2019 Annual Meeting &
Educational Conference

The 4th Industrial Revolution

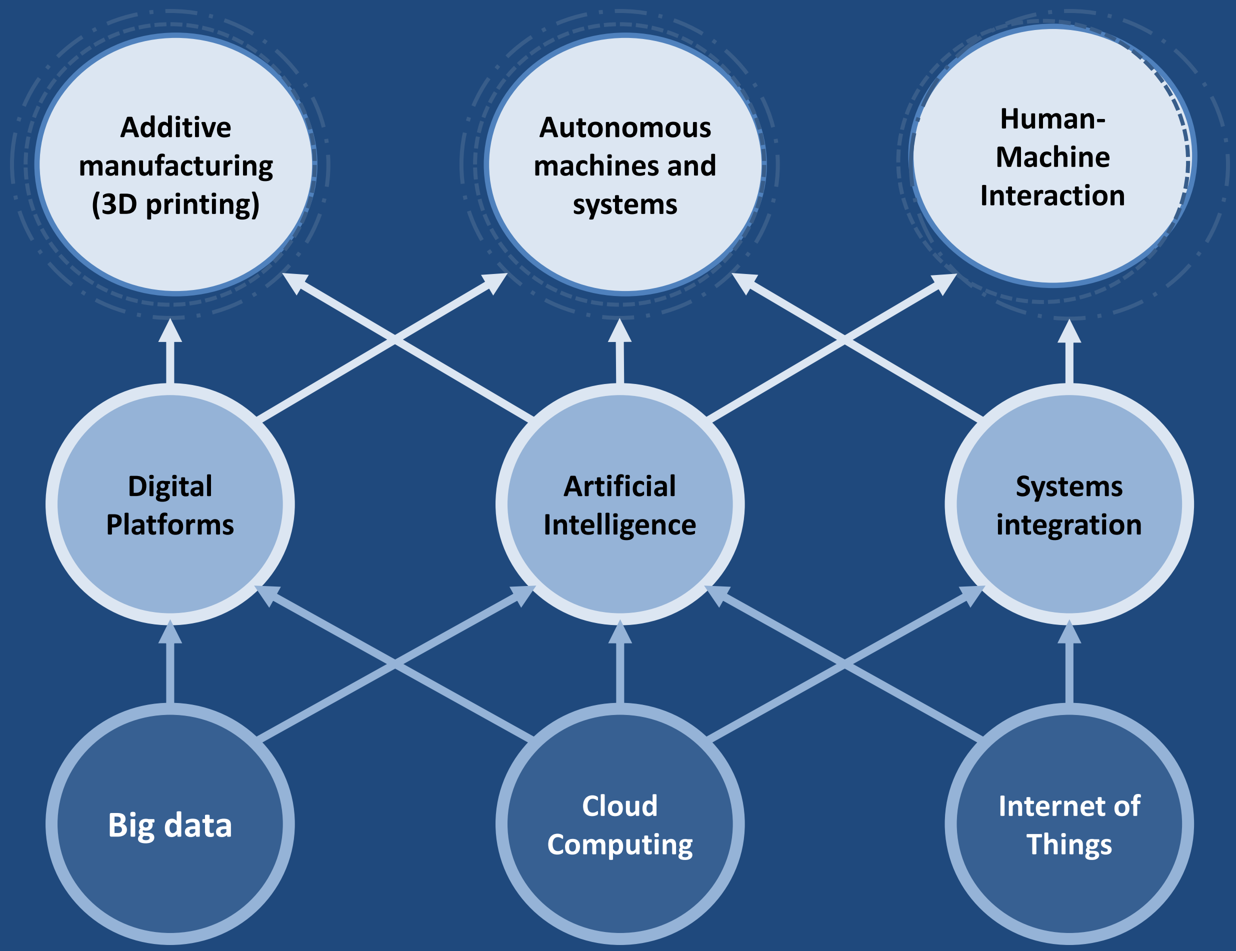
John Howard
National Institute for Occupational Safety and Health
U.S. Department of Health and Human Services
Washington, D.C.

10 June 2019
Hyatt Regency Grand Cypress
Orlando, Florida

Industrial Revolutions

- **First Industrial Revolution**
  – Used water and **steam power** to mechanize production
- **Second Industrial Revolution**
  – Uses **electric power** to create mass production
- **Third Industrial Revolution**
  – Uses **electronics** to automate production
- **Fourth Industrial Revolution**
  – Use physical entities controlled by **digital algorithms** using **artificial intelligence**

Key Technologies Enabling the Future



Overview

- **Arrangements**
  - Standard
  - Nonstandard
- **Technologies**
  - Robotics
    - Artificial Intelligence
  - Advanced Manufacturing
    - Automation

3rd to 4th Transition: 1880—1980

- **Enterprise**
  - Companies became vertical organizations that differentiated jobs from one another more clearly than ever before—the rise of the corporation following WWII.
  - Employers got stable workforce in which they could invest with fair expectation of positive returns over time.
- **Worker**
  - "Good" job was being an employee of a particular company for your entire working life (or until age 65). "Standard employment relationship" became the dominant model during expansion after WWII until 1980s.
  - Employees got job security, benefits and legal protections from market forces.
- **Government**
  - Built social welfare laws using the same model

Model in Trouble: 1980 to Present

- **Erosion of standard employment relationship**
  - Rise of Co-employment
    - Russell Kelly—1946
    - Elmer Winter and Aaron Scheinfeld—1948
  - Rise of Digitally Intermediated Work
- **Decline in 3rd party representation**
- **Threats to solvency of social benefit programs**
  - SSA, Medicare
  - Defined contribution vs. defined benefit plans
- **Rise of the virtual workplace**
  - Locations technologically connected via a private network or the Internet without regard to geographic boundaries or time zones

Economic Work Arrangements

- **Employment Relationship (Employee)**
  - Organization <u>has</u> directive control:
    - **Standard employment relationship**
      - One employer—one employee
    - **Co-employment**
      - Two employers (agency and client)—one employee
- **Business Relationship (Independent Contractor)**
  - Organization <u>lacks</u> directive control
  - **Business relationship** exists
    - Specifies the *what,* the *when,* but not the *how*
    - No employer and no employees—entrepreneurial contract
- **Gig or Platform Work (Worker)**
  - Platform connecting the provider with the customer
  - Is the worker a contractor or an employee?

History of Work Arrangements

- Standard work arrangement may be the ***historical exception***
  - Origins can be found early to mid-20th century in ***mass production*** in large, manufacturing factories using *Fordist* assembly line techniques.

- Non-standard arrangements have a much longer history in capitalism than the standard employment relationship.

- Work organization used by digital platforms can best be understood as **return to long-standing work practices** beginning in early capitalism

Safety Net of Federal and State Laws

Applies Only to "Employee" as Defined in Each Statute

- Old-age assistance and disability benefits
  - Social Security Act of 1935
- Collective bargaining rights
  - National Labor Relations Act, 1935
- Minimum wage, overtime and child labor protections
  - Fair Labor Standards Act, 1938
- Employment discrimination protections
  - Title VII of the Civil Rights Act, 1964
  - Age Discrimination in Employment Act, 1967
  - Americans with Disabilities Act, 1990
- Workplace safety and health protections
  - Occupational Safety and Health Act, 1970
- Pension, health and other employee benefits
  - Employee Retirement Income Security Act, 1974
  - Family Medical Leave Act of 1993
- Unemployment insurance and workers compensation benefits
  - Various Federal and state laws

Gig Economics: On the Bright Side

- **Creates surplus value in the economy**
  – Monetizes unused time and assets
  – Provides more opportunities to work

- **Faster matching customer demand and worker supply**
  – Theory of the firm (Coase, 1937)
  – Reduces costly "search frictions" (Pissarides, 2010)
  – Control over workforce and production is cheaper than cost on the open market and haggling for each individual transaction

- **Lowers costs associated with a permanent workforce**
  – Intermediation drastically lowers firm transaction costs
  – Contractor status drastically lowers firm benefits costs

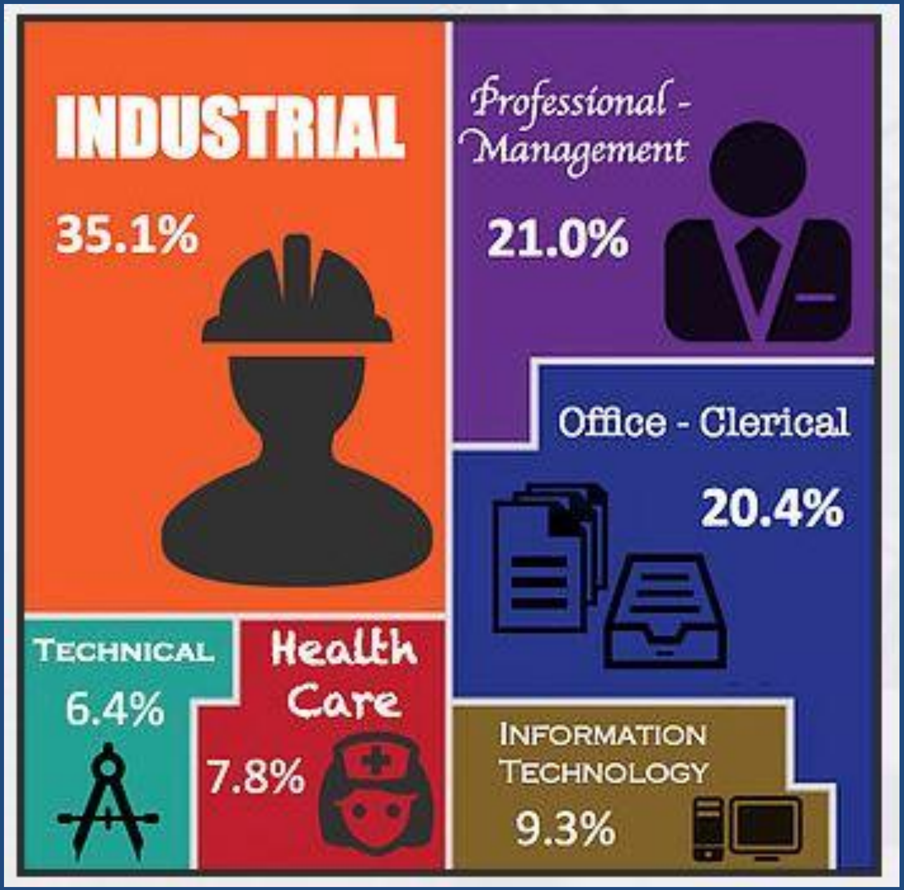
Gig Economics: On the Dark Side

- **Post-industrial firm**
  – Maximizes profit, but not through productive enterprise
- **Regulatory 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
- **Evasion of employment law?**
  – Classifying workers as contractors allows platforms to offer services without have to pay for the cost of workers
- **Devolution of all responsibilities to micro-entrepreneurs**
- **Negative externalities**

Co-Employment Arrangements

- Temporary staffing industry is best known for earlier years when it placed female clerical workers.

- But the industry has expanded to include nearly every occupation in the US and globally.



KELLY SERVICES

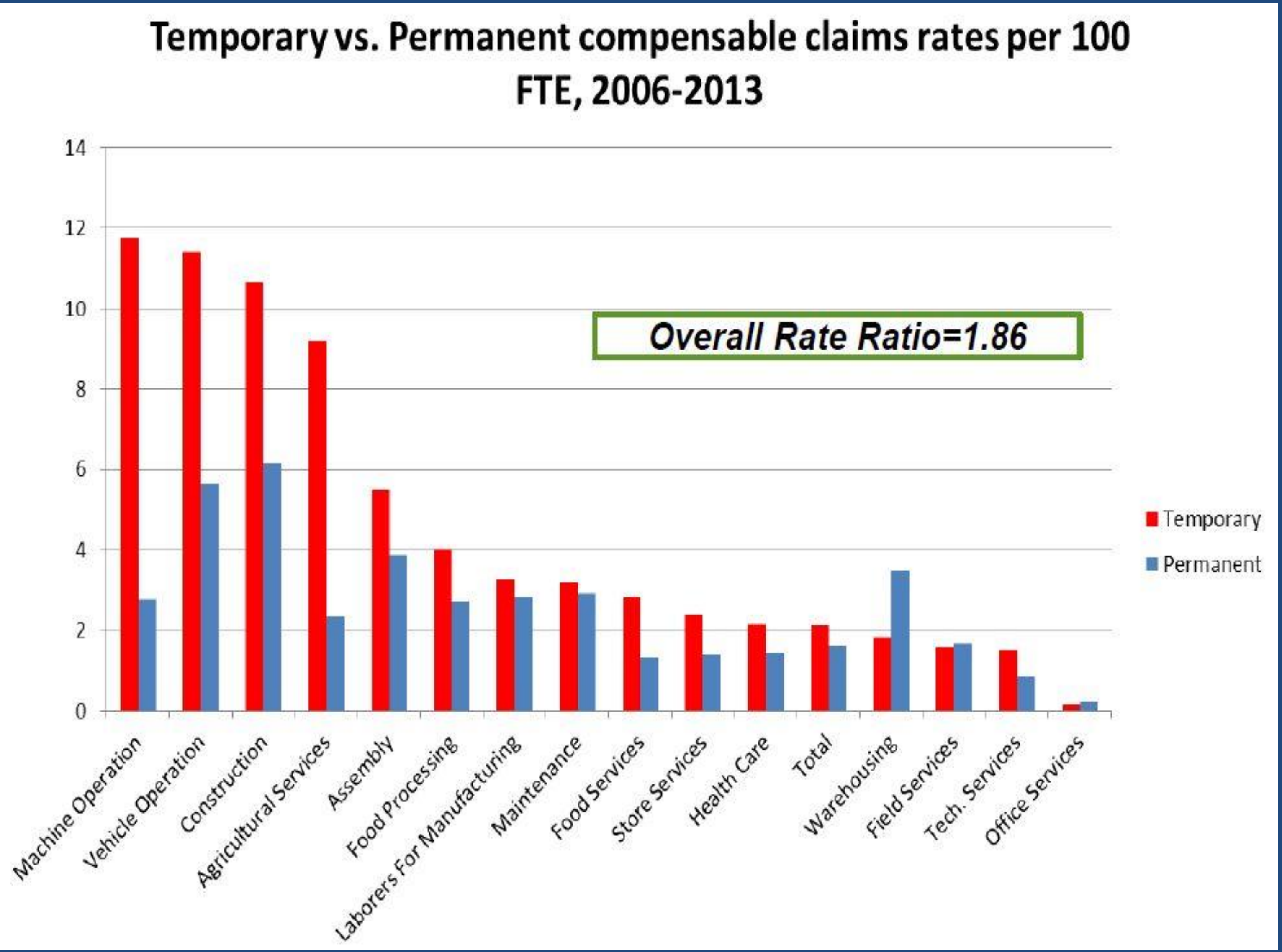
ManpowerGroup

Risk of Injury in Temporary Workers

- **European Studies**
  - 7 of 13 European reports show increased risk (Virtanen 2005).
- **U.S. Studies**
  - Higher injury rates in subcontracting turnaround procedures at *petrochemical* facilities (Rebitzer 1995).
  - Temps had twice injury rate at a *plastics* manufacturer (Morris 1999).
  - Workers' comp injury claim rates for temps double those of permanent workers in Washington state (Smith 2010).
  - ***PROPUBLICA,*** using Florida workers' compensation data and BLS data, found an injury odds ratio of close to 4 for temporary workers compared to all other workers (Pierce 2013).

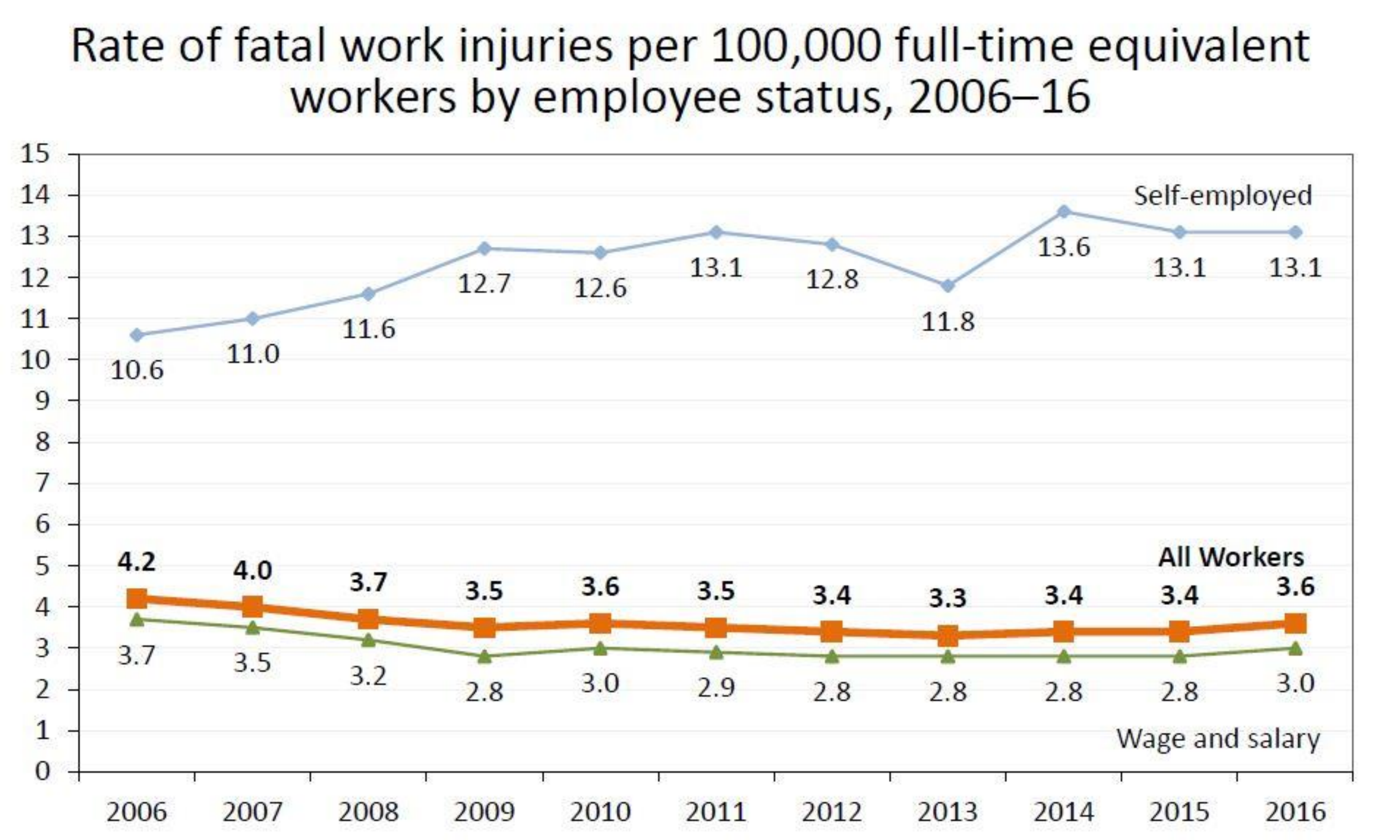
Injury Claims

Washington State Department of Labor and Industries (SHARP)



Mortality Risk—U.S.

https://www.bls.gov/iif/oshwc/cfoi/cfch0015.pdf

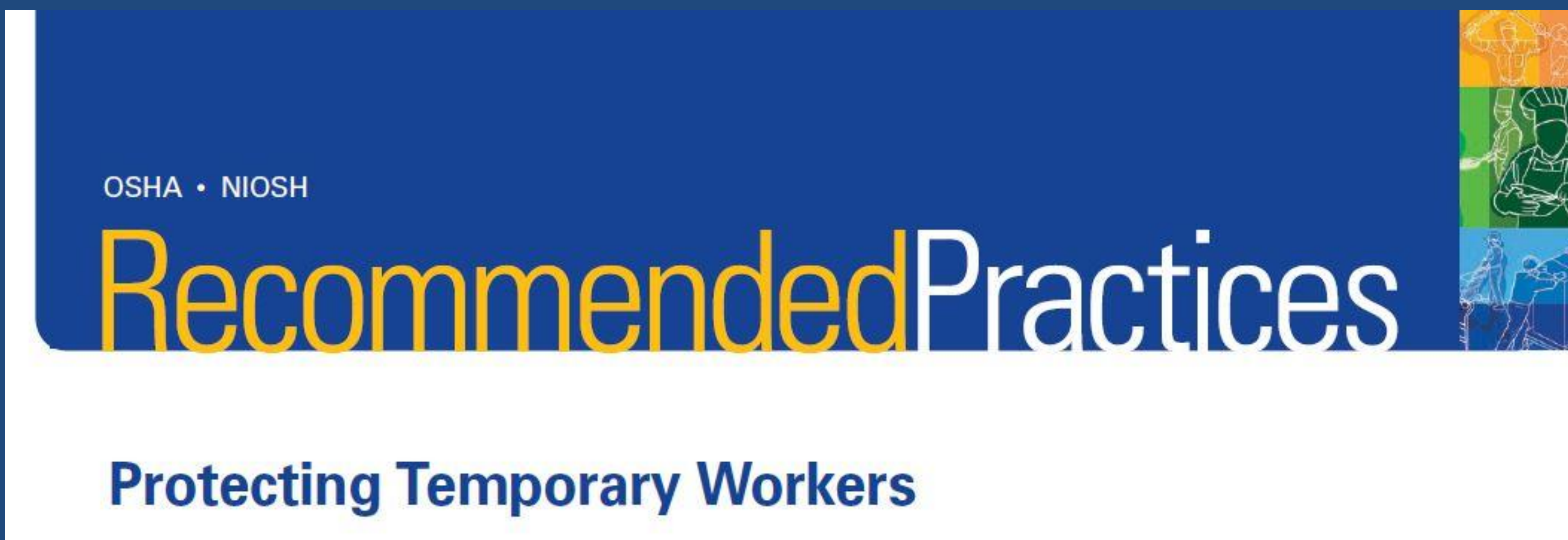


Temporary Workers: Differential Injury Risks

- **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 temporary 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, hybrid analysis, IRS test, differing 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



Work Arrangement Exposures

ERSO

Exposures	NIOSH Scale	EPRES Scale (Vives et al., 2010)
Temporariness	Job security Part/full time Salaried/hourly paid Job tenure	Contract duration Temporary contract (in last 12 months)
Disempowerment	Freedom to decide Decision making involvement Daily flexibility in start/quit time	Decision taker in scheduling, work hours, wage and salary (collective or top-down)
Vulnerability	Relationship with management Treatment at work Management trust Discrimination Supervisory concern Promotion chances	Afraid to demand better work condition Defenseless towards mistreatment Afraid of being fired Discriminatory treatment Authoritative treatment Felt easily replaceable
Wages	Volatile income Family financial situation Relative family income Fringe benefits	Meet basic needs Meet unexpected expenses Take home monthly wage

Research Challenges

- No agreed on definitions of nonstandard work arrangements

- Improved surveillance methods about extent of nonstandard arrangements and number of workers involved in each type are needed

- Existing models for employment quality that relate to health outcomes may not be useful for non-standard work arrangements

- Studies needed*:*
  - Prospective study of health consequences of nonstandard arrangements
  - Intervention effectiveness study of a range of policy approaches

New BLS Survey Data on June 7, 2018

Contingent and Alternative Employment Arrangements, May 2017

https://www.bls.gov/news.release/pdf/conemp.pdf

- **Contingent Workers**
  - Range of estimates from 1.3% to 3.8%
  - Total of 2.08 to 6.08 million

- **Alternative Employment Arrangements**
  - Independent contractors (6.9%)
  - On-call workers (1.7%)
  - Temporary help agency workers (0.9%)
  - Workers provided by contract firms (0.6%)

Alternative Employment Totals

U.S. Bureau of Labor Statistics

Contingent and Alternative Employment Arrangements, May 2017

	1995	2005	2017
Independent contractors	6.7	7.4	6.9
On-call workers	1.7	1.8	1.7
Temporary help agency	1.0	0.9	0.9
Contract workers	0.5	0.6	0.6
Total	9.9	10.7	10.1

Was the BLS Survey An Underestimate?

- **BLS only asks about respondent's "main job"**
  - "Fails to capture much secondary work activity leading to an understatement of multiple job holding rate" (Katz & Krueger, 2019).
- **BLS only asks about work during a one-week period**
  - 42% of independent workers freelance less than weekly (Freelancing in America, 2017).
- **BLS allows responses from "proxy" respondents**
  - "Proxy respondents may be less accurate. BLS should consider using on self-responses" (Katz & Krueger, 2019).
- **BLS questions are poorly worded and unclear**
  - Leads to miscoding respondents as employees (Gallup, 2018).

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

Contingent Work and Alternate Work Arrangements

Project Description

The committee will review the Contingent Worker Supplement (CWS) of the Current Population Survey (CPS), which provides key measures of contingent workers, alternative work arrangements, and insights on the "gig" economy. There are disagreements among researchers and policymakers about definitions and measures of these employment concepts. The committee will carefully review the CWS and other existing data sources (survey and nonsurvey), as well as the methodological issues surrounding measurement of these concepts. A workshop to discuss the views of data users, stakeholders, and survey experts will be convened. A report with conclusions and recommendations will be issued at the end of the study to provide guidance for improving the measurement of these aspects of the modern economy, as well as a rapporteur-authored proceedings of the workshop.

Meeting Dates

Meeting 1

Friday, March 29, 2019 (9:00 AM - 3:00 PM)
The Keck Center of the National Academies
Conference Room 101 (Keck floor plan)
500 Fifth St. NW
Washington, DC 20001

Agenda

Staff

Chris Mackie, *Study Director*
Anthony Mann, *Program Associate*

Sponsors

U.S. Department of Labor
Bureau of Labor Statistics

Committee Members

Susan Houseman (Chair), *W.E. Upjohn Institute for Employment Research*
Katharine Abraham, *University of Maryland, College Park*
Annette Bernhardt, *University of California, Berkeley*
Jennifer Dykema, *University of Wisconsin-Madison*
Diana Farrell, *JPMorgan Chase Institute*
Arne Kalleberg, *University of North Carolina at Chapel Hill*
Kristen Olson, *University of Nebraska-Lincoln*
Barbara Robles, *Federal Reserve Board*
Michael Strain, *American Enterprise Institute*
David Weil, *Brandeis University*

Employee or Contractor: Recent Update

- **National Labor Relations Board—Advice Memorandum—April 16, 2019**
  - NLRB used 10 factors that collectively determine whether a worker is an employee or contractor
    - Animating principle—whether the worker had an opportunity to profit from the activity in same way an entrepreneur would.
    - NLRB takes a “permissive view” of entrepreneurship in that drivers cannot set prices or market their personal services to potential customers

- **U.S. Department of Labor—Wage and Hour Division Opinion Letter—April 29, 2019**
  - Under FLSA, workers connected to jobs via an *unnamed* app do not meet the definition of employee.
  - DOL/WHD used 6 factors to determine degree to which a worker is economically dependent on an employer.

- **WHD Joint employment status under FLSA**
  - NPRM—Comments due 10 June 2019
  - https://www.dol.gov/whd/flsa/jointemployment2019/joint-employment_faq.htm

Technologies

Theory of Robotics

- How a robot works is as follows:
  - The robot **senses**, the robot **thinks,** and the robot ***acts***…

- How?
  - **Sensing** is done through interpretation of data perceived by:
    - Environmental sensors for an embodied robotic device
    - Data inputs for a digital assistant.
  - **Thinking** is done through the use of forms of artificial intelligence or AI.
  - **Acting** is done through:
    - *Effectors* for embodied robots
    - *Control or decision* outputs for white collar robots

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**
  - 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.

Sensing

Sensor Technologies

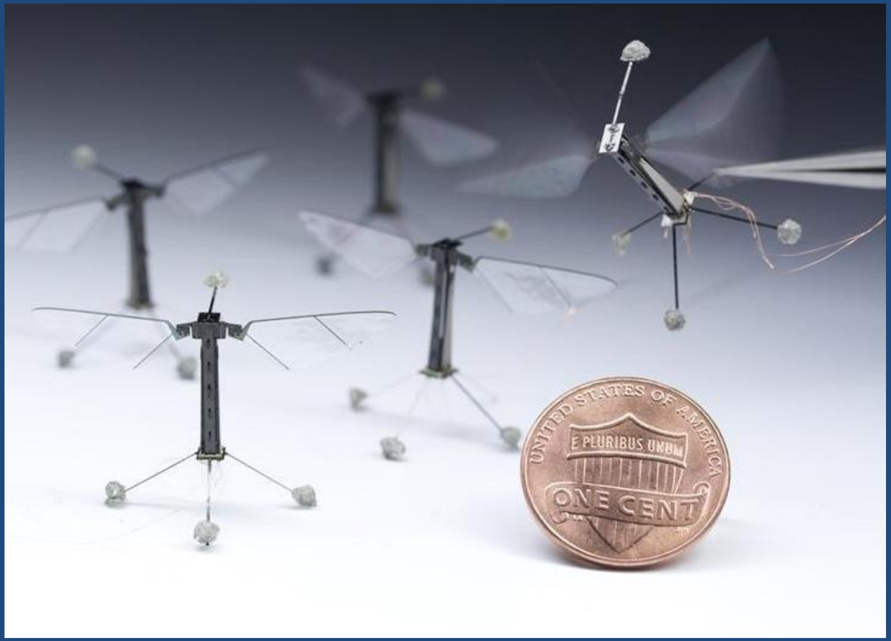
- **Enabling capabilities increasing exponentially because of improvements in:**
  - Types of exposures that can be measurement by a miniature sensor
  - Quality of geographic, proprioceptive, and environmental sensors
  - Miniaturization of environmental sensors for chemical/biological exposure assessment

- **Types of Intelligent Sensors—Using IoT and AI**
  - **Placeables**
    - Ground, air, water
    - In-vehicle monitors
  - **Wearables**
    - Clothing
    - Hard hats
  - **Implantables**
    - Ingested
    - Transcutaneous

Sensors Summit 2019
DECEMBER 10 - 12, 2019
HILTON SAN DIEGO RESORT & SPA
SAN DIEGO, CA

Insect-Inspired Robots

- 80-milligram flapping-wing robot modeled loosely on the morphology of flies (*Diptera*).
- Harvard School of Engineering and Applied Sciences (SEAS) and the Wyss Institute for Biologically Inspired Engineering at Harvard.
- Nano-enabled with sensors and cameras?

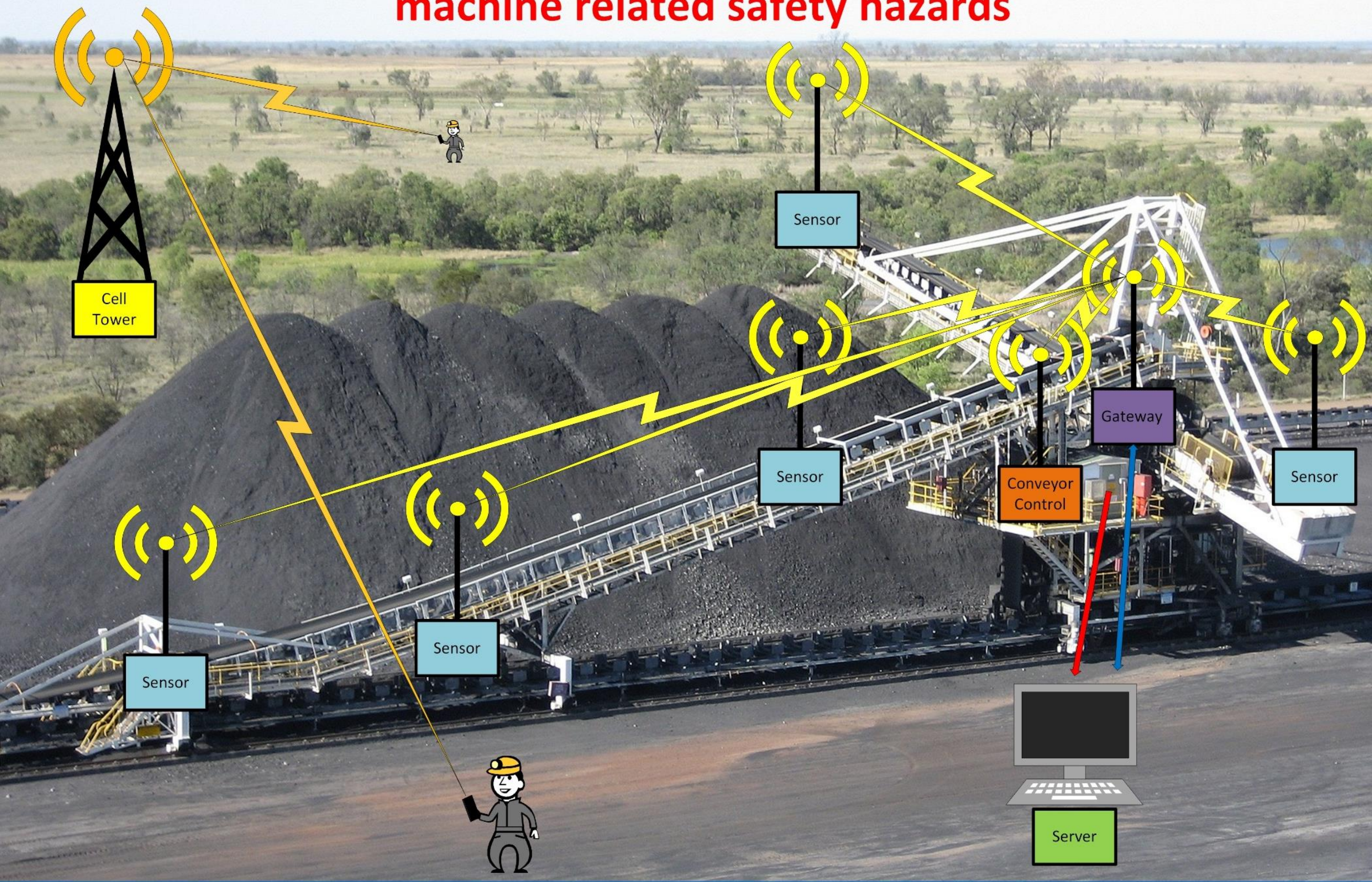


- Ma KY et al. *Science* 2013;340:603-607

Internet of Things (IoT)

- **OMO (online-merge-of-offline)**
  - Combining of our digital and physical worlds such that every object in our surrounding environment will become an data input for the Internet
- **Sensors are at the heart of the *Industrial Internet***
  - Deploying sensors, entire workplace and everyone in it become data input sources.
  - Workplace sensors become intelligent assets operating in physical <u>and</u> virtual space.
- **Sensor improvements can be easily uploaded to the cloud**
  - Immediate and universal sensor connectivity
  - Universal sensor upgradability
- **Cloud-based sensor data inputs**
  - Occupational data analytics
  - Use of AI to support risk decision making
  - Occupational professional as decision scientists

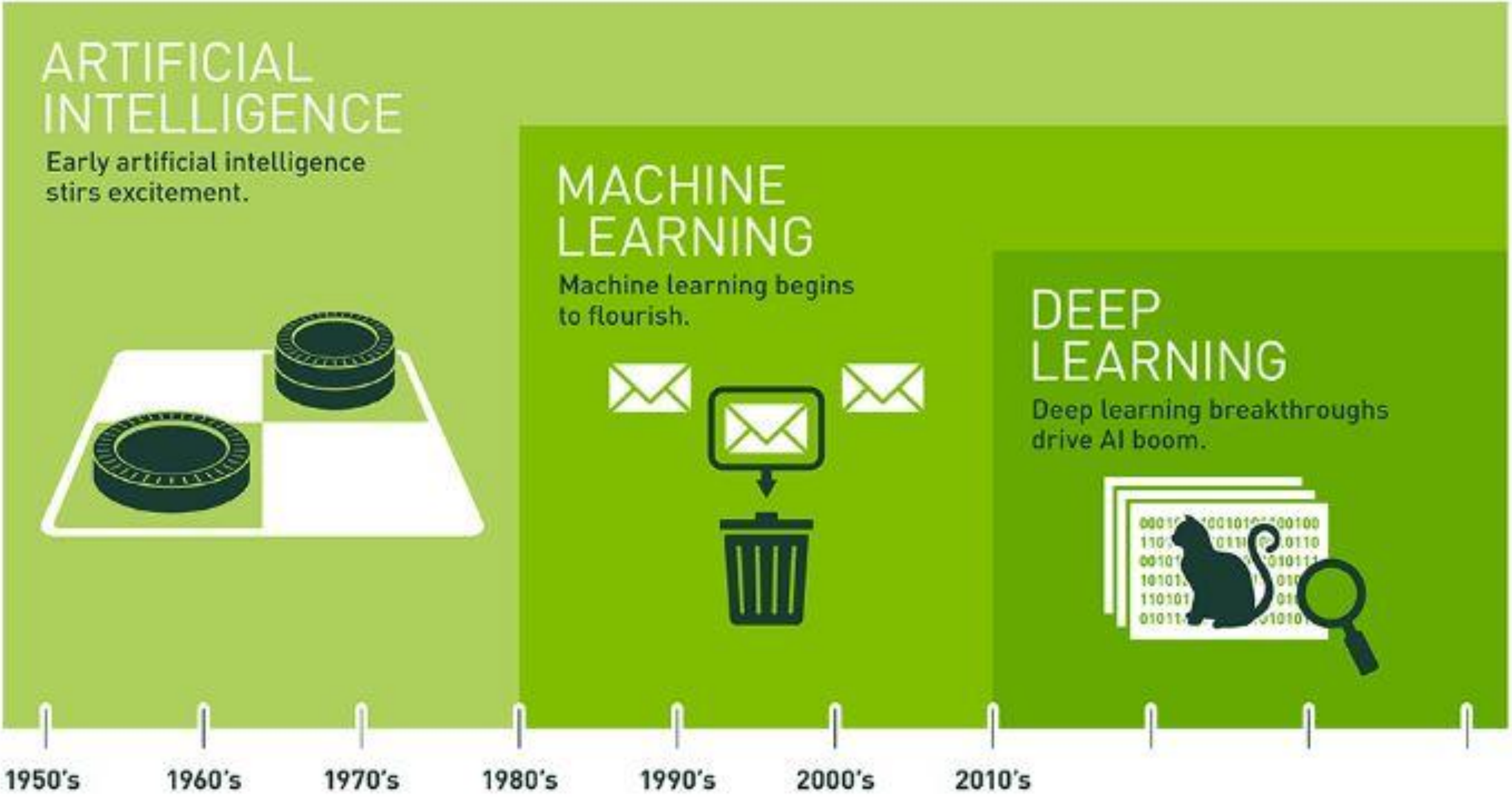
Application of Internet of Things Technology to detect and mitigate machine related safety hazards



Advanced Fabrics—Wearable Sensors

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

Thinking


ARTIFICIAL INTELLIGENCE
Early artificial intelligence stirs excitement.
MACHINE LEARNING
Machine learning begins to flourish.
DEEP LEARNING
Deep learning breakthroughs drive AI boom.
1950's
1960's
1970's
1980's
1990's
2000's
2010's

Artificial Intelligence

- **Central idea**
  - You can represent reality by using a mathematical function that an algorithm (stepwise procedure) does not know in advance, but which it can guess after seeing some data, recursively accuracy of the probability guess.

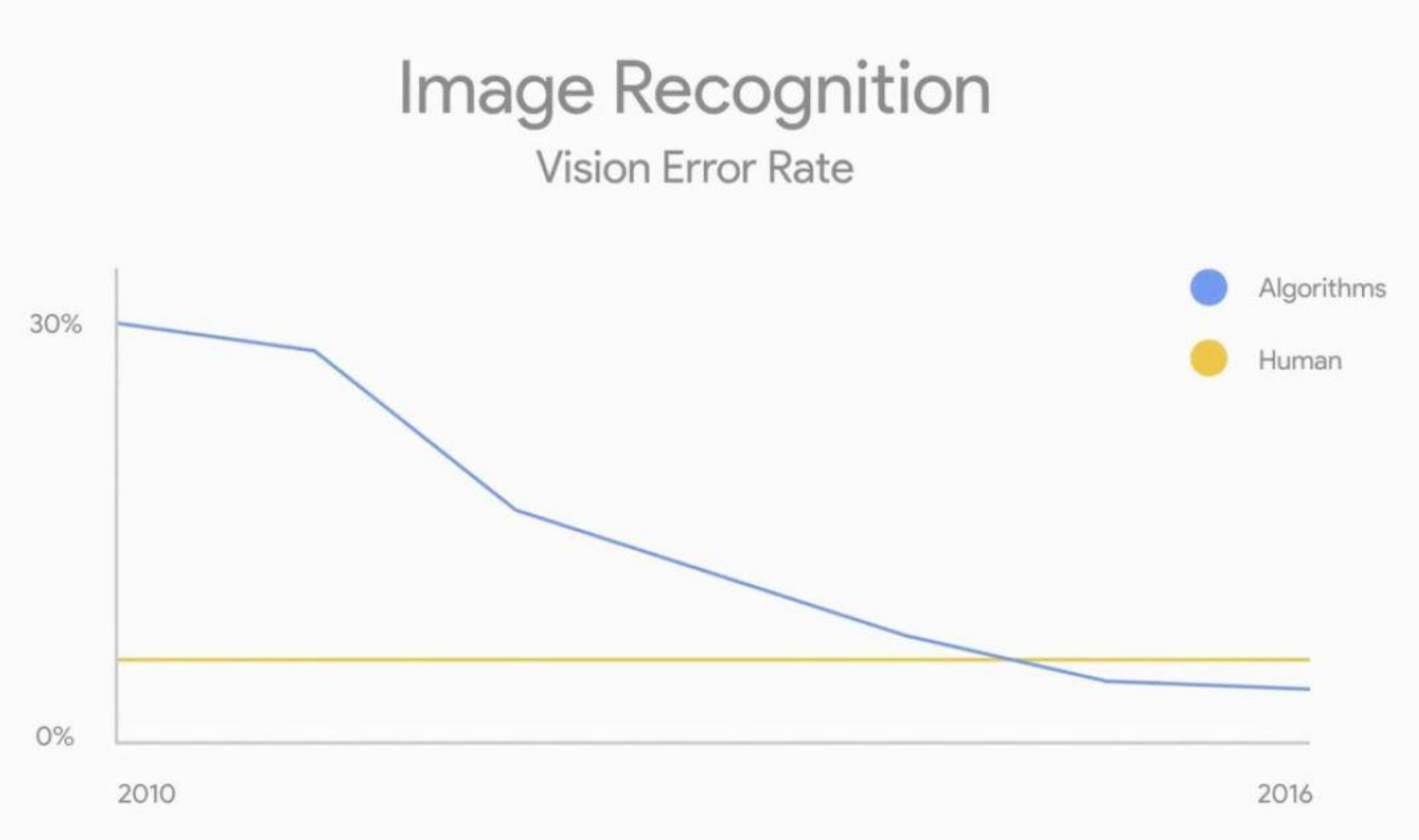
- **Origin**
  - 1956 Dartmouth College workshop computer scientists predicted that machines that could reason as well as humans would require, at most, a generation to come about. We think of this as "General AI."
  - They were wrong and several AI winters followed. And then in 2010s, AI exploded because of the wide availability:
    - **GPUs** that make parallel processing ever faster, cheaper, and more powerful
    - Practically infinite **storage capacity**
    - Flood of data (***big data***)

What is Artificial Intelligence?

- Oxford Dictionary defines AI as "the theory and development of computer systems able to perform tasks normally requiring human intelligence."
- Joke among computer scientists that AI defines what machines cannot yet do.
  - Before a machine could beat a human at chess, such a win would mean AI.
  - After IBM's Deep Blue beat Gary Kasparov, playing chess was called computer science.
  - Beating a human at game of Go 圍棋) was AI; after Lee Sedol (2016) and Ke Jie (2017) were beaten by Google's AlphaGo, it was just computer science.

AI vs Human Image Error Recognition Rates

Brynjolfsson et al. 2019

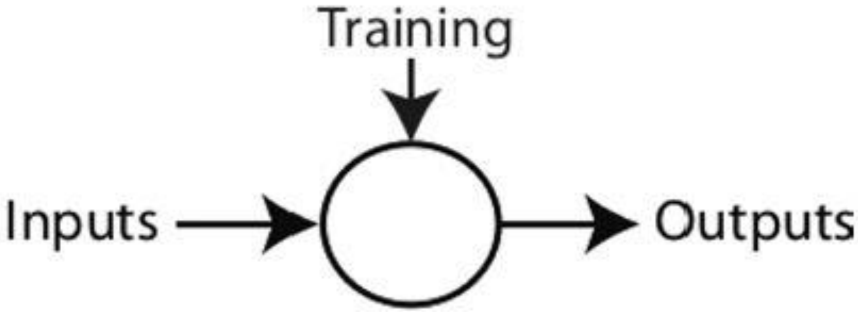


Machine Learning

- Machine learning is the most important subfield of AI.
- Goal is to enable computers to learn from experience to improve their ability to think, plan, decide and act.
- Machine-learning technology powers many aspects of modern society:
  - From web searches to content filtering on social networks to recommendations on e-commerce websites; natural language processing and computer vision
  - Increasingly present in consumer products, such as cameras, smartphones.

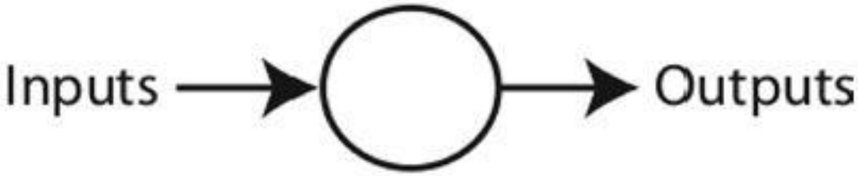
Supervised learning

Learns known patterns
Takes labeled input data
Predicts outcome/future



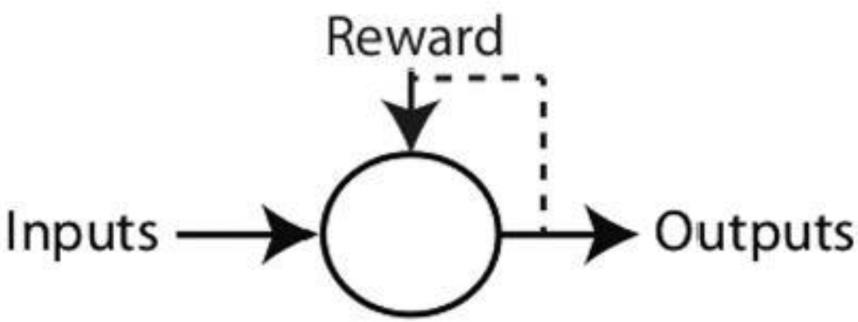
Unsupervised learning

Learns unknown patterns
Takes unlabeled input data
Finds hidden patterns



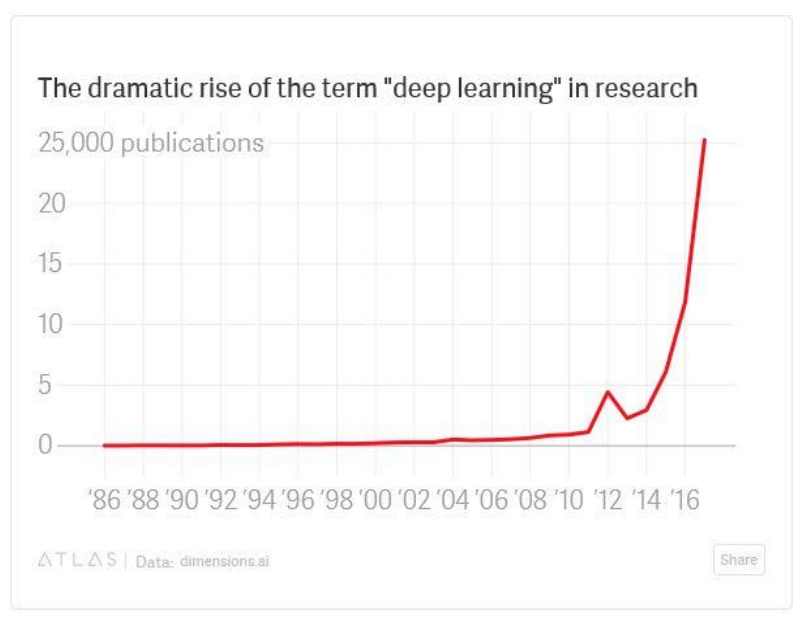
Reinforcement learning

Generates data
Takes labeled input data
Interacts with environment
Learns series of actions



Deep Neural Networks

- Human learning occurs by modifications of synapses between neurons based on stimuli received by trial and error experience.
- Neural networks provide a way to replicate this process:
  - Neural networks have different layers, each one having its own **weights.**
  - Uses a mathematical method called *backpropagation*—correction—weights can be changed to limit the “loss function.”
  - N*eural network* is asked to solve a problem, which it attempts to do over and over, each time strengthening the connections that lead to success and diminishing those that lead to failure, i.e., the loss function.



U.S. Government and AI

– https://www.whitehouse.gov/ai/

U.S. Government: AI Lockdown

- 0n 19 November 2018, the U.S. Department of Commerce proposed new restrictions on the export of AI technologies, including neural networks and deep learning, natural language processing, computer vision, and expert systems. *See* https://www.gpo.gov/fdsys/pkg/FR-2018-11-19/pdf/2018-25221.pdf

- ***Representative Technology Categories***
  - Artificial intelligence (AI) and machine learning technology, such as:
    - Neural networks and deep learning
    - Computer vision (*e.g.,* object recognition, image understanding);
    - Expert systems (*e.g.,* decision support systems, teaching systems);
    - Speech and audio processing (*e.g.,* speech recognition and production); and
    - Natural language processing (*e.g.,* machine translation).
  - AI cloud technologies; and
  - Quantum information and sensing technology (among others).

Acting

Occupational Robotics

- Commercial Types:
  - In ***physical*** space
    - Industrial robots
    - Collaborative robots
    - Service robots
    - Social Robots
    - Industrial Exoskeletons
    - Mars Rover *Curiosity*
  - In ***digital*** space
    - Control systems
    - Decision support systems

Traditional Industrial Robots

- Decades of safety experience
- Used since the 1970s in auto manufacturing industry
- Safety measures that keep human workers ***separated*** from robot workers is standard

Collaborative Robots (Cobots)

Collaborative Robots: Challenge

- 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.

- ***Grasping*** a previously unknown object, one for which a 3-D model is not available, is the biggest challenge.
  - https://berkeleyautomation.github.io/dex-net/

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

Service Cobots

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

Service Robots: Autonomous Ground Vehicles Mining

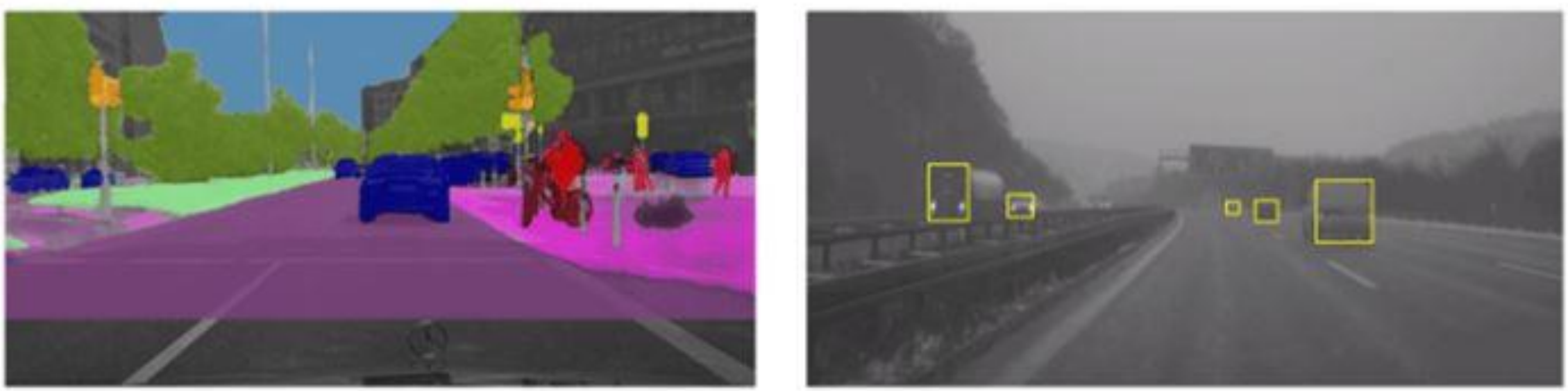
- Service robots used by Rio Tinto in Pilbara, Western Australia
  - No coffee breaks, fatigue and driver changeovers.
  - Stops only once a day for refueling.
- Autonomy enables drilling to run for almost a third longer on average than with manned rigs, and to churn through 10% more ground meters/hour.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

Self-Driving Vehicle Challenge

Computer Vision

- Self-driving cars rely on deep learning for visual tasks like understanding road signs, detecting lanes and recognizing obstacles.

- That's the value of AI deep learning; it can learn, *adapt*, and improve—distinguishing a pedestrian from a shadow.

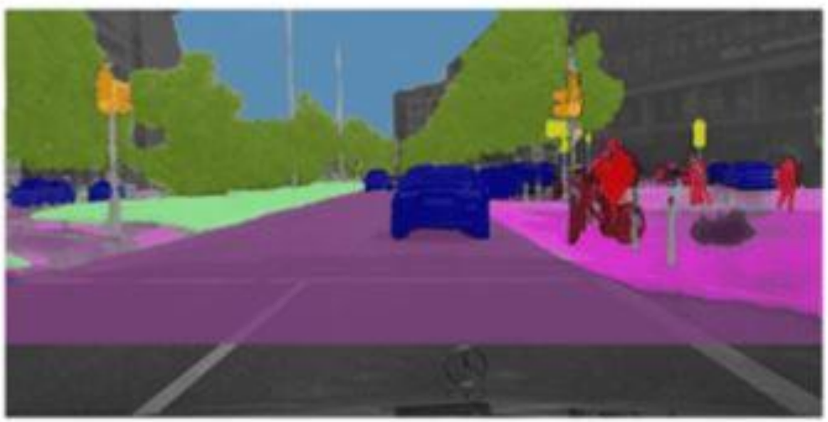


Daimler was able to bring "the vehicle's environment perception a significant step closer to human performance and exceed the performance of classic computer vision" with NVIDIA DriveNet.

Using a dataset from our partner Audi, NVIDIA engineers rapidly trained NVIDIA DriveNet to detect vehicles in an extremely difficult environment – snow.

Self-Driving Challenge: Computer Vision

- You cannot write algorithms that anticipates every possible scenario a self-driving car might encounter.
- That's the value of deep learning; it can learn, adapt, and improve. Science is building an end-to-end deep learning platform called NVIDIA DRIVE PX for self-driving cars — from the training system to the in-car AI computer.



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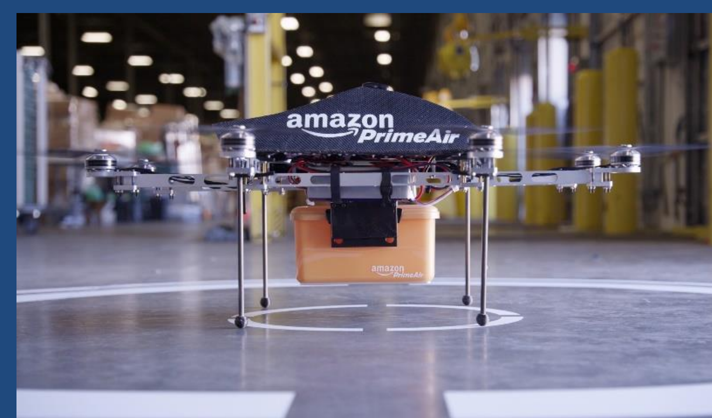
Service Robots

Unmanned Aerial Vehicles

Military

Recreational

Public



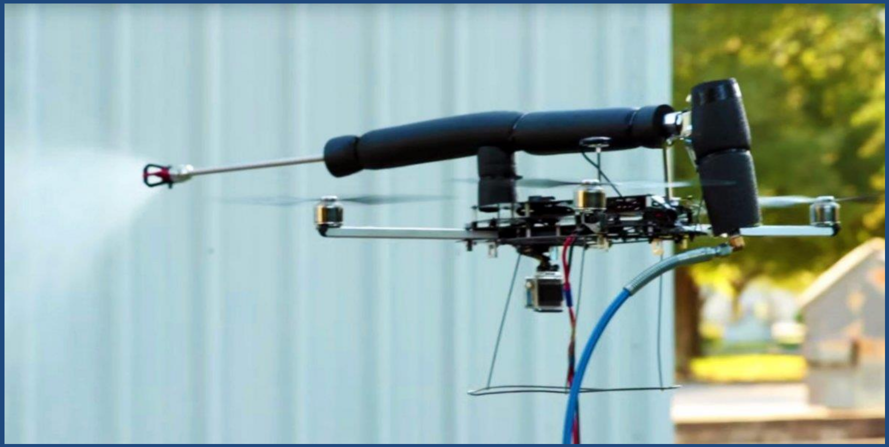
Commercial

UAVs Uses in Construction

Monitoring

Inspection

Maintenance



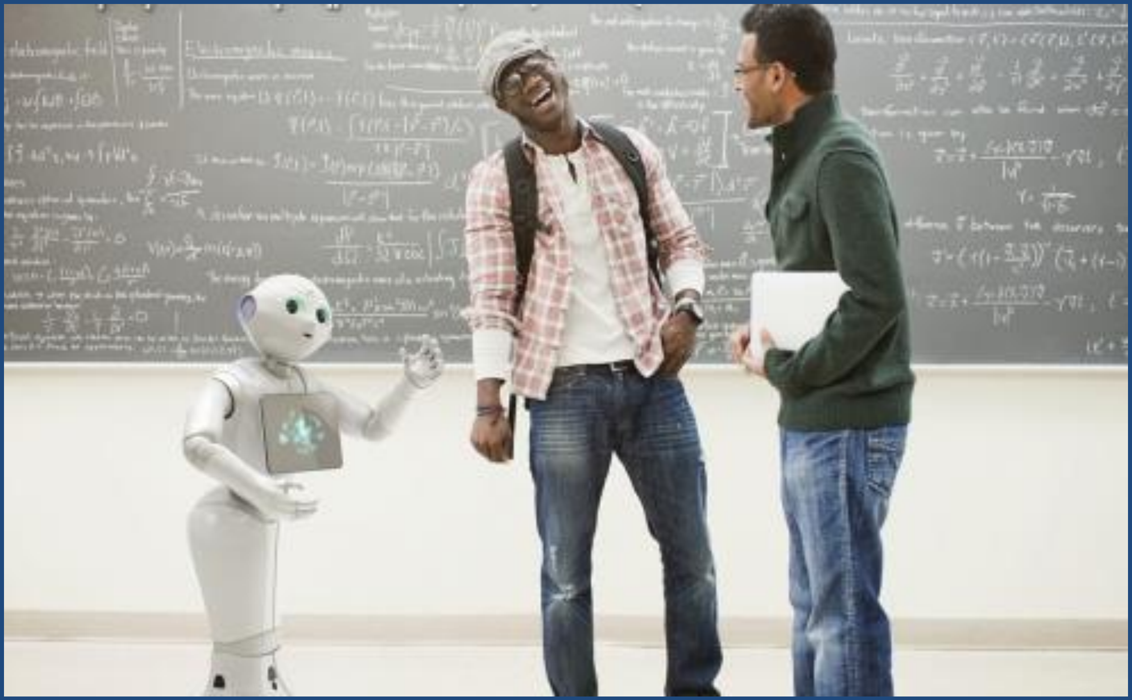
Hazardous Applications

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

Social 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.



Exoskeleton Robotics

- **Definition**
  - Wearable device that augments, enables, assists, and/or enhances physical activity through mechanical interaction with the body.
- **Return-on-Investment**
  - Injury savings
  - Productivity gains
  - Quality gains
- **Domains**
  - **Medical**
    - Enable paraplegics, amputees, and others to walk
  - **Military**
    - Weight reduction for fit soldiers is a crucial application
  - **Commercial**
    - Ski exoskeletons
  - **Industrial**
    - Manufacturing, construction, agriculture, healthcare

Safety Benefits and Risks

<u>Potential</u>

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

<u>Concerns</u>

- Likely increase in robot-related human injuries
  - New varieties of MSDs
- New types of robots will require refined and new protection strategies
  - Robot with *dynamic* machine learning capabilities can challenge *static* safety procedures
- Rapid advances in technology will outpace guidance/standards setting
- Stress associated with changing workplace and potential for human worker displacement

Accountability in Human-Robot Interaction

- **Theory**
  - Automated systems will help humans to their jobs better
  - While systems will be automated, keeping a “human in the loop” assures that human judgment will ***always*** be able to trump an automated system
  - Collaboration with be fluid and control shared seamlessly

- **Practice**
  - Dynamics of shared control are complex—there are phase delays
  - Mishaps occur because of human—machine struggles for control
    - Air France Flight 447
  - Common belief is that automated systems have no fault in mishaps despite human factors research showing that “humans have always been inept at leaping last minute into emergency situations with a level head and clear mind.”
  - “Moral crumple zone” protects the robotic system at expense of nearest human operator
    - https://datasociety.net/output/moral-crumple-zones-cautionary-tales-in-human-robot-interaction

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.

Theory of Intelligent Digital Robots

Sensors → Data Inputs

Thinking → Artificial Intelligence

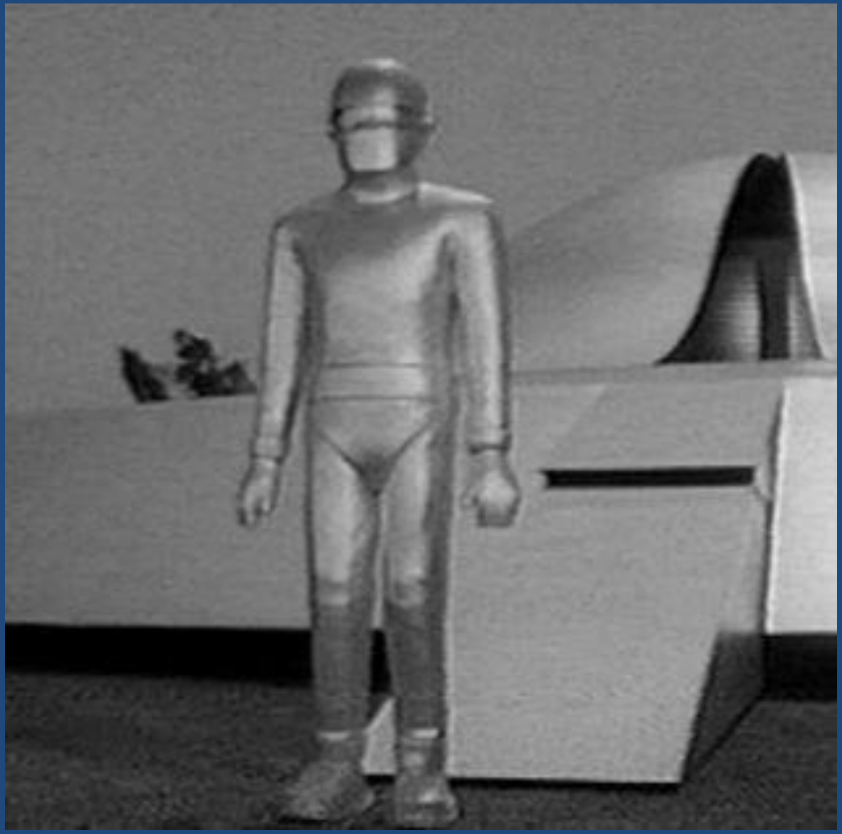
Acting → Control or Decision Support Systems

White Collar Robots

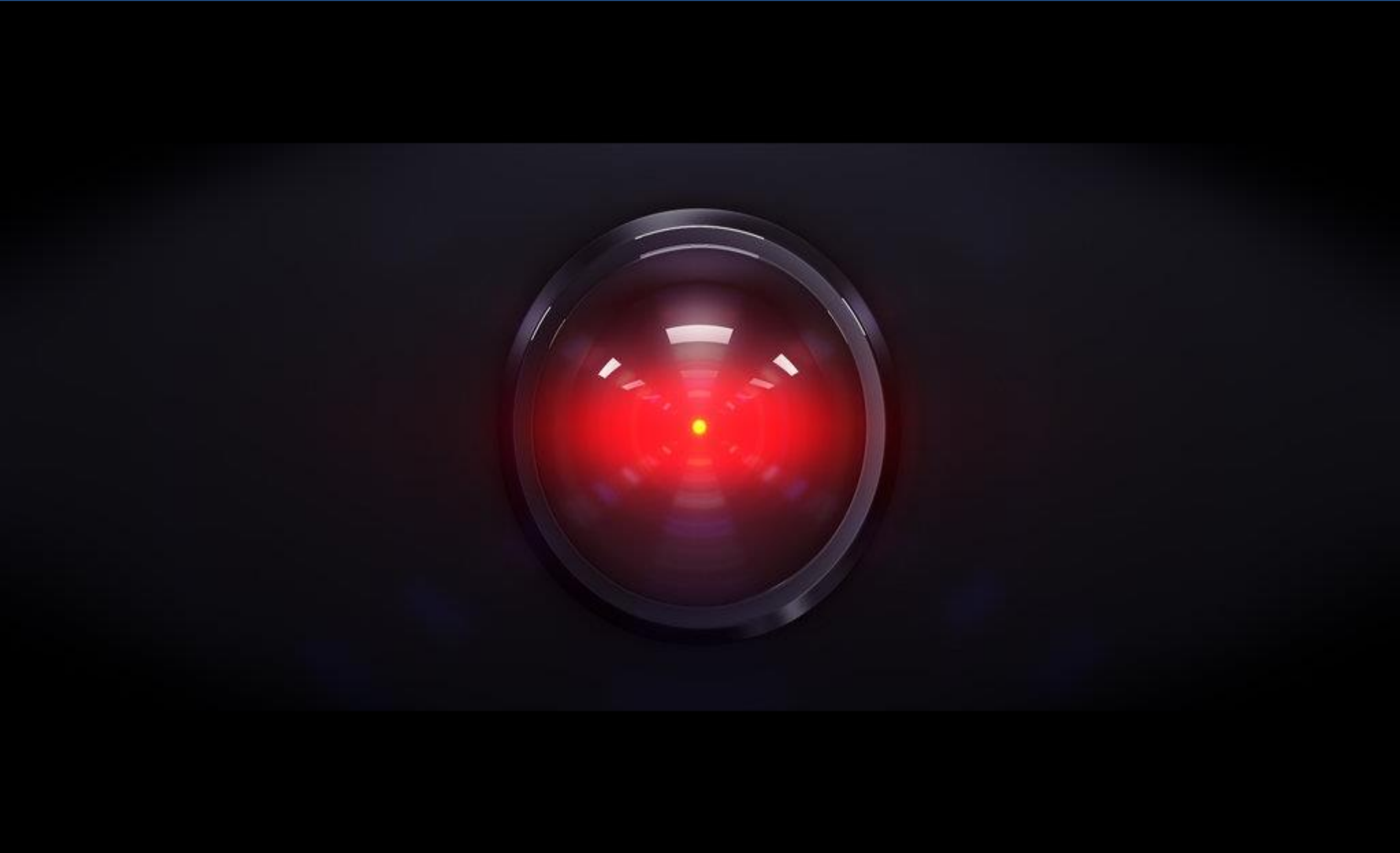
- Amelia
  - Works at Swedish Bank SEB and Zurich for UBS and speaks 20 languages
  - Handles thousands of call simultaneous
  - Can memorize a 300 page manual in 30 seconds
- Advantages
  - Cheaper than humans
  - Leaves digital trail that make reporting for regulatory compliance faster/surer
- Other WCRs
  - Erica—Bank of America
  - IBM—Suite of Watsons
  - Einstein—Salesforce
  - Nia—Infosys
  - Microsoft—Cortana
  - Amazon—Alexa

AI-Enabled Safety Management

- Aid in determining choices under conditions of uncertainty.
- Assist in recognizing a near-misses.
- Offer more accurate risk mitigation recommendations than humans.
- Take control to prevent human actions that may create safety and health hazards.
- Pictured—*Gort* (1951)
  - Member of interstellar police force, holding irrevocable powers to "preserve the peace" by destroying any aggressor.
  - *"The Day the Earth Stood Still"* 1951 Movie
  - "***Klaatu barada nikto***"



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

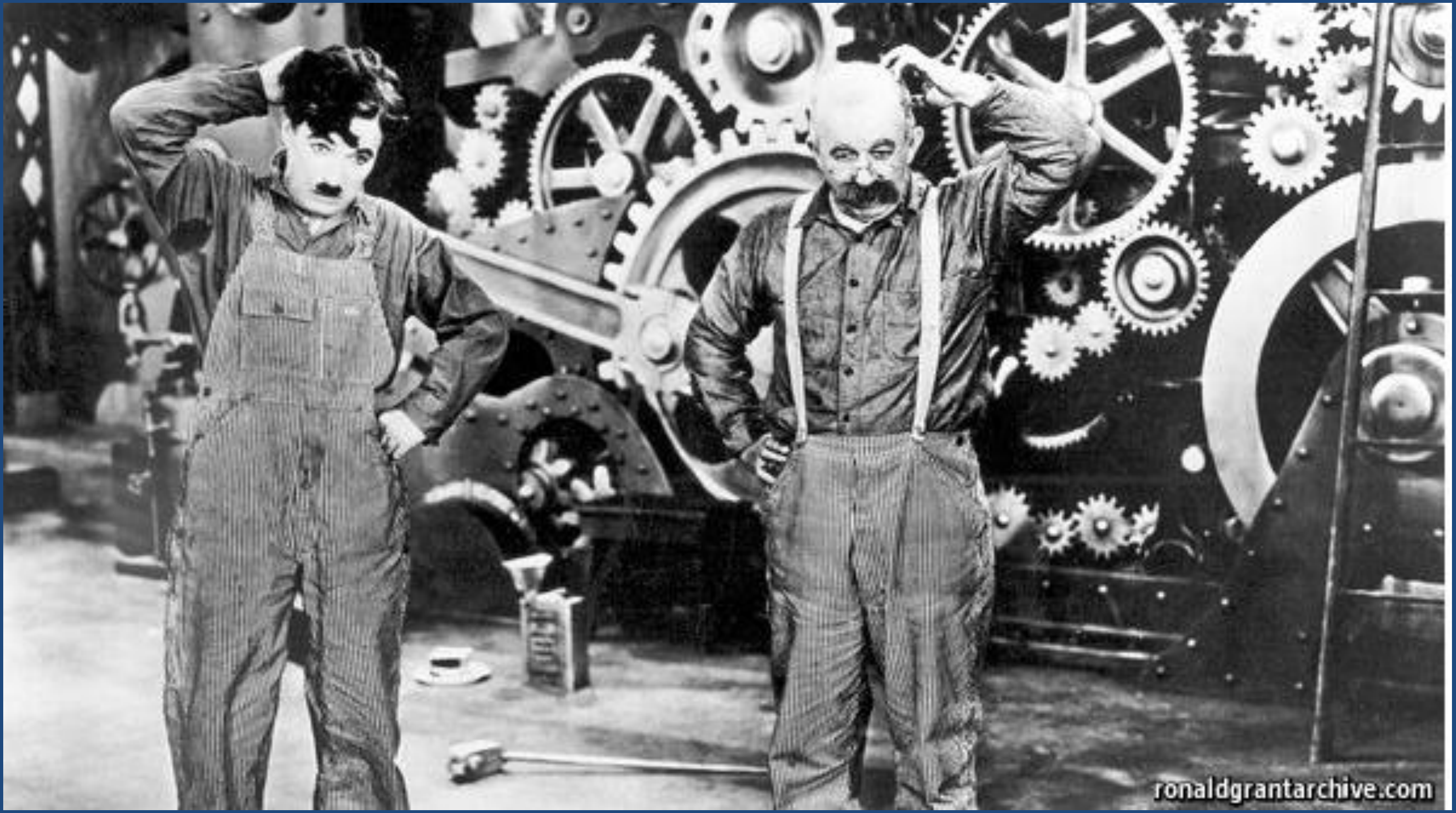


“An unprecedented jobs boom”

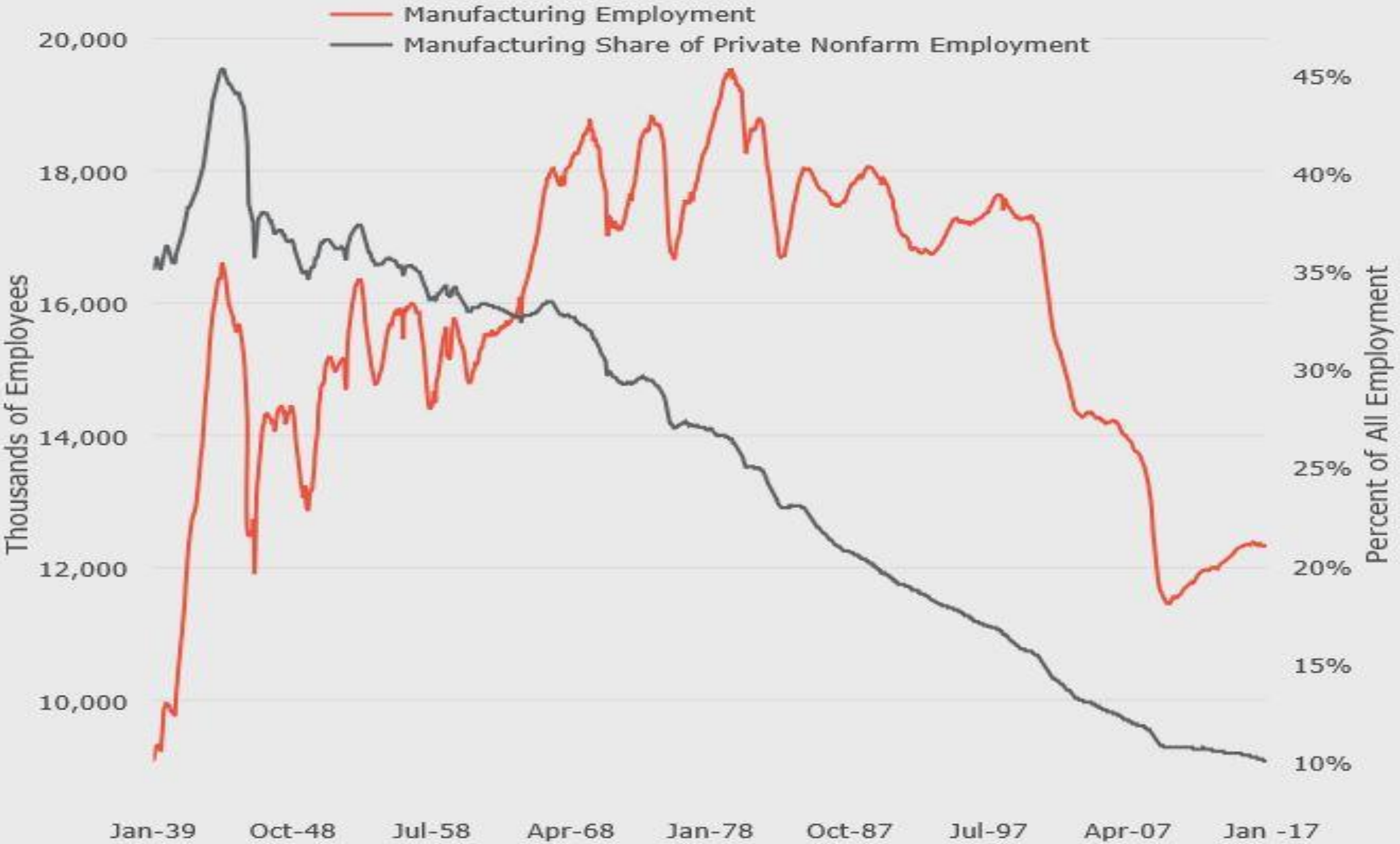
Economist May25th-31st, 2019

- “In manufacturing, machines have replaced workers over a period of decades. This seems to have contributed to a pocket of persistent joblessness among American men.”

The Special Case of Manufacturing



Manufacturing Employment Trends, 1939-2016



Source: Current Employment Statistics.

Manufacturing Jobs

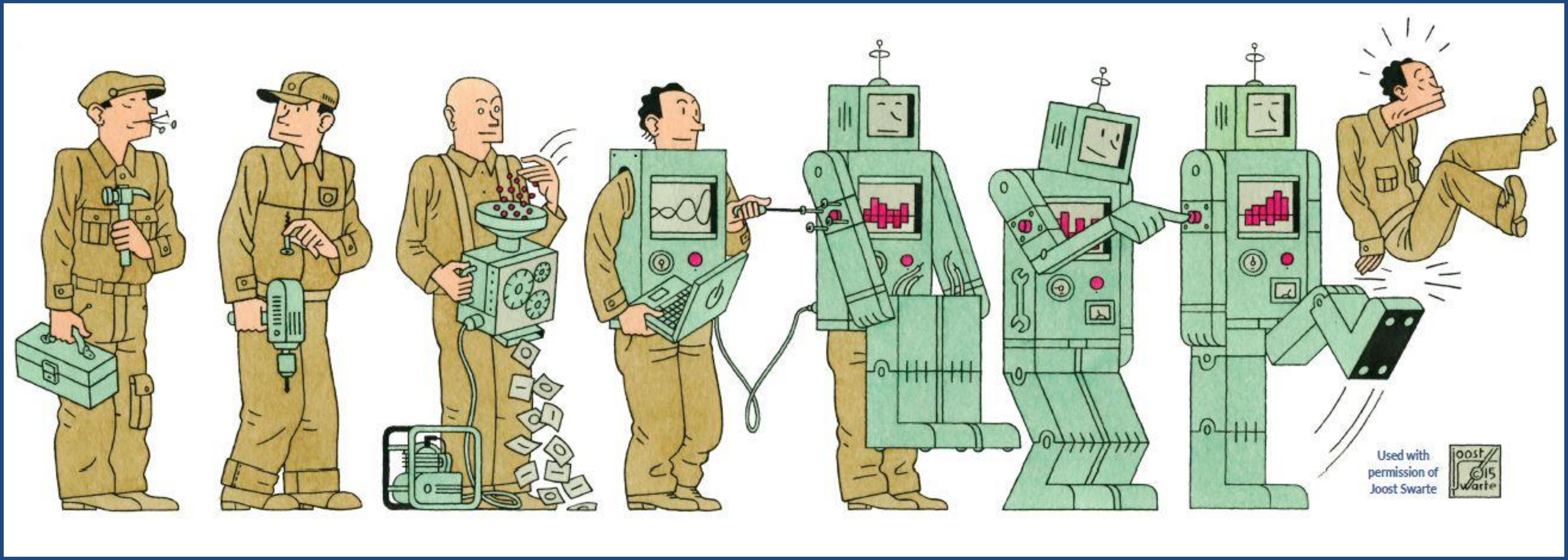
- **Total employment**
  - Sharp decline in total manufacturing employment from 17.2M in 1999 to 12.3M in 2016.

- **Job Density**
  - Manufacturing job density—the number of jobs per process—is declining.
  - In 1980, it took 25 jobs to generate $1 million in manufacturing output in the U.S. Today, it takes five jobs.

- What is causing the drop in manufacturing employment—is it technology or is it trade?

It’s Technology

- **Technology (Robotic Automation)**
  - Brynjolfsson, *Race Against the Machine and Second Machine Age*
  - If the trend toward the automation of routine jobs in manufacturing continues, the application of new technologies is likely to do much more to boost growth in value added than to expand employment on the factory floor.
    - Autor & Dorn (2013). The Growth of Low Skill Service Jobs and the Polarization of the US Labor Market. *American Economic Review*, 103(5), 1553-1597.



It’s Trade

- **Trade (China)**
  - Between 1990 and 2011 the share of global manufacturing exports originating in China surged from 2% to 16% (Hanson, 2012). Intensifying import competition from China means a reduction in demand for goods U.S. manufacturers produce and a corresponding contraction in the number of workers they employ.
    - Autor, Dorn & Hanson (2013). The China Syndrome: Local Labor Market Effects of Import Competition in the United States. *American Economic Review,* 103(6): 2121–2168.

Job Displacement Estimates

Between Big and Enormous

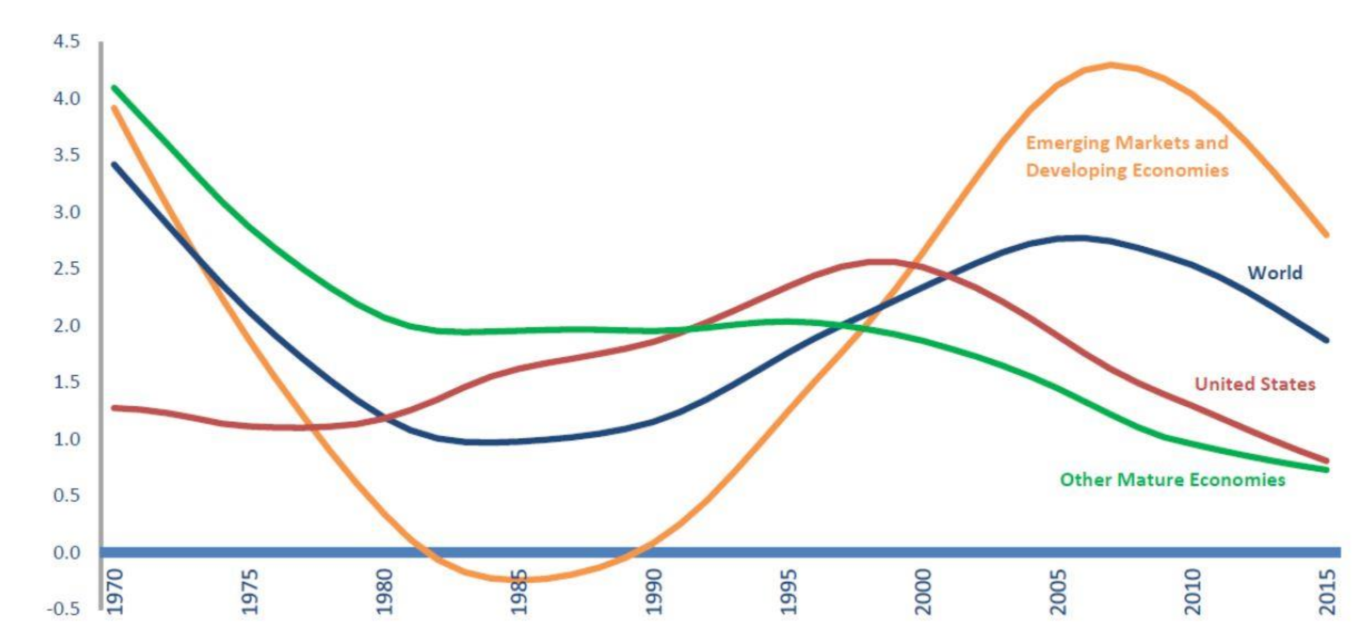
Organization	Estimates
University of Oxford	47% of workers in America at high risk of jobs replaced by automation
PricewaterhouseCoopers	38% of jobs in America, 30% of jobs in UK, 21% in Japan and 35% in Germany at risk to automation
ILO	ASEAN-5: 56% of jobs at risk to automation in next 20 years
McKinsey	60% of all occupations have at least 30% technically automatable activities
OECD	OECD average: 9% of jobs at high risk. Low risk of complete automation but an important share (between 50% - 70%) of automatable tasks at risk
Roland Berger	Western Europe: 8.3m jobs lost in industry against 10m new jobs created in services by 2035.
World Bank	2/3 of all jobs in developing countries are susceptible to automation.
Bruegel	EU countries: between 47% and 54% of jobs are risk of automation

Source: Frey and Osborne (2015); Roland Berger (2016); McKinsey Global Institute (2016); PwC (2017); World Bank (2016); Chang and Huynh (2016); Bowles (2014) and Bruegel Blog (2014)

Substitute or Complement?

- In the workplace, robotic device/system can perform:
  - The entire job of a human worker:
    - The robot acts as a ***substitute*** for a human worker.
  - Assist a human worker to perform a task of a job:
    - The robot acts as a ***complement*** to a human worker.

Optimism vs Productivity Stats



Source: The Conference Board Total Economy Database™ (Adjusted version), November 2016.
Notes: Trend growth rates are obtained using HP filter, assuming a l=100.

- **False Hopes**
  - Timeline has been exaggerated
- **Mismeasurement**
  - Technology benefits not reflected in GDP because there is no way to count them
- **Concentrated Distribution**
  - Benefits enjoyed only by a small fraction
- **Implementation Lag**
  - Deployment of General Purpose Technology is always slow

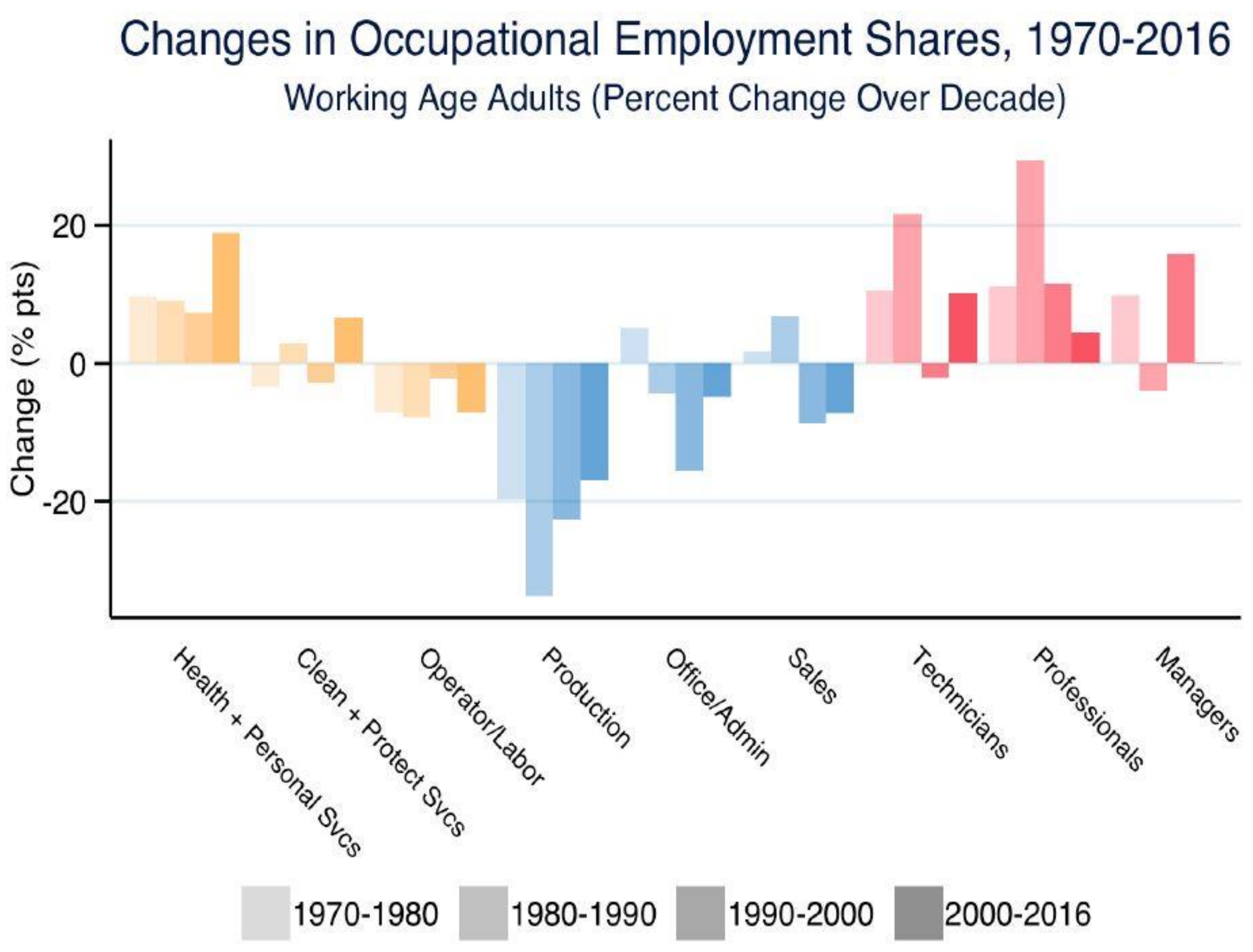
Could Automation Predictions Be Wrong?

Cass, *The Once and Future Worker*, 2018

- **Magnification Error**
  - Magnifies current innovations while taking for granted equally fundamental past innovations like steam, electricity, Internet.
- **Overstates Diffusion Rate**
  - Predictions ignore the gradual timeline on which transformations usually occur. Deployment of new technology is always slow.
- **Complement Over Substitution**
  - Technology often makes incremental improvements to a worker's productivity leading to higher quality output rather than to lower demand for her work. Substitute versus complement. An abstract description rarely captures the full complexity of any job.
- **Ignoring Reality**
  - Dire predictions ignore the positive. E-commerce is creating new jobs faster than retail is destroying them.

Occupational Polarization

Autor, D (2019), "Work of the Past, Work of the Future", NBER working paper 25588



Key Observation — Polarization of Work

High skill jobs

- **Rising** employment in professional, technical and managerial work

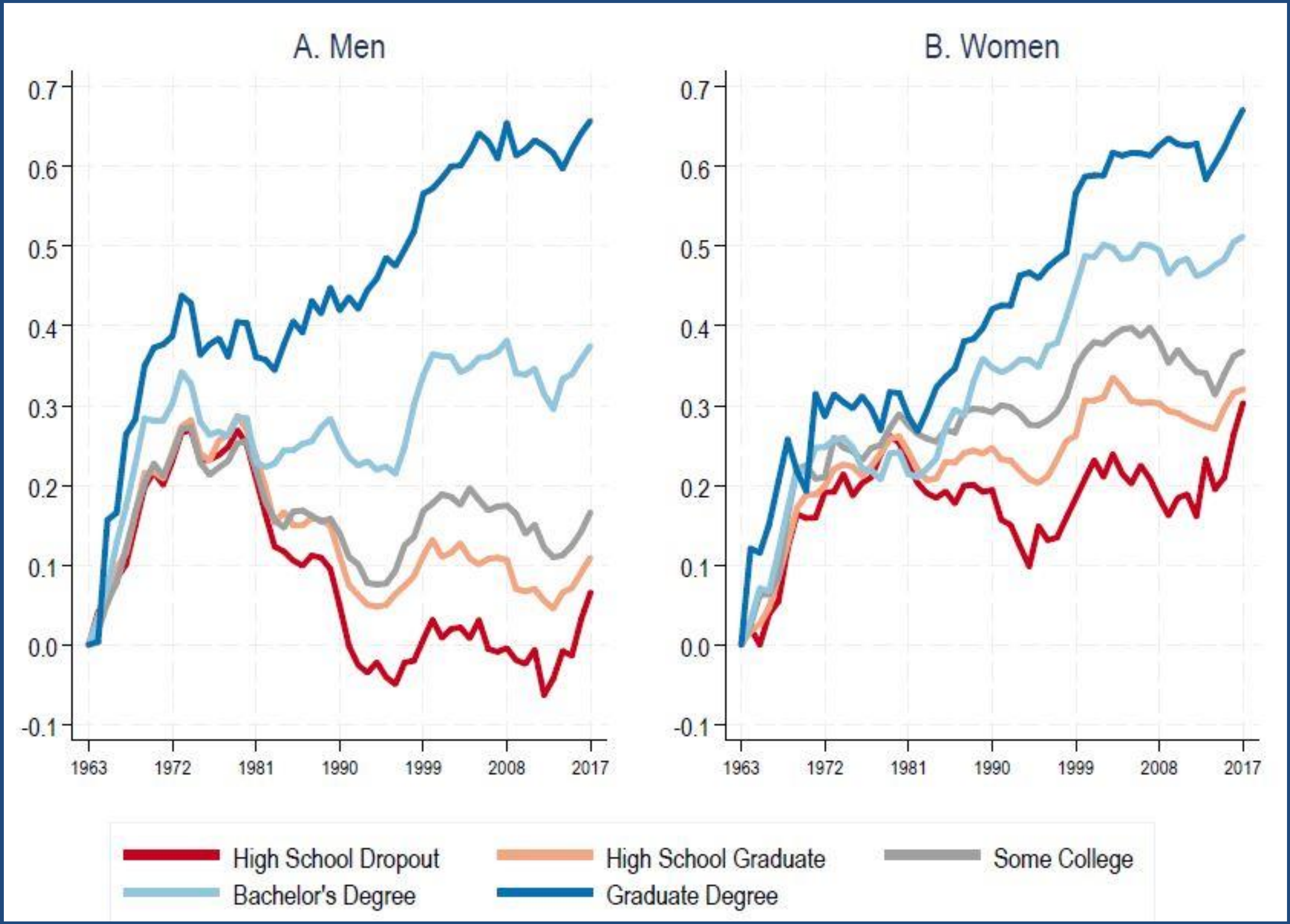
Low skill jobs

- **Rising** employment in personal services — Cleaning, security, recreation, health aides

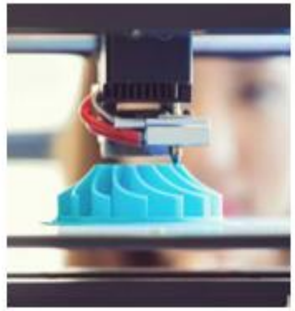
Mid skill jobs

- **Falling** employment in production work, office/clerical, and sales

Cumulative Change in Real Weekly Earnings Working Age Adults Ages 18-64, 1963-2017

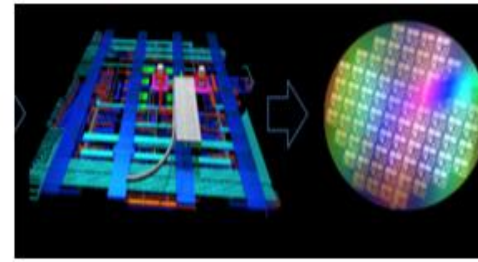


Additive Manufacturing



3D Printing

Functional Fabrics



Photonics

Advanced Manufacturing

Flexible Sensors

Robotics

Light Weighting

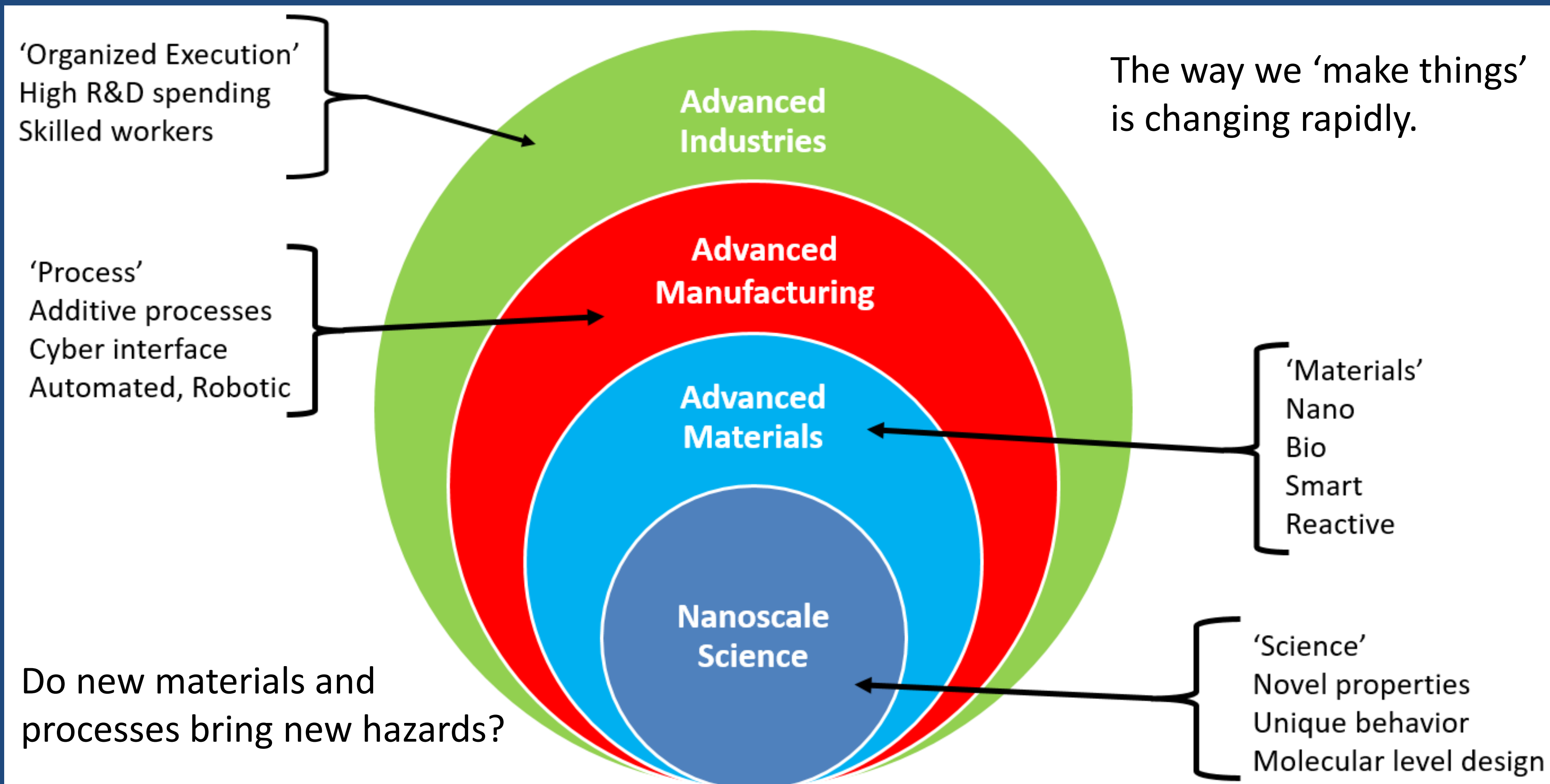
Advanced Composites

Clean Energy

Engineered Biology

Some processes and some products.

Advanced Manufacturing and Industry 4.0



The way we 'make things' is changing rapidly.

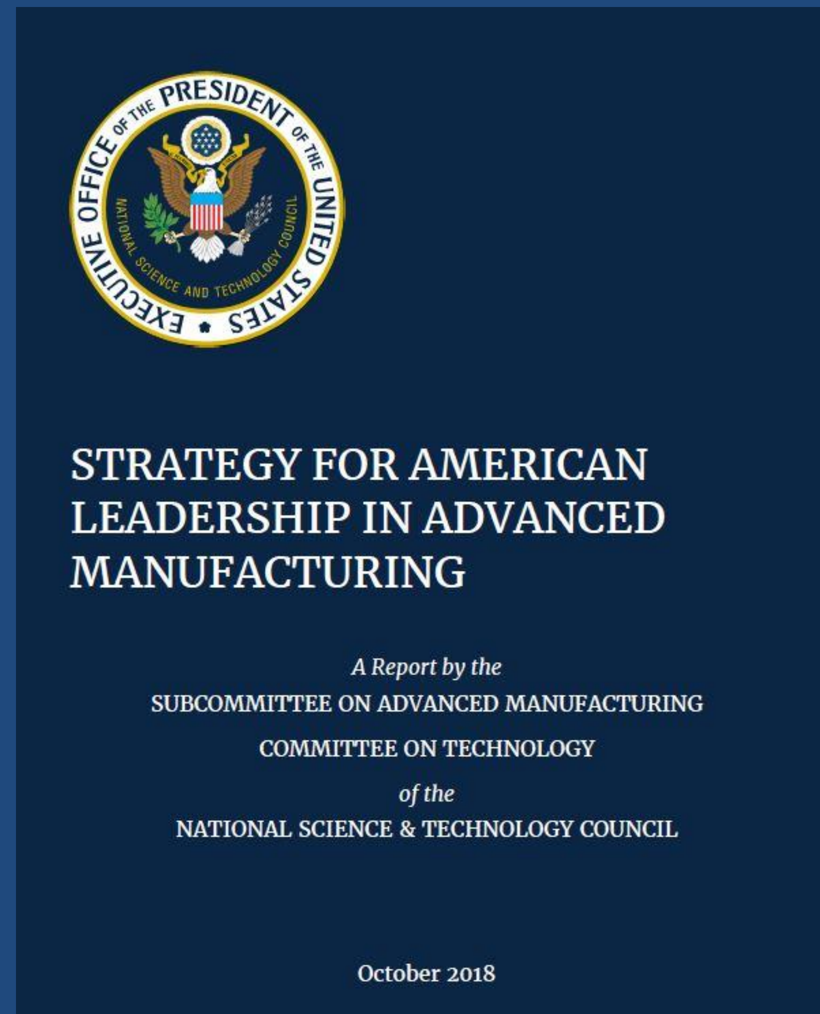
Do new materials and processes bring new hazards?

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?


STRATEGY FOR AMERICAN LEADERSHIP IN ADVANCED MANUFACTURING

A Report by the

SUBCOMMITTEE ON ADVANCED MANUFACTURING

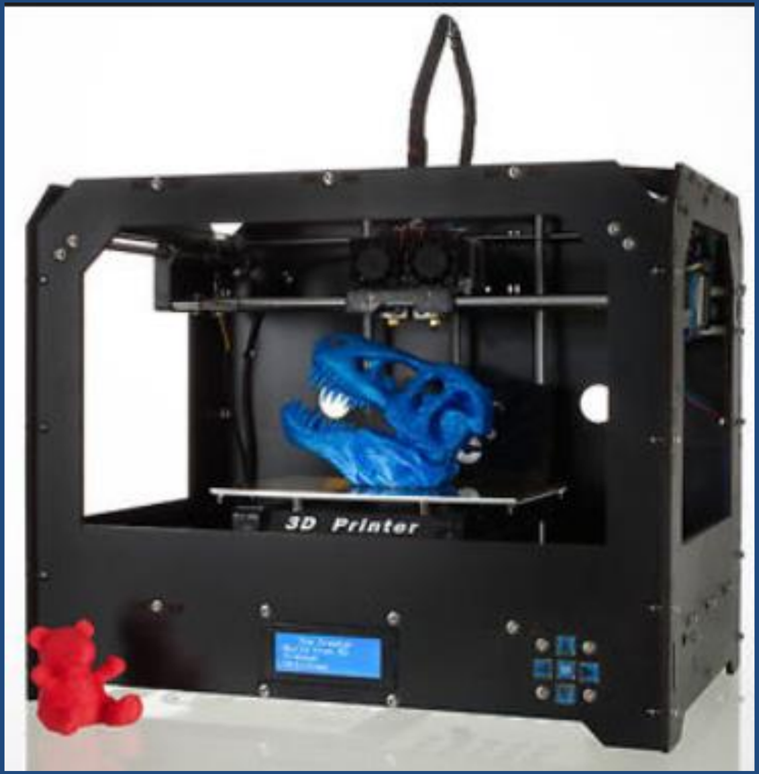
COMMITTEE ON TECHNOLOGY

of the

NATIONAL SCIENCE & TECHNOLOGY COUNCIL

October 2018

Desktop 3D Printing



- Devices are readily available
- Multiple polymer strands available
- Custom ‘at home’ strand compounding (DIY)
- Prices dropping, units getting larger

Industrial 3D Printing

Potential Hazards: Advanced Manufacturing

Roth et al. [2019] JOEH at https://www.tandfonline.com/doi/full/10.1080/15459624.2019.1591627

Category	Feedstock Materials	Feedstock Form	Binding/Fusing	Most Prominent Potential Hazards
Material extrusion	Thermoplastics (may include additives)	Spooled filament, pellet, or granulate	Electrical heating element-induced melting/cooling	Inhalation exposure to VOCs, particulate, additives; burns
Powder bed fusion	Metal, ceramic, or plastic	Powder	High-powered laser or electron beam heating	Inhalation/dermal exposure to powder, fume; explosion; laser/radiation exposure
Vat photopolymerization	Photopolymer	Liquid resin	Ultraviolet-laser induced curing	Inhalation of VOCs; dermal exposure to resins and solvents, ultraviolet exposure
Material jetting	Material jetting Photopolymer or wax	Liquid ink	Ultraviolet-light induced curing	Inhalation of VOCs; dermal exposure to resins and solvents, ultraviolet exposure
Binder jetting	Metal, ceramic, plastic, or sand	Powder	Adhesive	Inhalation/dermal exposure to powder; explosion; inhalation of VOCs, dermal exposure to binders
Sheet lamination	Metal, ceramic, or plastic	Rolled film or sheet	Adhesive or ultrasonic welding	Inhalation of fumes, VOCs; shock, laser/radiation exposure
Directed energy deposition	Metal	Powder or wire	Laser/electron beam heating	Inhalation/dermal exposure to powder, fume; explosion; laser/radiation exposure

Example: 3D Rocket Printing

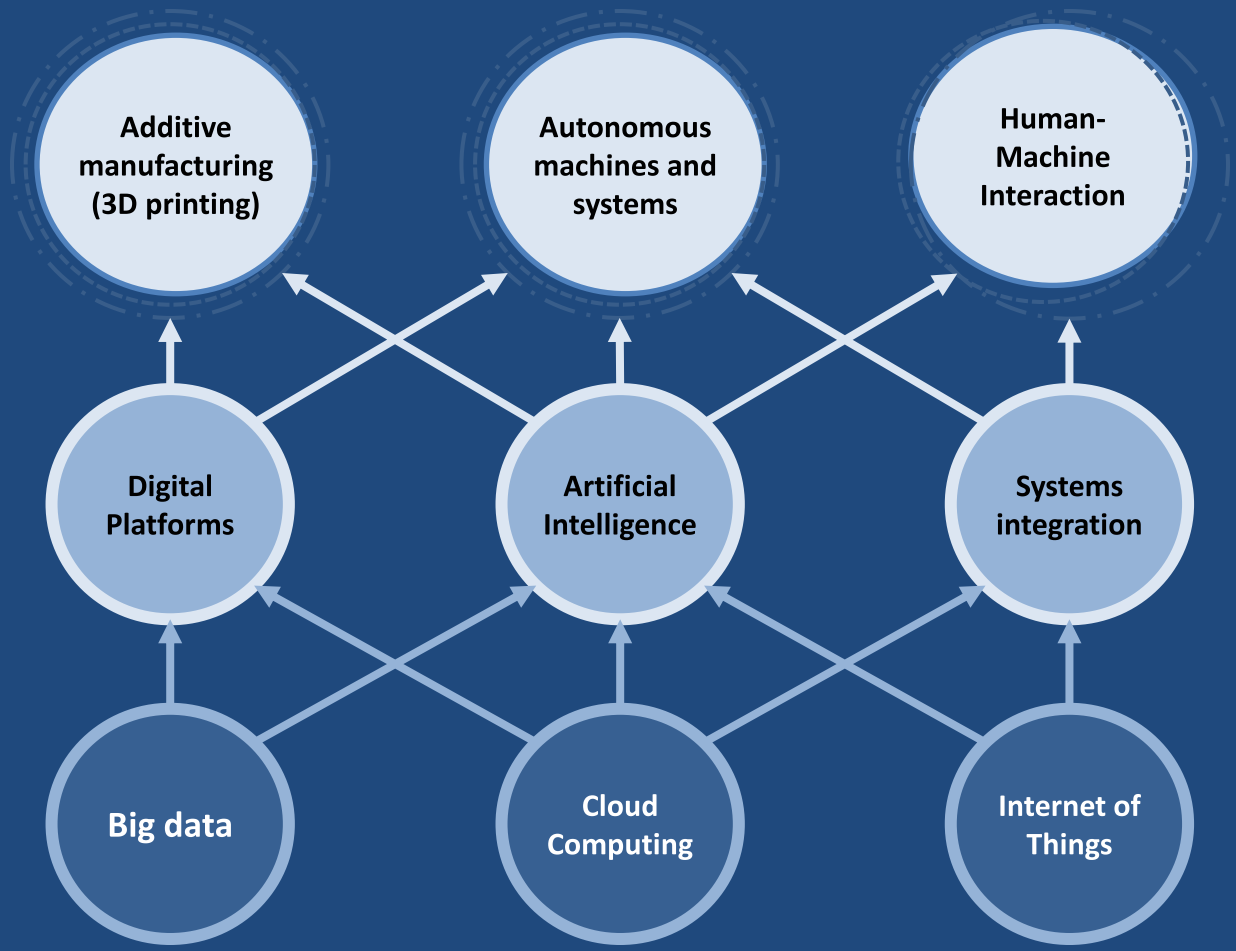
- Fuel tank produced in days with additive manufacture
- Traditional (subtractive) manufacture in one year
- Laser-printed rocket engine and fuel tank tested 85 times at NASA facility in Mississippi without failure

Advanced Manufacturing Effects

Tectonic Retooling of American Manufacturing?

- 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
  - Back to the beginning of the talk

Key Technologies Enabling the Future



Organizational Checklist

- Is your data in the shape that you can use it rapidly? Do you have the apps associated with the data that you can use to derive value from the data?
- Do you have staff to **understand** the data, to **derive** insights from the data, and to make **decisions** about how best to reduce risks based on the data?
- How do you plan to prevent *biased* decision making from poor data sets?
- Have you built a “digital twin” of your high hazard processes in to test your risk control decision making?

- Russell & Novig, Artificial Intelligence: A Modern Approach, 3rd ed. (2015)
- Daniel Hulme, https://www.strategy-business.com/article/Understanding-the-Potential-of-Artificial-Intelligence

Thank You!

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