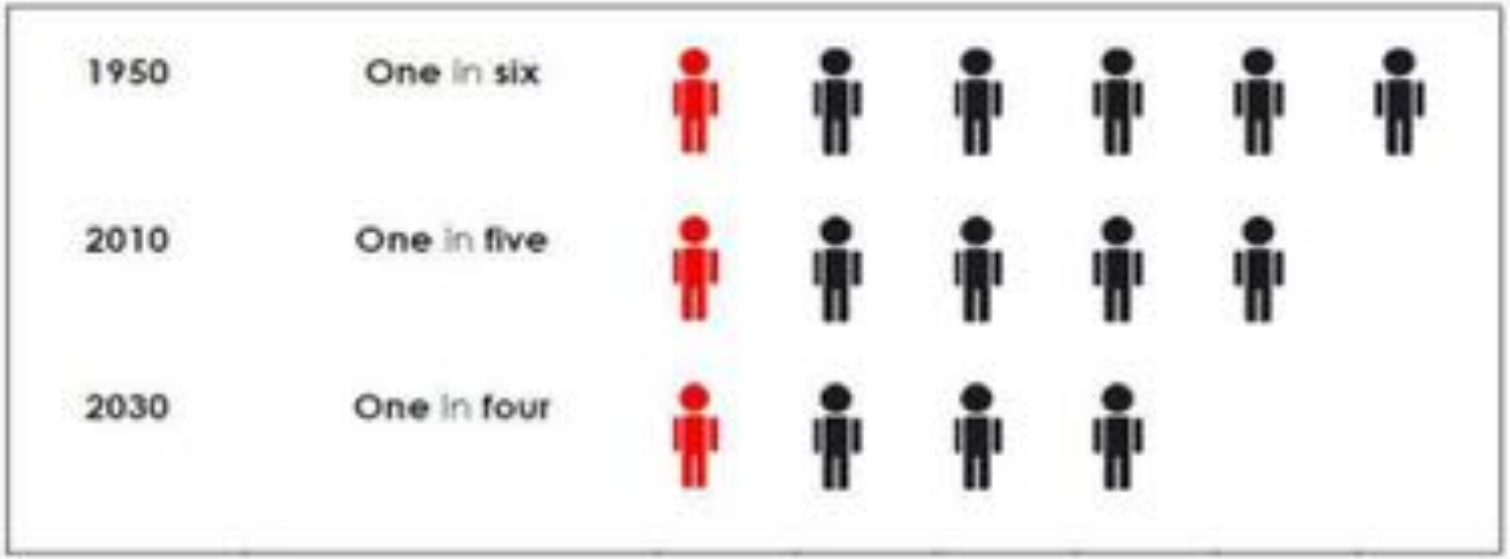
- Participation rate:
  - 60% in 1950s
  - 67% in 2000
  - 63% in 2018

- Reasons:
  - Baby-boomer retirement
  - Decline in prime-age male workers
    - 98% in 1954 to 88% 2017
  - Why?
    - Wage gap
      - In 1973, men with high school education earned 72% of wages of college-educated males. In 2016, percent was 51%

- Participation rate in late 2020s is projects to be only 59%



Chronologically Gifted



Sources: Bureau of Labor Statistics, "Labor Force Projections to 2018: Older Workers Staying More Active," *Monthly Labor Review*, November 2009; Bureau of Labor Statistics, "New Look at Long-term Labor Force Projections to 2050," *Monthly Labor Review*, November 2006.

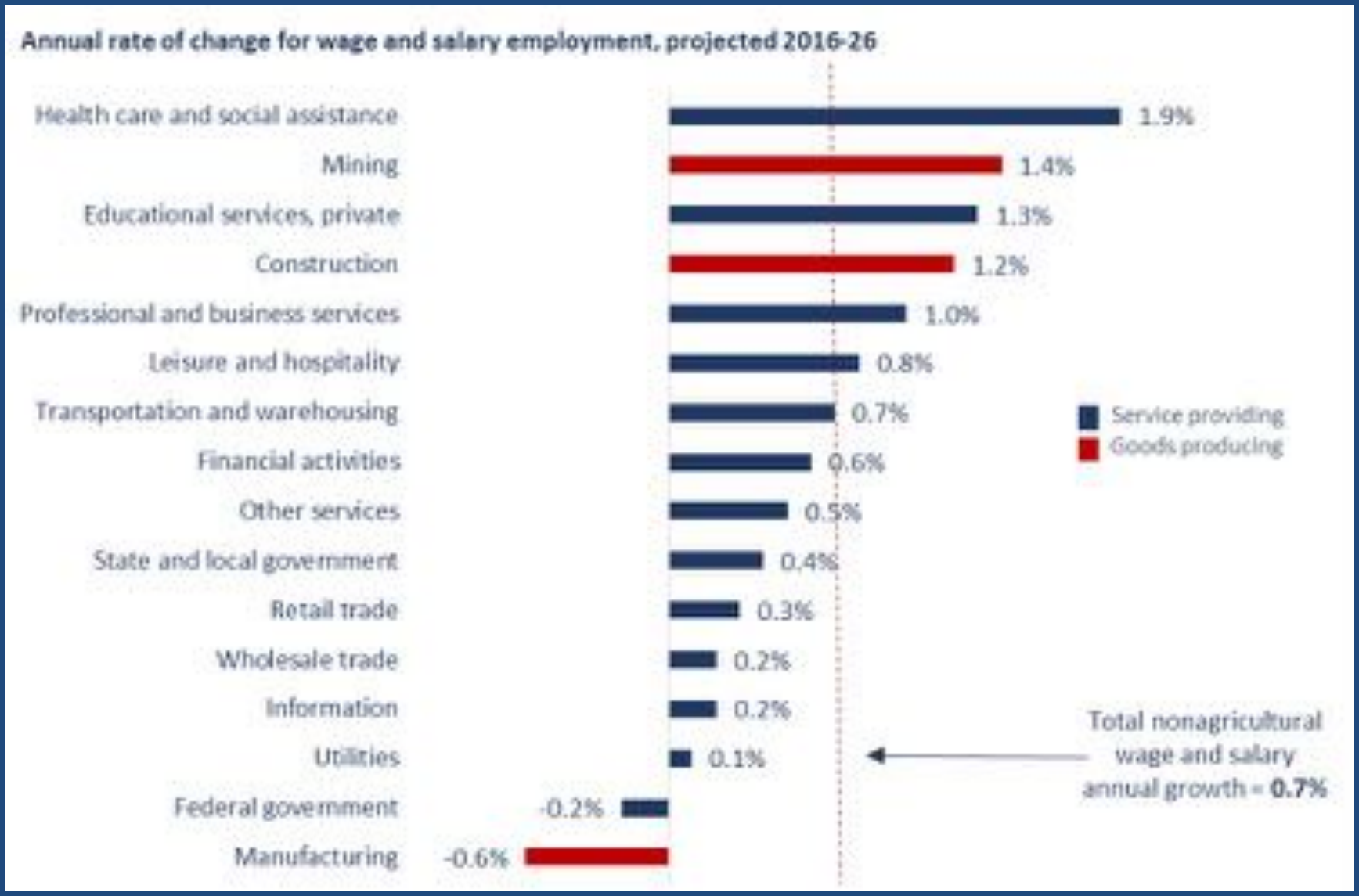
Total Chronic Condition Burden

Percentage of Adults age 55 and over (Total, Male & Female), with one or more, two or more, or three or more of a possible six chronic conditions: United States, 2008.

	Total		Male		Female	
	%	SE	%	SE	%	SE
Age 55 years and over	(n=70,688,633)		(n=32,130,140)		(n=38,558,493)	
1+ chronic conditions	78.0	0.6	75.3	0.9	80.1	0.7
2+ chronic conditions	47.0	0.7	41.8	1.0	51.3	0.9
3+ chronic conditions	19.0	0.5	16.1	0.7	21.4	0.7
Age 55 to 64 years	(n=33,502,260)		(n=16,123,407)		(n=17,378,853)	
1+ chronic conditions	69.5	1.0	67.7	1.4	71.1	1.2
2+ chronic conditions	37.1	1.0	32.3	1.4	41.5	1.3
3+ chronic conditions	14.4	0.7	11.1	0.9	17.4	1.0
Age 65 years and over	(n=37,186,373)		(n=16,006,733)		(n=21,179,640)	
1+ chronic conditions	85.6	0.6	83.0	1.0	87.6	0.7
2+ chronic conditions	56.0	0.9	51.4	1.4	59.4	1.1
3+ chronic conditions	23.1	0.7	21.2	1.2	24.6	1.0

Source: CDC/National Center for Health Statistics: National Health Interview Survey.

Projected Percent Change in Industry Employment—2016 to 2026




Classification of Economic Work Arrangements
Economic work
Activity undertaken for another party in exchange for compensation
Employment
Organization has directive control
Contract work
Organization lacks directive control
Direct employment
Full directive control
Direct relationship involving two parties: employer & employee
Coemployment
Shared directive control
Indirect relationship involving three parties: client organization, third party (agency), & worker
Closed contracts
Direct contracting
Direct relationship involving two parties: client organization & worker
Closed contracts
Subcontracting
Indirect relationship involving three parties: client organization, third party (vendor), & worker
Closed contracts
Full-time employees
Part-time employees
On-call employees
Direct hire temporary employees
Professional employer organizations (PEOs)
Leased employees
Agency temporary workers
Independent contractors
Day laborers
Vendor-on premises
Sourcing arrangements
Work is completed offsite
Vendor's employees rarely come into contact with the client's employees

Economic Work Arrangements

- **Employment Work Arrangements (Employee)**
  - Organization has directive control
    - **Standard employment relationship**
      - One employer—one employee
    - **Co-employment**
      - Two employers—one employee (agency and client)
      - Two employers are often confused about safety & health responsibilities

- **Contract Work Arrangements (Independent Contractor)**
  - Organization lacks directive control
  - **Business relationship** exists (offer and acceptance)
    - Specifies the *what, the when, but not the how*
    - No employer and no employees

- **"Gig" Work Arrangements (Employee/contractor?)**
  - Does the organization lack directive control?
  - No employer? No employees? What looks like an employer is really just a digital platform connecting customers with providers
  - Micro-entrepreneurs vs. employees?

History of Work Arrangements

- Work organization used by digital platforms can best be understood as return to long-standing practices seen in the history of capitalism
  - On-demand work, piece work compensation, home work, and triangulated relationships, have a much longer history in capitalism than the standard employment relationship (SER).

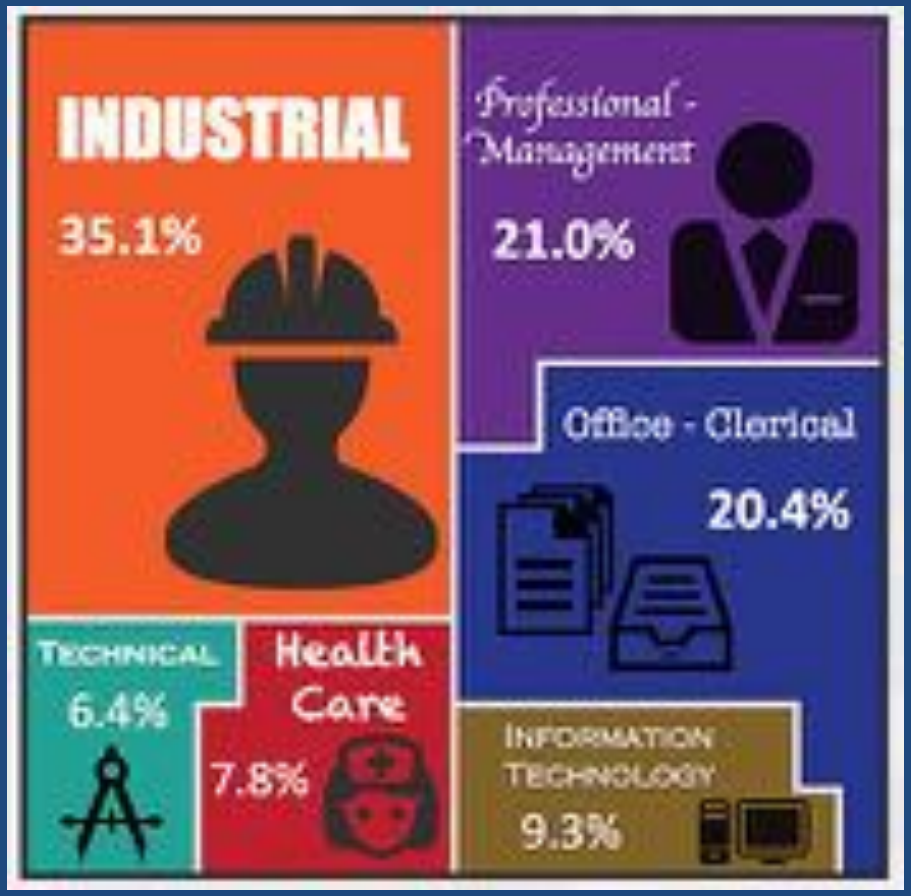
- Mid-20th century work arrangement is the ***historical exception*** rather than a universal model
  - Origins can be found in ***mass production*** in large, manufacturing, factories using *Fordist* assembly line techniques
  - Major features of the SER—one employer, work year-around on a full-time basis, at employer's premises, using capital equipment owned by employer, with ***mutual expectation*** of a life-time duration.

- Labor market institutions and labor law (federal and state) evolved beginning in 1911 and more strongly in the two decades after WWII to reinforce the SER as the *normative* benchmark of employment in the developed world.
  - Remember there were independent contractors in the mid-20th century (many fewer than today) and they had ample ability to protect themselves.

Co-Employment

- Temporary staffing industry is perhaps best known for its earlier years when it placed female clerical workers and day laborers/farm workers.
  - Russell Kelly, 1946
  - Elmer Winter and Aaron Scheinfeld—1948

- But the industry has expanded to include nearly every occupation in the US and globally.
  - 2015, Kelley Services placed 550,000 persons
  - Across all industries & occupations



KELLY SERVICES

ManpowerGroup

Employee or Contractor?

- **How to decide if a worker is an employee**
  - **OSHA—**Common Law Agency Test—Direct and Control (10 factors)
  - **DOL—**Economic Realities Test (FLSA)—Consider whether workers are economically dependent on the business for which they labor.
  - **IRS** uses a 20 factor test in three areas: (1) behavioral control; (2) financial control; and (3) the relationship of the parties

- No one test or grouping of factors has achieved national legal consensus because the definition of employee is adapted to meet the purpose of the individual act which makes for very fact-dependent analysis
  - Exception: Congress confined definition of employee under NLRA to the common law definition of employee ("right to control"), excluding independent contractors

- The law of the employment relationship is VERY confusing.

New BLS Survey Data—June 2018

- **Total U.S. Nonfarm Employment** = 150M
  - Total Non-Standard Workers = 21M (14%)

- **Contingent Workers** (1.3 to 3.8%, or 5.9 million)
  - Workers who do not have an implicit or explicit contract for ongoing employment.

- **Alternative employment arrangements** (10.1%)
  - Independent contractors (6.9% or 10.6 million)
  - On-call workers (1.7% or 2.6 million)
  - Temporary help agency workers (0.9% or 1.4 million)
  - Workers provided by contract firms (0.6% or 933,000)

- BLS, CONTINGENT AND ALTERNATIVE EMPLOYMENT ARRANGEMENTS —MAY 2017 (June 7, 2018). https://www.bls.gov/news.release/pdf/conemp.pdf

New BLS Survey Data—September 2018

- BLS added four questions to the May 2017 Contingent Worker Supplement to measure electronically mediated work
  - Short jobs or tasks that workers find through websites or mobile apps that both connect them with customers and arrange payment for the tasks.
- After extensive review, BLS determined that these questions did not work as intended.
- BLS manually recoded the data using verbatim responses available only on the confidential microdata file.
- Using these recoded data, BLS estimates that electronically mediated workers accounted for **1.0%** of total employment in May 2017.
  - https://www.bls.gov/opub/mlr/2018/article/electronically-mediated-work-new-questions-in-the-contingent-worker-supplement.htm

Differential Costs

- **Workers**
  - More hazardous work assigned to temporary workers.
  - Higher injuries rates in temporary workers depending on industry
  - Worker might quickly find herself out of a job and, depending on the severity of an injury, the prospects of new employment might be slim.

- **Society**
  - Employer-based health insurance is a rarity for NSWA workers, so the costs of treating injuries are sometimes shifted to the worker or the public at large (e.g., SSA disability insurance benefits)

- **Employers**
  - Client—do not directly pay for workers' compensation and health insurance—they are insulated from premium adjustments based on the cost of workers' injuries.
  - Employers of NSWA workers escape the financial incentives that drive employer decisions to eliminate hazards for their workers.

Differential Risks

- Temporary jobs can be more hazardous than standard worker jobs
  - Less experience & familiarity with operations due to short tenure at a worksite
  - Fewer hours of safety training relevant for the specific job assignment
  - More distant relationships with longer-term workers who could help navigate worksite hazards

- Limited availability & use of personal protective equipment

- Less likely to report unsafe conditions because of risks associated with precarious employment

- Confusion (real or perceived) about who is responsible for worker safety:
  - Who is the responsible employer? How do you tell?
    - Common law test, economic realities test, IRS test, various court cases

OSHA/NIOSH Recommended Practices

- 8 recommendations for staffing agencies and host employers.
- https://www.osha.gov/Publications/OSHA3735.pdf
- http://www.cdc.gov/niosh/docs/2014-139/pdfs/2014-139.pdf

Gig Economics: On the Bright Side

- **Creates surplus value in the economy**
- **Faster matching customer demand and worker supply**
  - Digital platform "intermediates" between customers and workers
  - Relies on proprietary algorithms and a sophisticated rating system
  - Reduces costly "search frictions" (Pissarides, 2010)
- **Platform removes transaction hassles**
  - Theory of the firm (Coase, 1937)
  - Control over workforce and production is cheaper than cost on the open market and haggling for each individual transaction
  - Intermediation drastically lowers firm transaction costs
- **Replaces workforce with an external "crowd"**
- **Lowers costs associated with a permanent workforce**

Gig Economics: On the Dark Side

- Post-industrial corporation
  - Maximize profit but not through productive enterprise
  - Create value through asset manipulation, speculation, and regulatory arbitrage
- Regulatory entrepreneurship
  - Tax opportunism
    a) Taking advantage of an existing gap in the law available due to inherent features of the new sharing model
  - Arbitrage
    - Deliberate manipulation of the structure of a deal to take advantage of a gap between the economic substance of the transaction and its regulatory treatment.
      - Fire all workers, rehire them as independent contractors
- Core of gig business model
  - Evasion of employment law?
  - Classifying workers as contractors allows platforms to offer services without have to pay for the cost of workers
- Leads to negative externalities and devolution of responsibilities to micro-entrepreneurs

Physical

What is a Robot?

- No consensus on definition
  - Our understanding is strongly influenced by science fiction

- Essential elements:
  - **Structures**
    - Before its sensors, processing power, and actuators can be chosen, a robot much have a base chassis
  - **Sensors**
    - Awareness of where it and its attached parts are in physical space
  - **Computation**
    - Computing architectures, programming language
  - **Actuators**
    - Once sensing the whatever degree of cognition generates a command, robots must execute the command

Occupational Robotics

- New field of practice for safety and health practitioners
- Robots & Exoskeletons
- Risky interactions between human and robot workers?

Organizational Profile

- **Superior Performance**
  - Robot workers are simply better than people at some tasks
    - Mundane, repetitive, and precise jobs as clear candidates.
    - Robot workers already taken over as the primary worker in many industrial factories.
  - With perfect memories, internet connectivity, and high-powered processors for data analysis, robots can also provide informational support beyond any human capability.
    - Keep perfect record of project progress
    - Provide real-time scheduling and decision support
    - Have perfect recall
- **Managerial Promise?**
  - Robots be placed in management positions where they can remind a team of deadlines, procedures, and progress
- **Operational Cost Reduction Derivative from Automation**
  - Permanent employees cost a lot of money—30 to 40% more than salary
  - Costs barely $8 an hour to use a robot for spot welding in the auto industry, compared to $25 for a worker—and the gap is only going to widen.

5 Types of Robots

- **Industrial robots**
  - Fixed in location
  - Humans and robots are separated
- **Collaborative robots**
  - Designed to work together with humans
- **Exoskeletons**
  - Wearable robotics
- **Service robots**
  - Autonomous ground vehicles (Driverless cars)
  - Unmanned aerial vehicles (Drones)
  - Household service robots
- **Companion robots**
  - Express human emotion

1. Traditional Industrial Robots

- Decades of experience
- Used since the 1970s in auto manufacturing
- Established safety measures that keep human workers ***separated*** from robots

2. Collaborative Robots (Cobots)

2. Collaborative Robots

- Designed to work alongside human workers
- Controlled by human workers, by an algorithm, or by both
- Equipped with sensors designed to stop robot when contact with human worker occurs

Filling a bin with objects for the Dex-Net 4.0 robot grasping research. Credit: Adriel Olmos, UC Berkeley

Arm Grasping

Robo-Business Conference Silicon Valley, September 2018

- Grasping is a hard problem where demand is driven by e-commerce.
- The first method involved programming robots with precise data of an object's characteristics.
- The second wave involved gathering real-world data and reinforcement learning, said Goldberg, citing Google's "arm farm"
  - "After one year and 10 million grasps, they got to a 20% failure rate, but that's still high," he said. "With good perception and control algorithms, you can have minimalist hardware, but you don't want noisy data."
- The third wave is a hybrid, combining modeling and empirical data.
  - "Fog robotics" distributes computing tasks among the cloud, the gateway layer, and edge devices.
- Inspired by ImageNet's 80 million images, Goldberg and his team have created Dex-Net, a curated repository of 3D models of a wide range of items.
    - https://berkeleyautomation.github.io/dex-net/

Newer Collaborative Robots

- Move alongside, and in shared space, with human workers

Extreme Collaborative Robots

MATT SIMON SCIENCE 12.06.17 05:00 PM

SAN FRANCISCO JUST PUT THE BRAKES ON DELIVERY ROBOTS

WIRED

3. Exoskeleton Robotics

- Mobile with the human
- Reduce mechanical stress
- Amplify or transform worker or soldier movements
- Industrial market projected to grow 229% per year between 2016 and 2021
  - Suit X, U.S. Bionics
  - Winter Green Research, Inc. (2015). Wearable Robots, Exoskeletons: Market Shares, Market Strategies, and Market Forecasts, 2015 to 2021. https://www.marketresearchreports.biz/reports/716060/wearable-robots-industrial-exoskeletons-shares-market-research-reports.pdf

4. Service Robots

- Automated Ground Robots
  - Currently operate in less controlled environments
    - May include human workers and manned vehicles
    - Agriculture, mining and manufacturing
    - Public roads and highways

4. Service Robots

Large Vehicles

- Service robots used by Rio Tinto in Pilbara, Western Australia
  - No coffee breaks, fatigue and driver changeovers.
  - Stops only once a day for refueling.
- Engineers at Rio's operations center in Perth (2 hours flight away) remotely control trucks
- Workforce at the mine is already about one-third lower as a result of automation.
- Autonomy enables drilling to run for almost a third longer on average than with manned rigs, and to churn through 10% more meters/hr. .

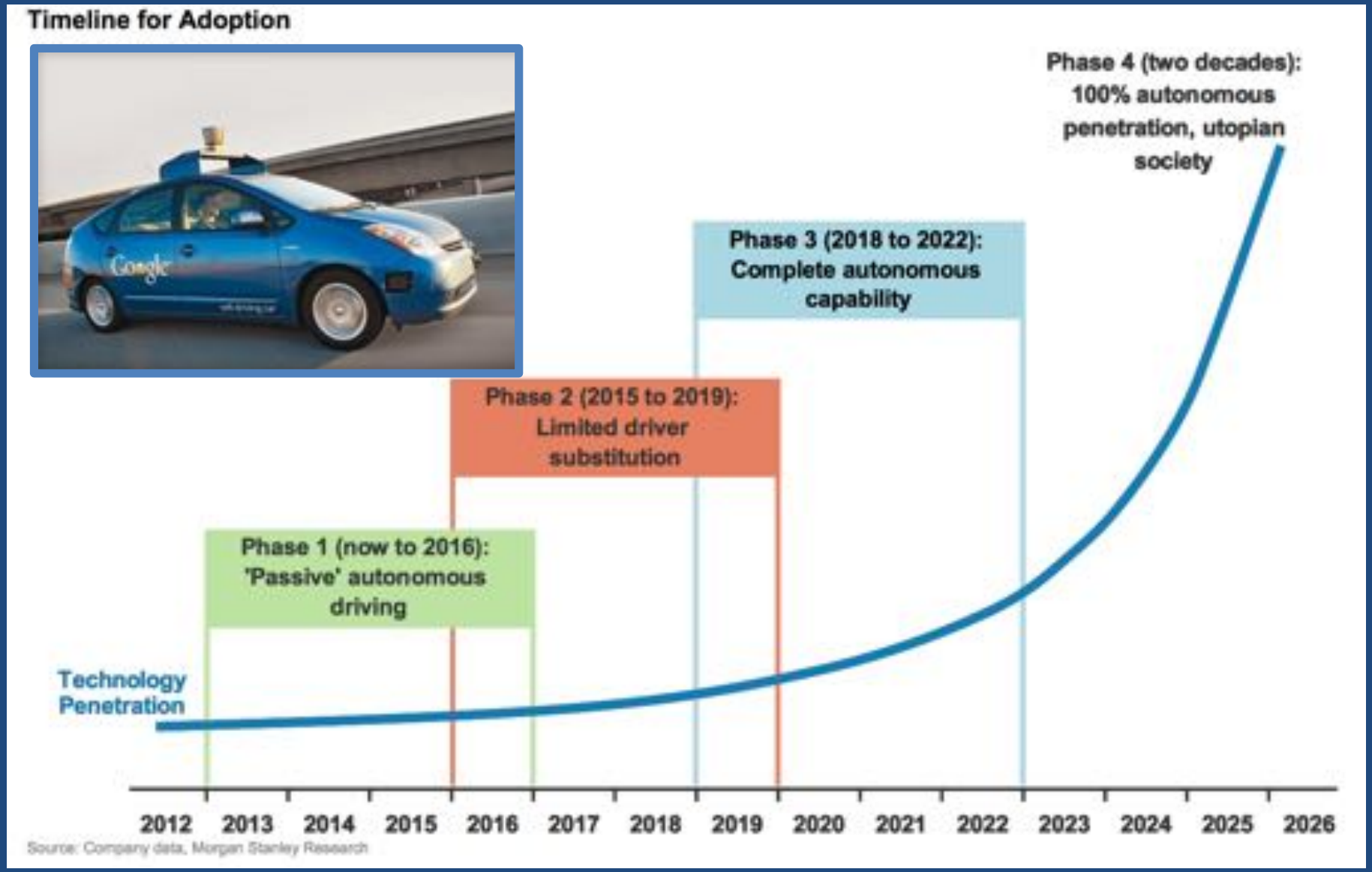
4. Service Robots:

Truck Platooning

- **Safety**
  - With the following trucks braking immediately, with zero reaction time, platooning can improve traffic **safety**.
- **Cost**
  - Platooning is also a **cost-saver** as the trucks drive close together at a constant speed. This means lower fuel consumption and less CO_2 emissions.
- **Efficiency**
  - Platooning **efficiently** boosts traffic flows thereby reducing tail-backs. Meanwhile the short distance between vehicles means less space taken up on the road.

4. Service Robots

Driverless Cars and Fleet Management



4. Service Robots

Unmanned Aerial Vehicles

Military

Recreational

Public

Commercial

UAVs Uses in Construction

Monitoring

Inspection

Maintenance

Hazardous Applications

Sources of Risk from UAVs

- **Engineering**
  - Errors in the drone's mechanics (e.g., loose connections across parts, faulty electronics and sensors).
- **Human**
  - Errors in programming, interfacing peripheral equipment, and connecting input/output sensors resulting in unpredicted movement or action by the drone;
  - Errors in judgment resulting from "over-attributing" to autonomous robots more human-like qualities and capabilities;
  - Errors in remote operating.
- **Environmental**
  - Unstable flying conditions, extreme temperature, poor sensing in difficult weather or lightning conditions leading to incorrect response

5. Companion Robots

- ***Pepper*** is a humanoid robot by Aldebaran Robotics and *SoftBank* Mobile designed with the ability to read emotions. An emotional robot.
  - Introduced on 5th June 2014 to enhance human well-being.
  - Available on February 2015 at a base price of JPY 198,000 ($1,931) at Softbank Mobile stores.
- Pepper's emotion comes from the ability to analyze expressions and voice tones.

Robotics & Safety

Potential

- Expand dangerous work done by robots
- Robotic systems augment workers' abilities

Concerns

- Likely increase in robot-related human injuries

- New types of robots will require refined and new protection strategies
  - Robot with dynamic machine learning capabilities challenge static safety procedures

- Rapid advances in technology may outpace guidance/standards setting

- Stress associated with changing workplace and potential for human worker displacement

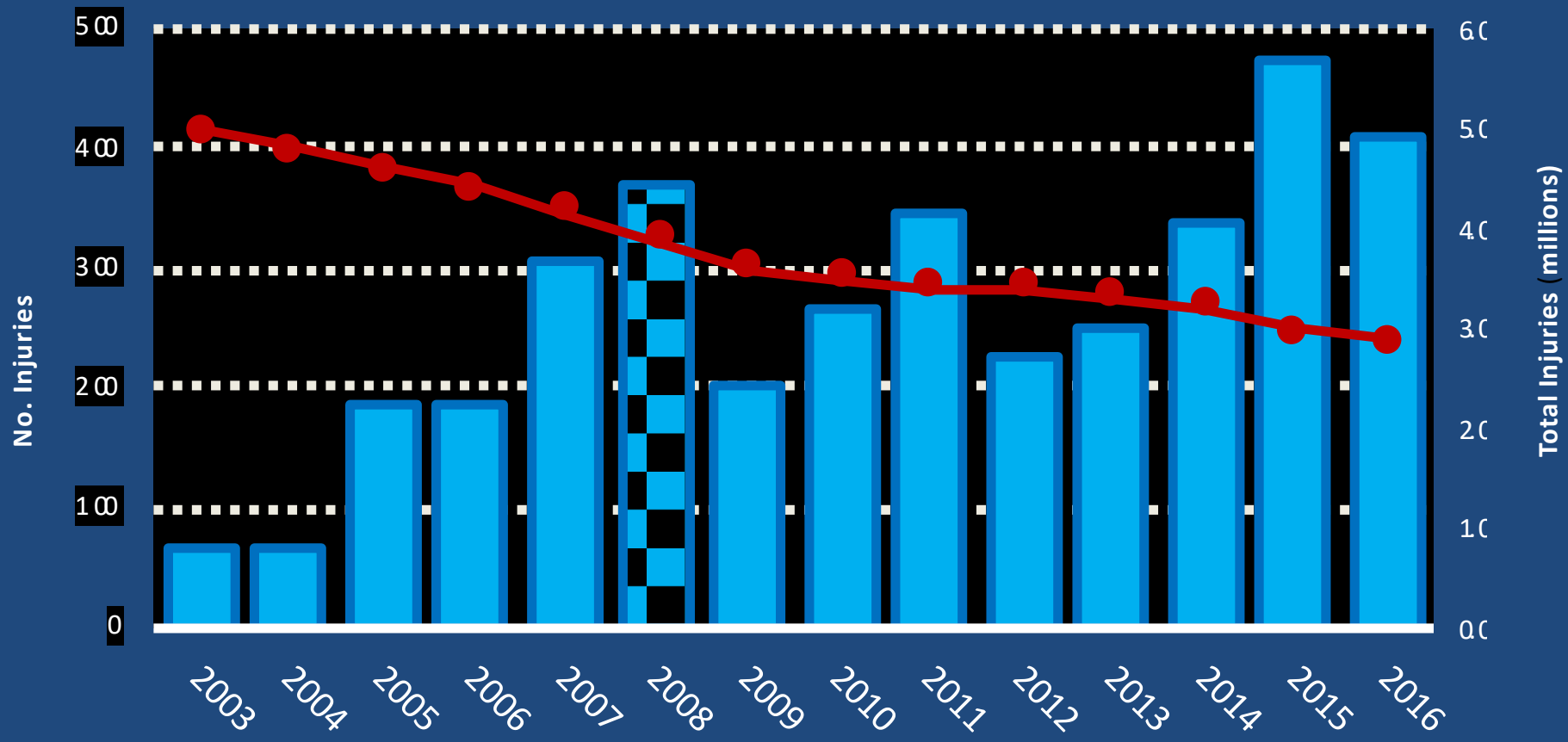
NIOSH Recommendation to BLS

- BLS currently lacks a direct way to identify robotic systems in machinery, motor vehicles, or industrial vehicles
- Solutions:
  - Add a 5th digit to the source codes to denote robotic systems (or)
  - Create a standalone variable for robotic systems

Injuries to Humans by Robots

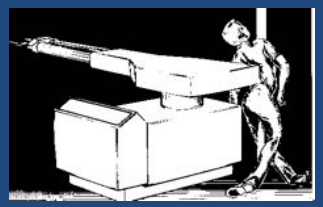
- **U.S. Census of Fatal Injuries (CFOI)**
  - 53 Robot-related deaths, 1992-2013
- **OSHA**
  - 38 Robot-related fatalities, 1983-2013
- **U.S. Bureau of Labor Statistics**
  - 61 robot-related deaths, 1992-2015 (CFOI)
- **Germany, July 2015**
  - 22-year-old worker died from injuries he sustained when he was trapped by a robotic arm and crushed against a metal plate

Estimated 3,730 Robot Injuries in U.S., SOII 2003-2016



Guidance on Working Safely with Robots

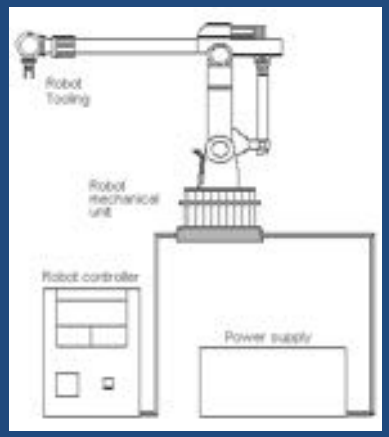
Preventing the Injury of Workers by Robots, NIOSH Pub. No. 85-103



1740. Robots and Robotic Equipment

Safe Maintenance Guidelines for Robotic Workstations, NIOSH Pub. No. 88-108

OSHA Instructional Manual, Chapter 4: Industrial Robots and Robot System Safety



ANSI/RIA Robotic Safety Standards

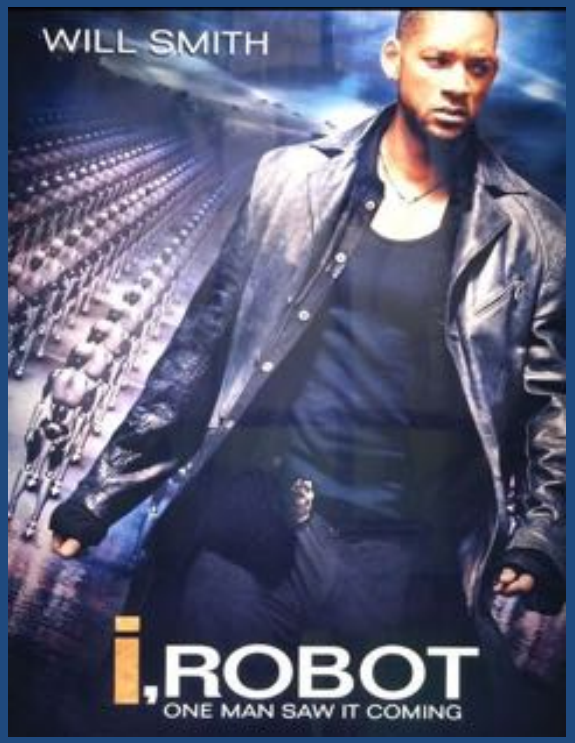
- **ANSI/RIA R15.06-2012**
  - American National Standard for Industrial Robots and Robot Systems- Safety Requirements
    - Approved March 28, 2013
    - Revision of ANSI R15.06-1999
  - Provides guidelines for the manufacture and integration of industrial robots and robot systems
    - Emphasis on their safe use, the importance of risk assessment and establishing personnel safety.
    - Key feature in the standard is “collaborative operation,”
      - Introduction of a worker to the loop of active interaction during automatic robot operation.

Robot Ethics

- **Two cars sinking in the water**
  - Detective Del Spooner (Will Smith)
  - Young girl, Sarah

- **Robot could save only one of them, Spooner yells *"Save the girl!"***
  - Probability of survival for Spooner was 45%
  - Probability of survival for Sarah was 11%

- **Robot saved Spooner; girl drowned.**

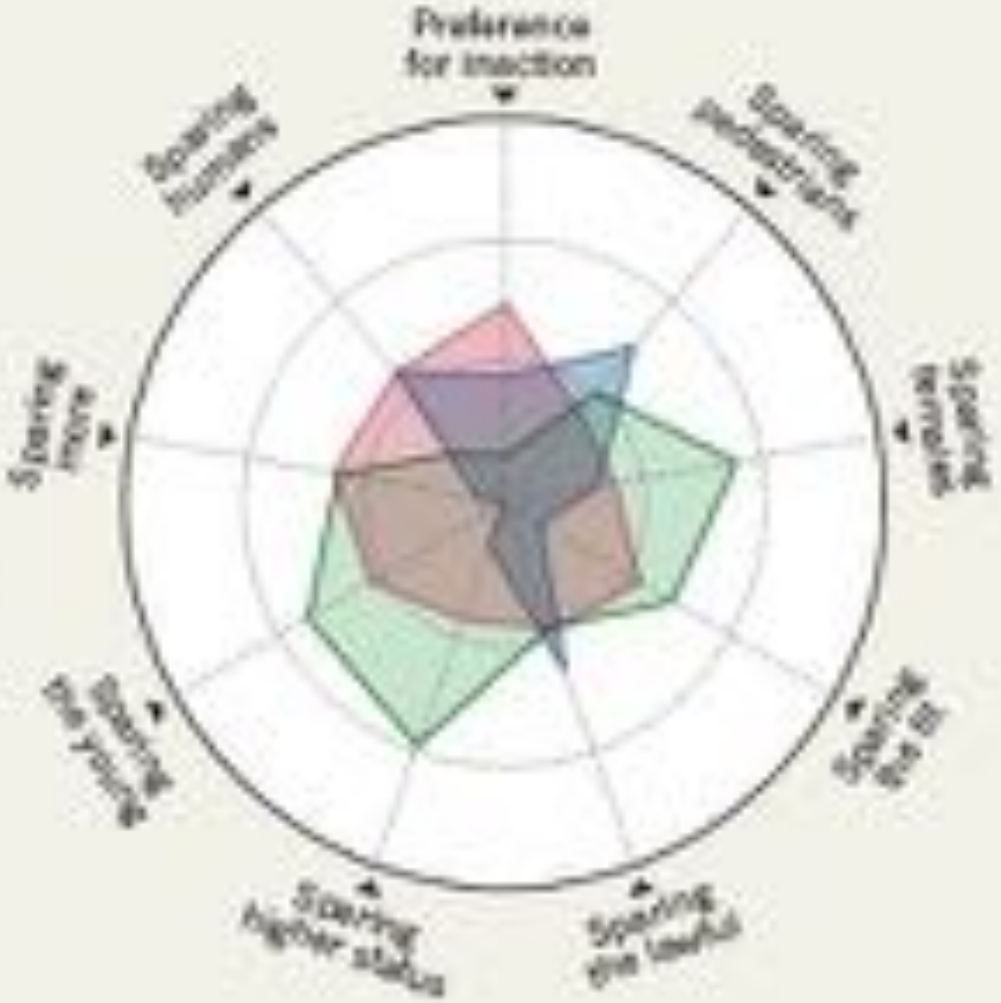


- Fleetwood, J. Public Health, Ethics, and Autonomous Vehicles. *Am J Pub Health*. 2017; 107(4): 532-537

MORAL COMPASS

A survey of 2.3 million people worldwide reveals variations in the moral principles that guide drivers' decisions. Respondents were presented with 13 scenarios, in which a collision that killed some combination of passengers and pedestrians was unavoidable, and asked to decide who they would spare. Scientists used these data to group countries and territories into three groups based on their moral attitudes.

Western Eastern Southern



Welcome to the Moral Machine! A platform for gathering a human perspective on moral decisions made by machine intelligence, such as self-driving cars.

We show you moral dilemmas, where a driverless car must choose the lesser of two evils, such as killing two passengers or five pedestrians. As an outside observer, you **judge** which outcome you think is more acceptable. You can then see how your responses compare with those of other people.

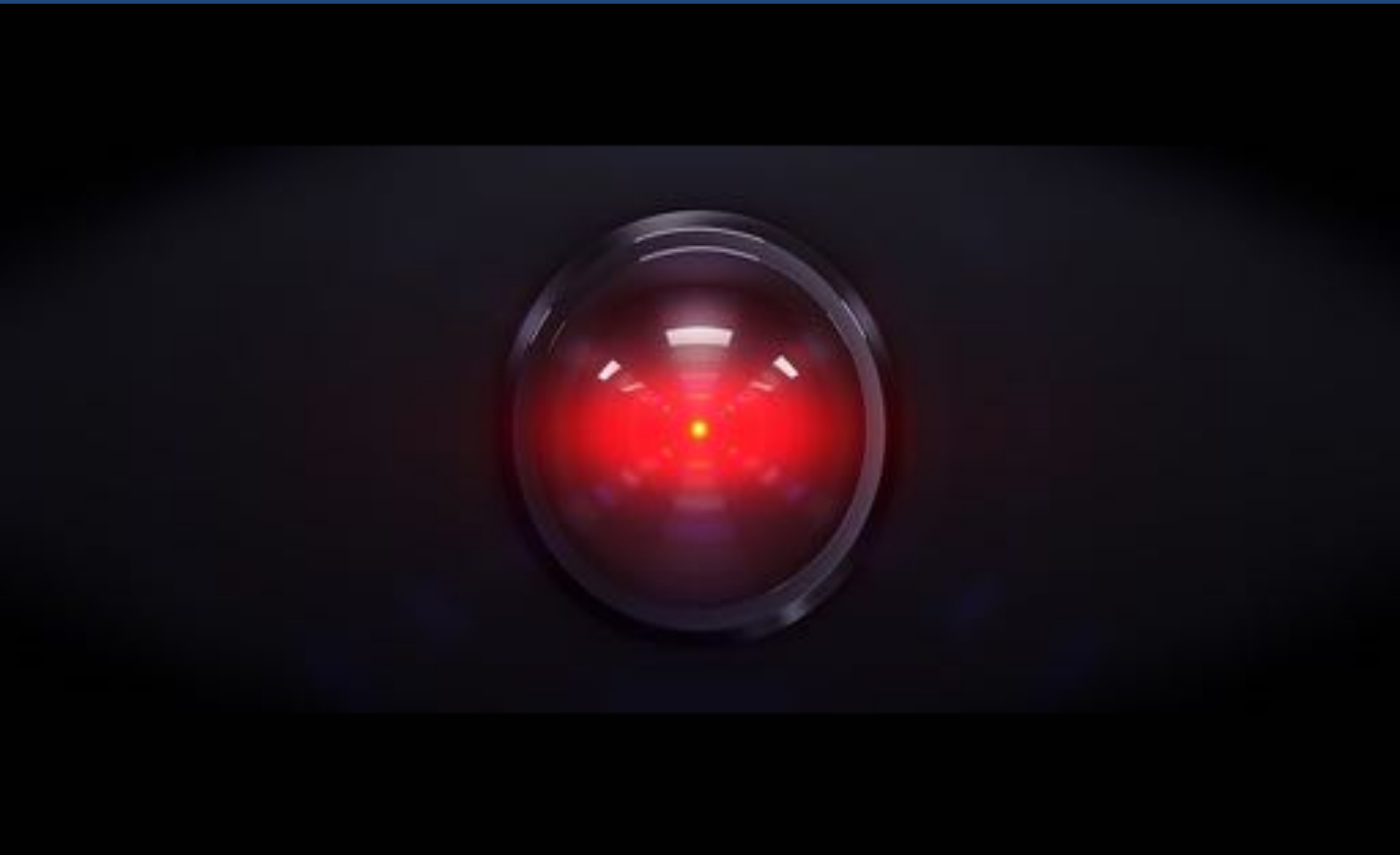
If you're feeling creative, you can also **design** your own scenarios, for you and other users to **browse**, share, and discuss.

Start Judging

Browse Scenarios

View Instructions

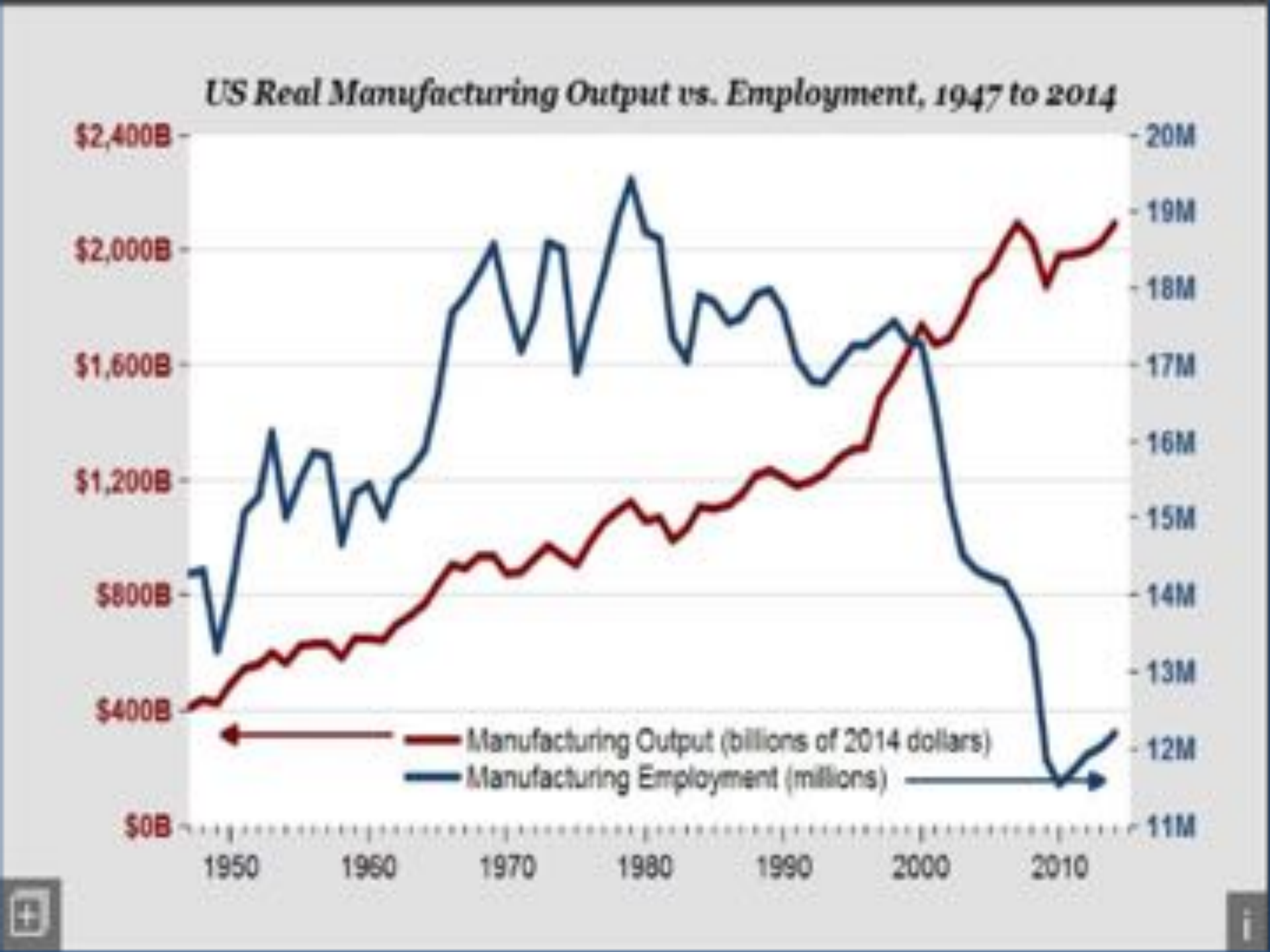
"I'm sorry Dave, I'm afraid I can't do that"



Automation:
The Case of Manufacturing

Manufacturing—What Next?


Manufacturing Employment Trends, 1939-2016
Manufacturing Employment
Manufacturing Share of Private Nonfarm Employment
20,000
18,000
16,000
14,000
12,000
10,000
Thousands of Employees
45%
40%
35%
30%
25%
20%
15%
10%
Percent of All Employment
Jan-39
Oct-48
Jul-58
Apr-68
Jan-78
Oct-87
Jul-97
Apr-07
Jan -17
Source: Current Employment Statistics.


US Real Manufacturing Output vs. Employment, 1947 to 2014
$2,400B
$2,000B
$1,600B
$1,200B
$800B
$400B
$0B
20M
19M
18M
17M
16M
15M
14M
13M
12M
11M
1950
1960
1970
1980
1990
2000
2010
Manufacturing Output (billions of 2014 dollars)
Manufacturing Employment (millions)

Technology & Job Density

- In manufacturing, as in other industries, job density—the number of jobs per process—is declining.
- The reason—automation—and robotics—and advanced manufacturing techniques.
- More generally, the "job intensity" of America's manufacturing industries—and especially its best-paying advanced ones—is only going to decline.
- In 1980 it took 25 jobs to generate $1 million in manufacturing output in the U.S..
- Today it takes five jobs.

Decline in Jobs: Is it Technology or Trade?

- **It's Technology (Robots)**
  - Erik Brynjolfsson, MIT Sloan School of Management
    - *Race Against the Machine*
    - *Second Machine Age*
- **It's Trade (China)**
  - David Autor, MIT Department of Economics
    - *The China Syndrome: Local Labor Market Effects of Import Competition in the United States. American Economic Review 2013, 103(6): 2121–2168*

KIVA

A Kiva Systems robot can scurry about the floor of a large warehouse to find ordered products. It then fetches the correct rack or pallet and brings it to a worker who packages the goods.

Technology & Job Loss

- Competition from China only explains about a fourth of decline in manufacturing during the 2000s.

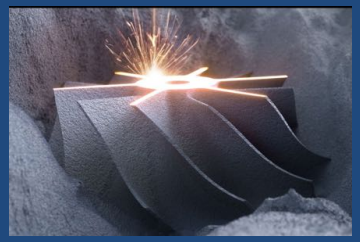
- Skills mismatch, as manufacturing sector shifts from low-skilled to high-skilled work—has also contributed to the decline

- Occupational polarization
  - Workers involved in tasks that are fully *codifiable* are most vulnerable to replacement by automations

  - Workers, parts of whose jobs are *codifiable*, will experience dislocations

- Technology is reshaping the skills need for work—enhancing cognitive skills over physical skills

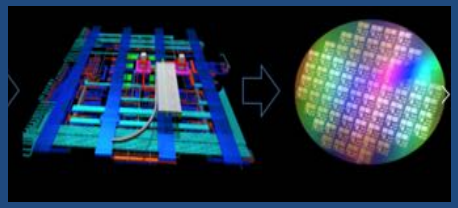
Advanced Manufacturing



Additive Manufacturing

3D Printing

Functional Fabrics

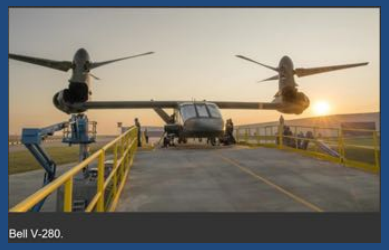


Photonics

Flexible Sensors

Robotics

Light Weighting



Advanced Composites

Clean Energy

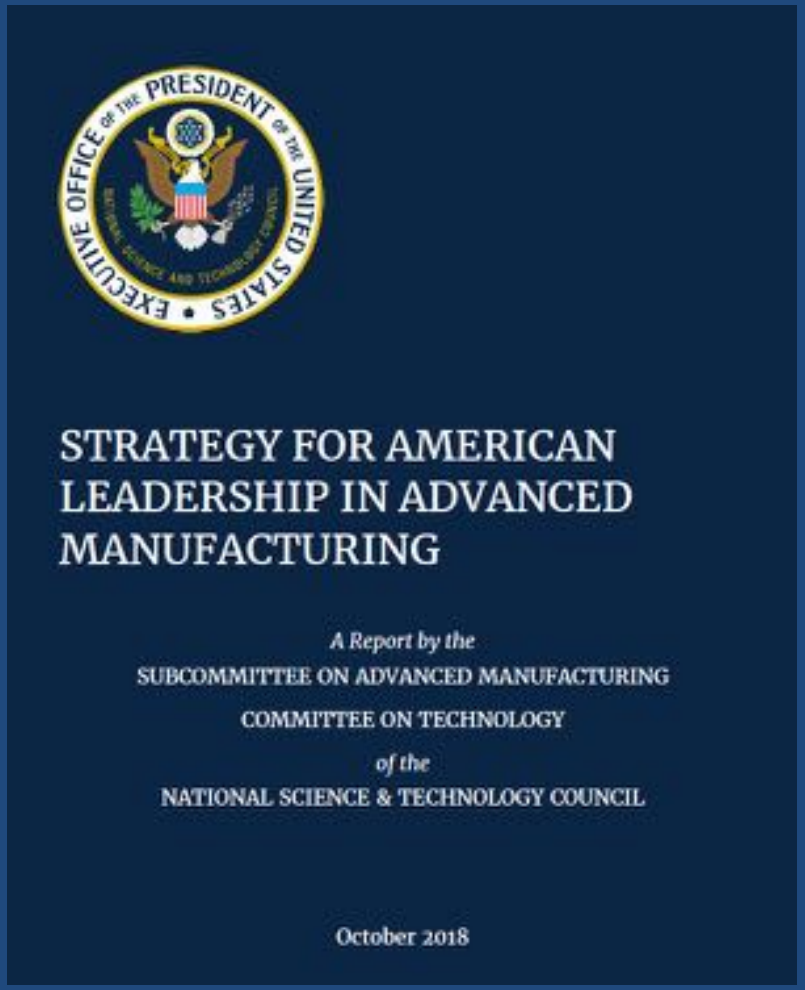
Engineered Biology

Additive Manufacturing

Plastic, Metal or Living Tissue

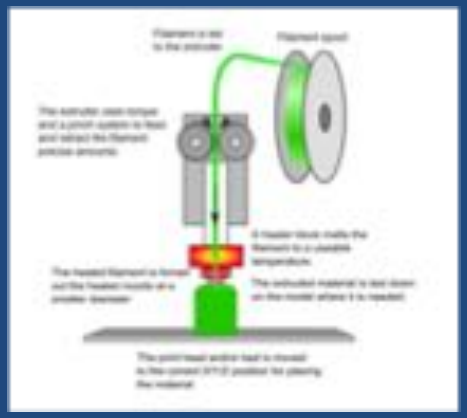
- **Techniques** (metal powder + laser)
  - Material extrusion
  - Material jetting
  - Binder jetting
  - Sheet lamination
  - Vat photopolymerization
  - Powder bed fusion
  - Directed energy deposition

- **Advantages**
  - Increases efficiency
  - Eliminates final assembly
  - Promotes customization over mass production
  - Democratizes manufacturing
  - Facilitates open design
  - Creates novel tort liabilities?



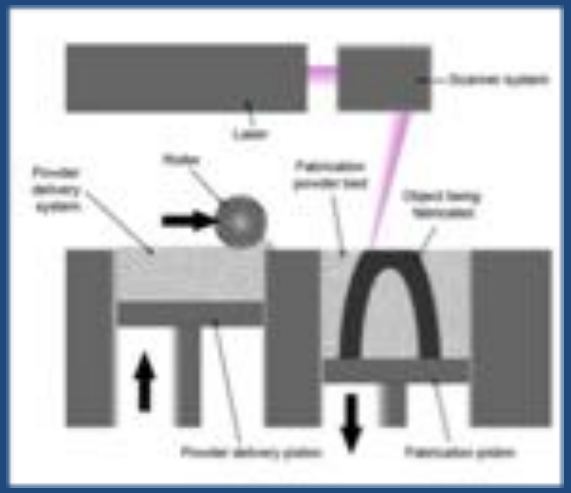
Illustrating Basic Techniques

Fused Filament Fabrication (FFF)

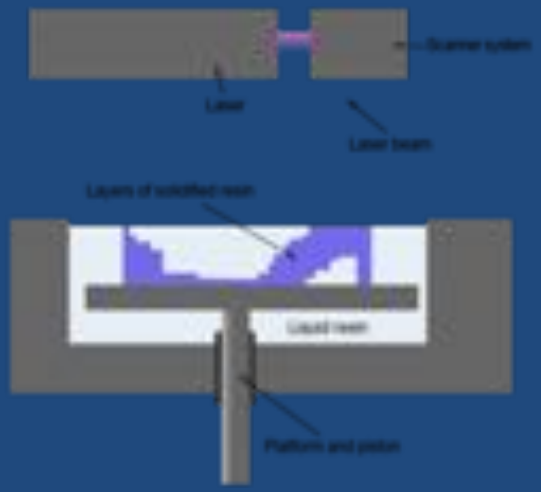


(3D Printing)

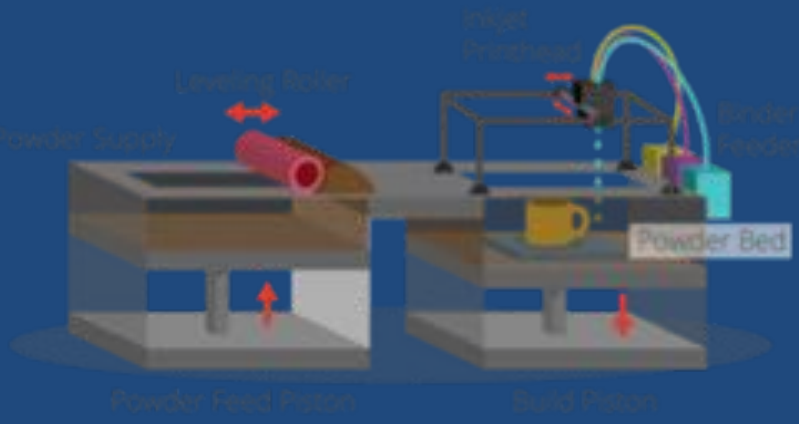
Selective Laser Sintering (SLS)



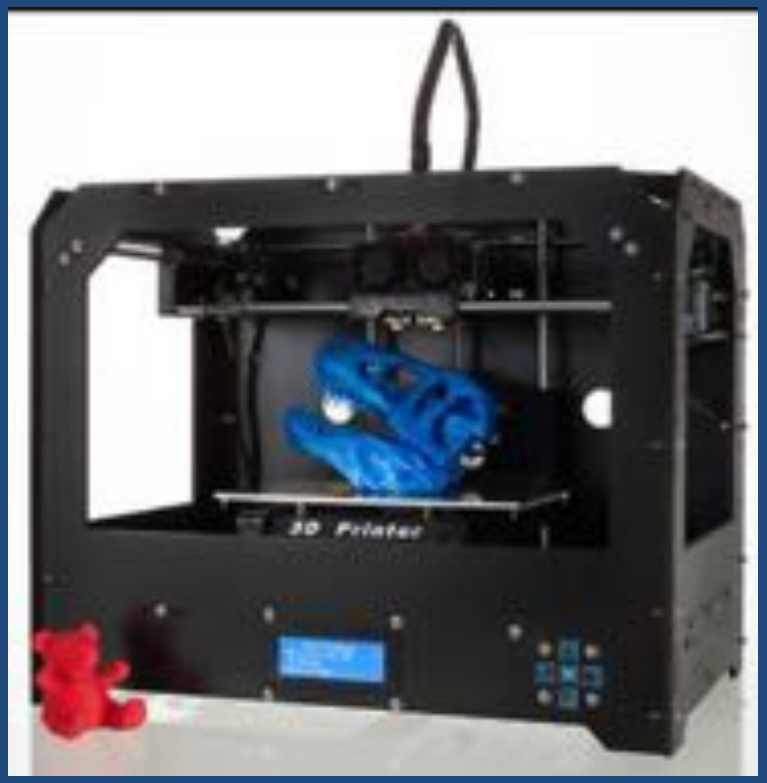
Stereolithography



Powder Bed Inkjet Binding



Desktop 3D Printing



- Readily available
- Multiple polymer strands available
- Custom ‘at home’ strand compounding
- Prices dropping, units getting larger

NTRC NANOTECHNOLOGY RESEARCH CENTER

This is also a 3D Printer

NTRC NANOTECHNOLOGY RESEARCH CENTER

Additive Manufacturing

Rethink risk management?

- EHS, Security, Response Issues
- Uses pure (pyrophoric) Aluminum
- **Up to 400 lb per charge**
- Warehouse feedstock for 10 charges
- Emission, exposure, waste

NTRC NANOTECHNOLOGY RESEARCH CENTER

Materials of Interest in Additive Manufacturing

Polymers

- Acrylonitrile-butadiene-styrene
- Polylactic acid
- Propylene fumarate
- Poly(vinyl alcohol)
- Polycarbonate
- Polyethylene
- Polystyrene

Solvents

- Dimethyl fumarate
- Isopropanol
- Acetone
- Methyl Ethyl Ketone
- 2-Butanone

Metals

- Ti-6Al-4V
- IN 625 & IN 718 (Ni, Cr)
- 17-4 PH stainless steel
- Cobalt chromium

Nanomaterials

- nFe (steel sintering)
- nAg (sintering, conductivity)
- nCB, CNT (conductivity, stiffness, tensile strength)
- $nSiO_x$ (polymer strength)

Advanced Manufacturing Effects

Tectonic Retooling?

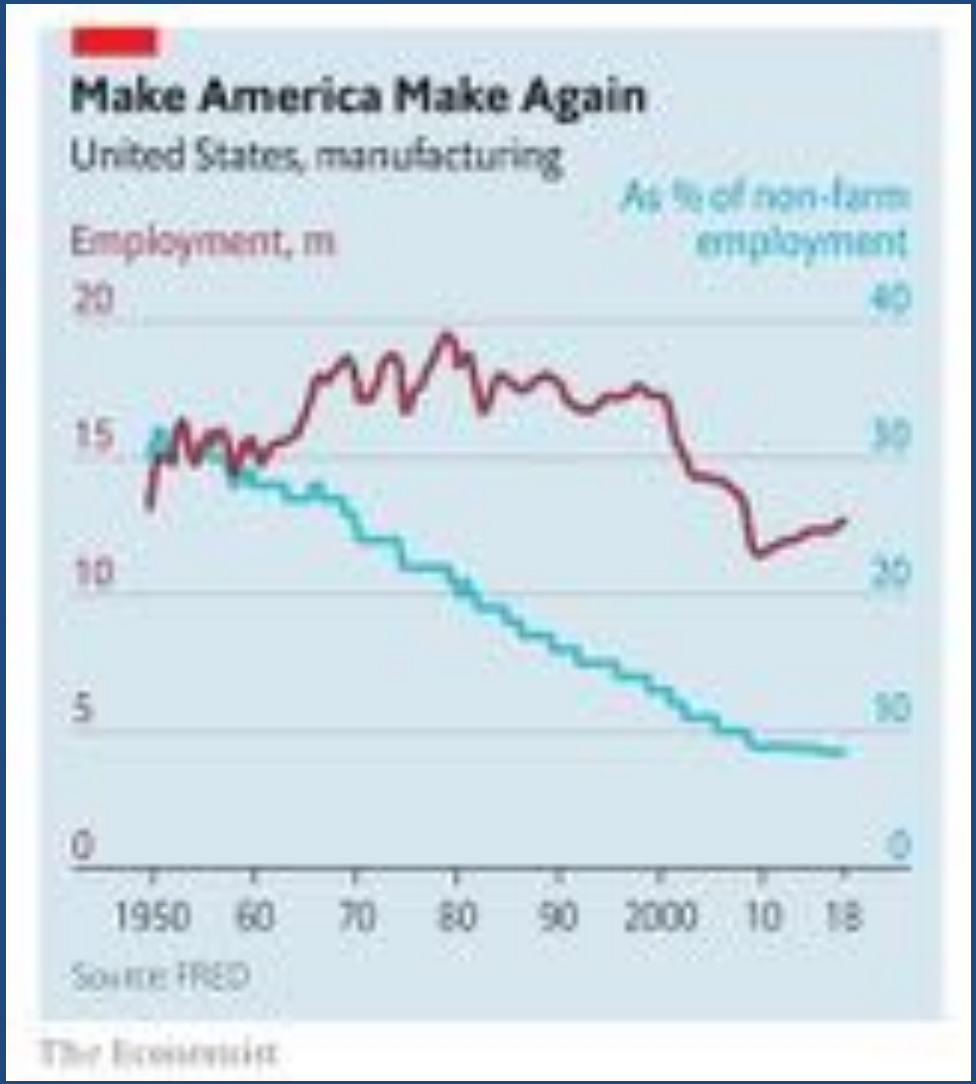
- Changes in the process of manufacturing
  - Customization
  - Reduction in parts
  - Reduction in time spent on production
- How designers go about their work
- What factory looks like
- Where production is located
- What production workers do
- Way business agreements are structured
- What work arrangements are used

3D Rocket Printing

- Fuel tank produced in days
- Traditional manufacture in one year
- Printed rocket engine and fuel tank tested 85 times at NASA facility in MS

Recent Manufacturing Employment

- Employment composition has shifted toward managerial and professional jobs, and away from jobs that can be done with less schooling.



Digital

Sensor Technology Is Expanding

- **Enabling capabilities increasing exponentially**
  - Improvement of measurement science
  - Readily available geographic and spatial information
  - Miniaturization of instruments
  - Utilization of smart phone/tablet technologies

- **Types of Sensors**
  - Placeables
    - Air, water environment
    - In-vehicle monitoring
  - Wearables
    - Clothing
    - Hard hats
  - Implantables
    - Ingested and transcutaneous

Abbott's FreeStyle Libre

- People with insulin-dependent diabetes stick their fingers up to 10 times a day to check their blood sugar.

- The *FreeStyle Libre* system eliminates the painful finger pricking. A small, round sensor on the upper arm contains a tiny ***filament*** that, when inserted just under the skin, continually monitors glucose. Patients use a smartphone-size scanner to check their levels.

21st Century Exposure Science:

- **Work environment**
  - Sampling & Analysis
  - Direct-reading instruments
- **Biologic environment**
  - Biomarkers of exposure
  - Biomarkers of effect

Advanced Fabrics—Wearable Sensors

Marty Ellis, of Inman Mills in South Carolina, checks a machine manufacturing fabric developed through AFFOA

Functional Fabrics

- **DEFENSE**
  Functional fabrics will lighten soldiers' gear, enhance situational awareness on the battlefield, and decrease fratricide.

- **CONSUMER PRODUCTS**
  High value-added products based on advanced woven & nonwoven technologies.

- **VENTURE CAPITAL**
  Fund the coming surge of wearable products and startup ventures.

- **TRANSPORTATION**
  Join the wave of intelligent transportation systems with functional fabrics.

- **MANUFACTURING MACHINERY**
  Producing new fibers and textiles will require next-generation equipment and machinery.

- **ARCHITECTURAL & INTERIOR TEXTILES**
  'This old house' can now monitor, act, and re-act all by itself.

- **APPAREL**
  Smart clothes that can cool, change color, adjust size, last longer, mask or transmit odors, take photos, and so much more.

- **SOFTWARE & DATABASES**
  IT combined with functional fabrics enables highly insightful and useful information.

- **MEDICAL TEXTILES & SCANNERS**
  Clothing that can detect impending medical events and save lives.

- **RAW MATERIALS**
  Manufacturers of advanced functional materials for fibers and fabrics.

- **CONSUMER ELECTRONICS**
  Enabling the "internet of wearables" transforming apparel into consumer electronics.

Internet of Things (IoT)

- Sensors are at the heart of the Industrial Internet
  - Deploying sensors, the entire workplace and everything and everyone in it can become a type of information system

- Sensors can become intelligent assets—devices equipped with sensors and connected to one another produce sensor-based analytics
  - Sensor maintenance = technician
  - Sensor placement, sensor data interpretation, control recommendations = occupational professional

Sensor-Enabled Exposure Assessment

- Was the worker overexposed?
  - Sensor measures concentration
- *Where* did the exposure occur?
  - Spatial positioning by satellite
- *When* did the exposure occur?
  - Timed exposure with atomic clock
- *Why* did the exposure occur?
  - Data stream makes it easier to analyze when correlated with simultaneous event video
- *Only issue left—controls*

Worker Protection Informatics

- The ***science and practice*** of determining ***which sensor information is relevant*** to protecting worker safety, health, well-being, and productivity, and then developing and implementing effective mechanisms
  - to *collect, validate, store, share, analyze, model, and apply the information, and then to confirm achievement of the intended outcome* from use of that information,
  - and then *conveying experience to the broader community, contributing to generalized knowledge, and updating standards and training*.

Adapted from http://www.internano.org/nanoinformatics/ and Hoover et al. 2015

Artificial Intelligence

&

Deep Learning

Rule-based

Neural networks

Four Waves of AI Development

- **Internet AI**
  - Largely about using AI algorithms as recommendation engines—systems that learn how personal preferences and then serve up content hand-picked for us.
- **Business AI**
  - Takes advantage of the fact that traditional companies have also been automatically labeling huge quantities for decades and can make predictions when combine across tens of millions of examples.
- **Perception AI**
  - Algorithms can now group the pixels from a photo or a video into meaningful clusters and recognize objects in much the same way our brain does.
- **Autonomous AI**
  - Once machines can see and hear the world around them, they'll be ready to move through it safely and work in it productively

AI Powered By Machine Learning

- One of the most important drivers of AI advances over the past two decades has been machine learning: computer algorithms that automatically improve their competence through “experience.”

- This experience is often in the form of historical data, which the machine-learning algorithm analyzes in order to detect patterns or regularities that can be extrapolated to future cases.
  - Given experience in the form of a historical database of medical records, machine-learning algorithms are now able to predict which future patients are likely to respond to which treatments.

Sensor Data Used by AI: Issues

- Do existing and proposed sensor methods **accurately measure** what they are supposed to be measuring?
- How can they be **adequately calibrated and validated**?
- When are they limited to use for screening and **when can they provide accurate characterizations** of specific hazards?
- Given the large to vast amounts of sensor data that may be collected, **how can those data be feasibly analyzed and interpreted by a occupational health data scientist**?

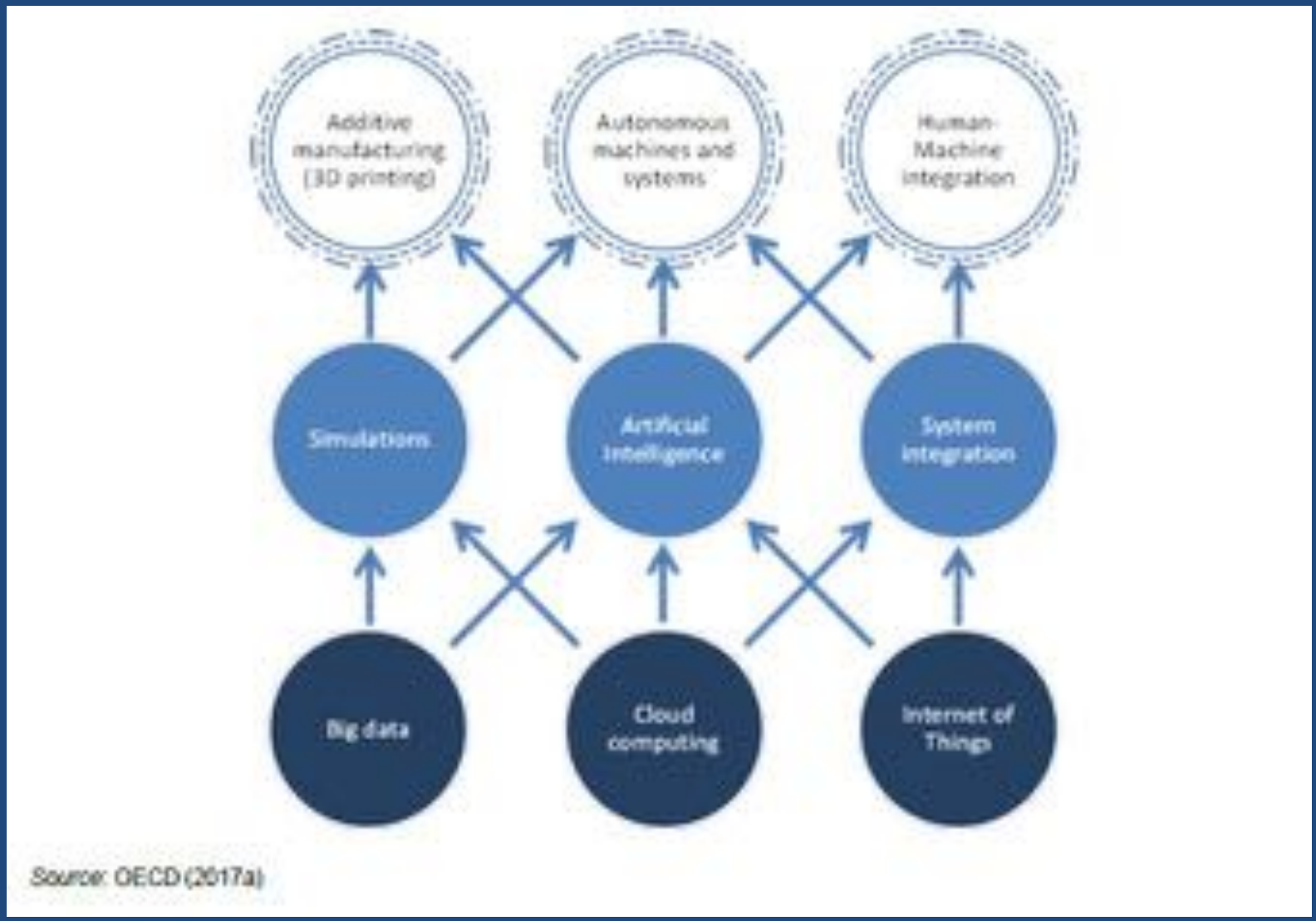


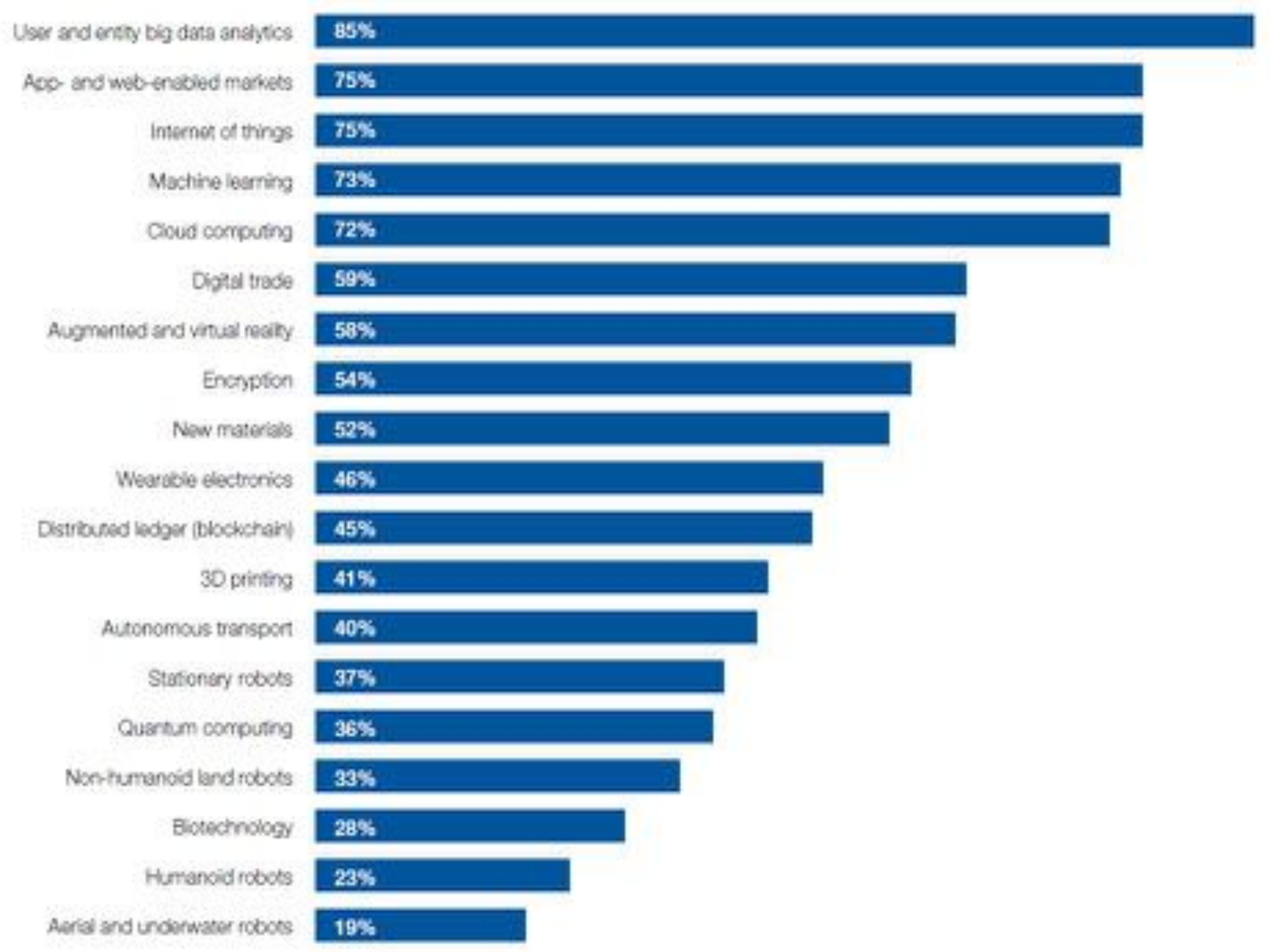


AI and Safety Management

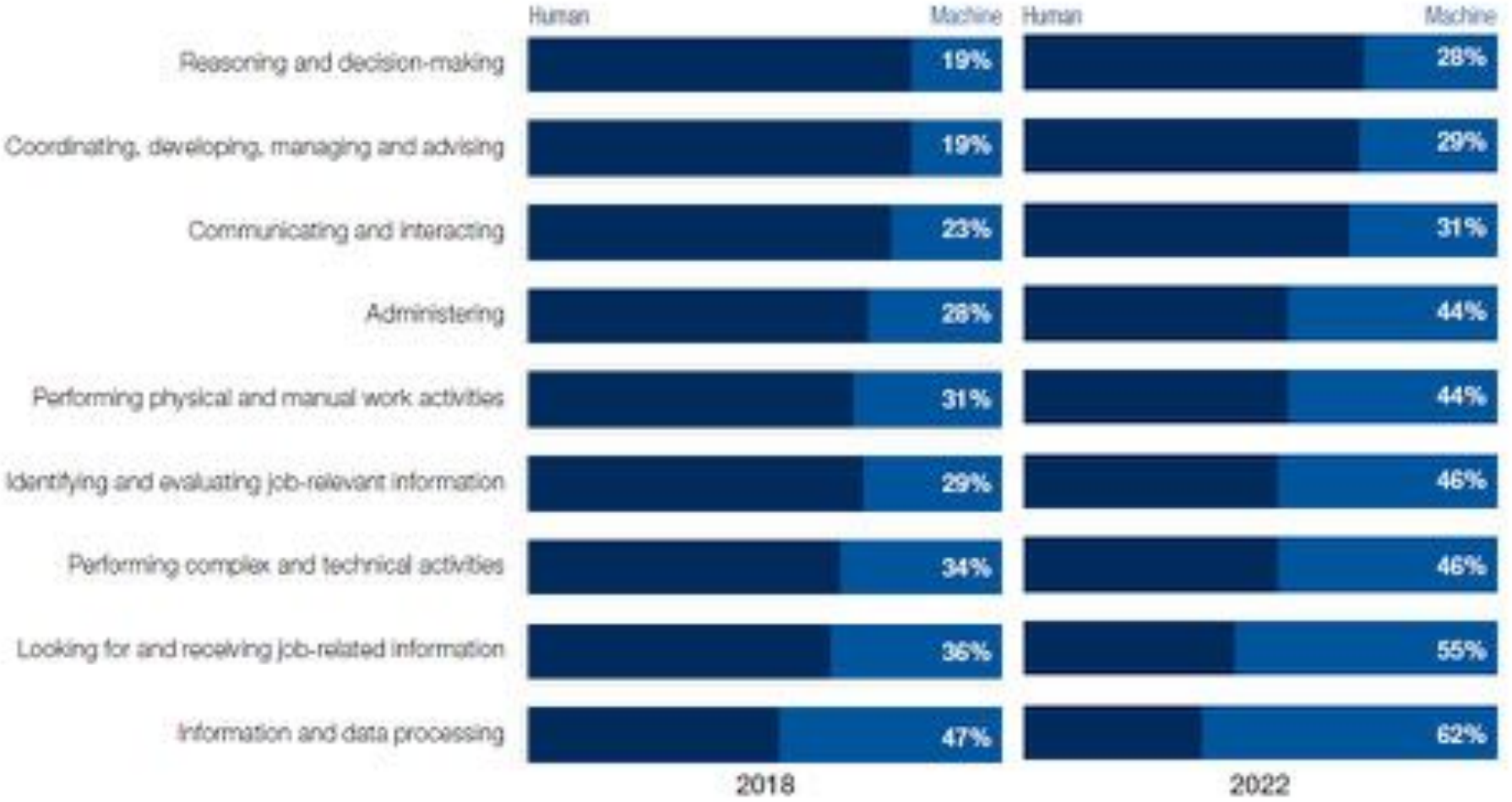
- Can AI recognize a near-miss?
- Can it assess data to present a risk assessment probability?
- Can it offer risk mitigation recommendations based on real-time sensor data and historical situations?
- Can it take control to prevent destructive human actions?

Confluence of Key Technologies Enabling Industrial Digital Transformation (Industry 4.0)




User and entity big data analytics
85%
App- and web-enabled markets
75%
Internet of things
75%
Machine learning
73%
Cloud computing
72%
Digital trade
59%
Augmented and virtual reality
58%
Encryption
54%
New materials
52%
Wearable electronics
46%
Distributed ledger (blockchain)
45%
3D printing
41%
Autonomous transport
40%
Stationary robots
37%
Quantum computing
36%
Non-humanoid land robots
33%
Biotechnology
28%
Humanoid robots
23%
Aerial and underwater robots
19%

Ratio of human-machine working hours, 2018 vs. 2022 (projected)



Source: Future of Jobs Survey 2018, World Economic Forum.

Robotization and National Economies

- Effect on employment
  - *Technological unemployment*
  - *Probably overstated in near term*
  - *Probable in longer term*

- Effect on productivity
  - Enhancement

- Effects on production technologies and organization of production
  - **Substitute** for low-skill labor and **complement** for high-skill labor

  - Decrease importance of labor costs in total production costs
    - Making relocation of productive activities attractive—reshoring or "botsourcing"

  - Enhance the flexibility of productive process—enabling greater customization of goods—autonomous machine will allow for producing smaller batches of a wider variety at a lower cost

Thank You!

References

Abraham KG & Kearney MS. Explaining the decline in the U.S. employment-to-population ratio: a review of the evidence. February 2018. http://www.nber.org/papers/w24333.pdf

Acemoglu D, Restrepo P. Robots and jobs: evidence from US labor markets. March 2017. http://www.nber.org/papers/w23285.pdf

Awad E et al. The moral machine experiment. *Nature.* https://doi.org/10.1038/s41586-018-0637-6

Awolusi I et al. Wearable technology for personalized construction safety monitoring and trending: Review of applicable devices. *Automation in Construction.* 85: 96-106 (2018).

Benach J, Muntaner C. Employment and working conditions as health determinants. In Improving Equity in Health by Addressing Social Determinants, eds. JH Lee, R. Sadana, pp. 165-195. Geneva: WHO, 2011.

Benach J et al. The challenge of monitoring employment-related health inequalities. *J Epidemiol Commun Health.* 66 (12): 1085-1087 (2012).

Benach J et al. Precarious employment: Understanding an emerging social determinant of health. *Annu Rev Public Health . 35:*229-253 (2014).

Benach et al. What should we know about precarious employment and health in 2025? Framing the agenda for the next decade of research. *Int J. Epidemiol.* 45(1):232-238 (2016).

References

Brynjolfsson E, Mitchell T. What can machine learning do? Workforce implications. *Sci.* 358(6370):1530-1534 (2017).

Bureau of Labor Statistics. *Contingent and Alternative Employment Arrangements—May 2017.* News Release, U.S. Department of Labor, June 7, 2018.

Charles KK et al. The transformation of manufacturing and the decline in U.S. employment. NBER, Working Paper 24468, March. 2018.

De Backer K et al. Industrial robotics and the global organization of production. OECD Science, Technology and Industry Working Papers, 2018/03, OECD Publishing, Paris.

Dotsy M et al. Where is everybody? The shrinking labor force participation rate. Federal Reserve Bank of Philadelphia. https://philadelphiafed.org/-/media/research-and-data/publications/economic-insights/2017/q4/eiq4_where-is-everybody.pdf

Ferrie JE et al. Flexible labor markets and employee health. *Scand J Work Environ Health Supp.* 6:98-110 (2008).

Frey CB, Osborne MA. The Future of Employment: How Susceptible are Jobs to Computerisation. *Technological Forecasting and Social Change*. 2013;114:254-280.

Haskel J, Westlake S. 2018. *Capitalism without capital*. Princeton University Press.

Howard J. Nonstandard work arrangements. *AJIM* 60:1-10 (2017).

References

Howard J et al. Unmanned Aerial Vehicles and Construction Worker Safety, *American Journal of Industrial Medicine.* 2018;61:3-10

International Labour Office. The future of work: a literature review. March, 2018. http://www.ilo.org/global/research/publications/working-papers/WCMS_625866/lang--en/index.htm

Jordan J. *Robots.* 2016. MIT Press

Katz LF, Krueger AB. *The rise and nature of alternative work arrangements in the U.S. 1995-2015*. National Bureau of Economic Research. September, 2016. http://www.nber.org/papers/w22667.pdf

Kivimaki M et al. Temporary employment and risk of overall and cause-specific mortality, *Am J Epidemiol.* 158(7):663-668 (2003).

Lehrer E. The Future of Work. *Nat Affairs* 36:35-52, (Summer, 2016).

National Academies of Science, Engineering and Medicine. *Information technology and the U.S. Workforce: where are we and where do we go from here?* Washington, DC: National Academies Press, 2017.

National Academies of Science, Engineering and Medicine. *The changing nature of work: implications for occupational analysis.* Washington, DC: National Academies Press, 1999.

References

World Economic Forum. “The Future of Jobs Report, 2018.” Geneva, Switzerland: Centre for the New Economy and Society. Available at https://www.weforum.org/reports/the-future-of-jobs-report-2018

OSHA/NIOSH (2015). *Protecting temporary workers*. http://www.cdc.gov/niosh/docs/2014-139/pdfs/2014-139.pdf

Posner E, Weyl G. *Radical markets: uprooting capitalism and democracy for a just society.* Princeton, NJ: Princeton University Press. 2018.

Rotman D. The productivity paradox. *MIT Tech Rev* 121:15 (2018).

Schall MC, et al. Barriers to adoption of wearable sensors in the workplace: a survey of occupational safety and health professionals. *Human Factors.* 2018;60(3):351-362.

Schulte PA, Grosch J, Scholl JC et al: Framework for considering productive aging and work. *Journal of Occupational and Environmental Medicine.* 2018;60:440.

Virtanen M et al. Temporary employment and health: a review. *Int J Epidemiol.* 34:610-622 (2005).

World Bank Group. *The changing nature of work.* World Development Report 2019. http://pubdocs.worldbank.org/en/816281518818814423/2019-WDR-Draft-Report.pdf

Weber L. The end of employees. Wall Street Journal. https://www.wsj.com/articles/the-end-of-employees-1486050443?mod=djmc_pkt_ff