

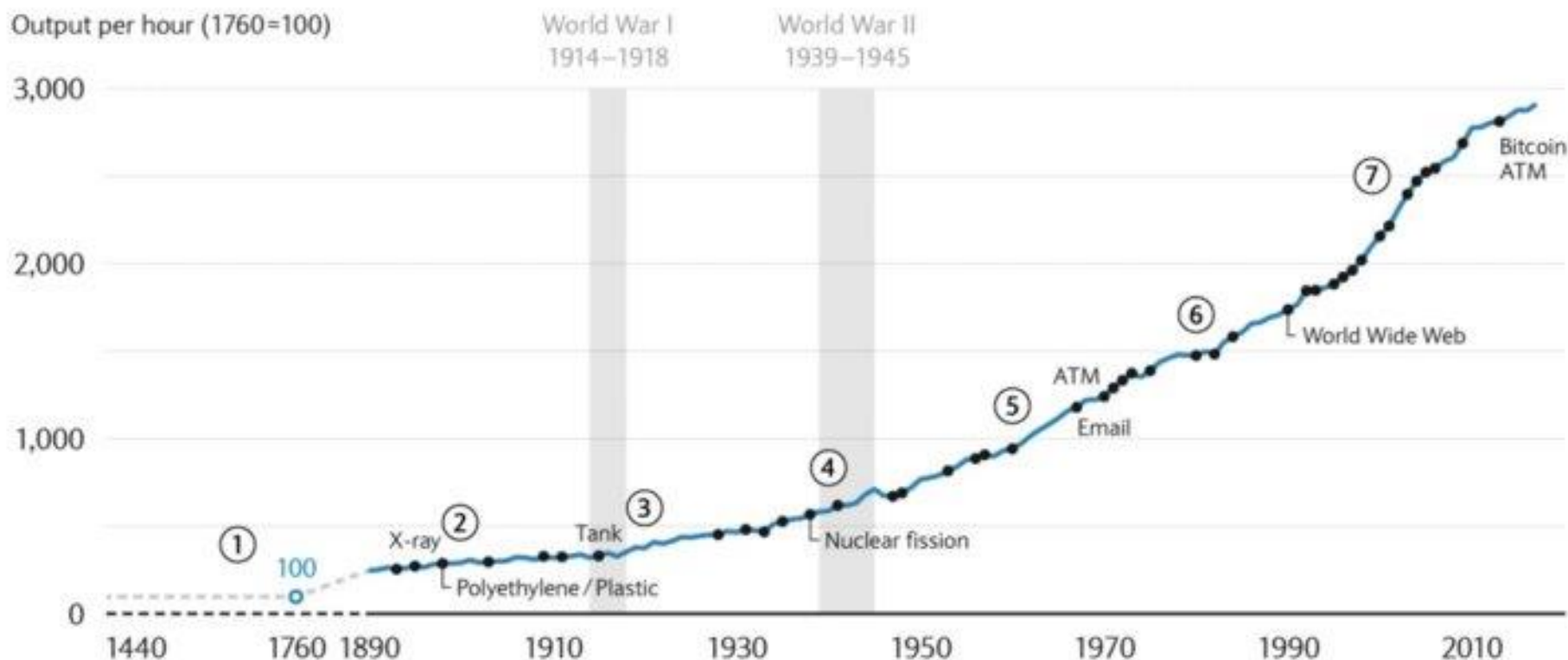


Transformational Considerations and Implications of the Era of Artificial Intelligence



Major technological innovations in the last 150 years and their impact on productivity

FIGURE 1
From the printing press to the global internet, technology has evolved, and human societies with it





Trends in Internet access, use:

Ubiquitous U.S. access, mobile use, and increasing global coverage^a

- ▶ Location data—movement of persons, vehicles—based on GPS,^b other location sensors
- ▶ Communications—e-mails, voice communications, text messaging; tweets, social-media postings
- ▶ Purchases and sales—retail, ratings of products and services, selling (eBay, Etsy)
- ▶ Searches
- ▶ Online banking, billing and payment, use of budgeting apps
- ▶ Many new apps
- ▶ Digital photographs taken with smartphones
- ▶ Entertainment online (for example, Netflix, Pandora radio)
- ▶ The gig economy (online platforms through which individuals earn income^c)



Public area data collection:

Sensor-based developments create marketing, surveillance data

- ▶ Video-recording in malls or near stores; also airports, other locations (may connect to facial recognition software)
- ▶ Identifying individuals' presence in certain areas via signals from their devices (e.g., WiFi)
- ▶ Drones with cameras or other sensors



Extensive datafication:

Documents, records, maps that are searchable, analyzable^d

- ▶ Electronic health records (EHR)
- ▶ Detailed maps for navigation
- ▶ Indexed documents and websites (to allow searches)
- ▶ Real-estate market information (Zillow, Trulia, etc.)



The open data trend:

Trend toward new releases of data to the public

- ▶ Pre-existing information (such as detailed weather data from Department of Commerce and crop-yield data from Department of Agriculture)
- ▶ Data from cities in areas such as public health and transportation, including real-time data (such as city data on open parking spots)

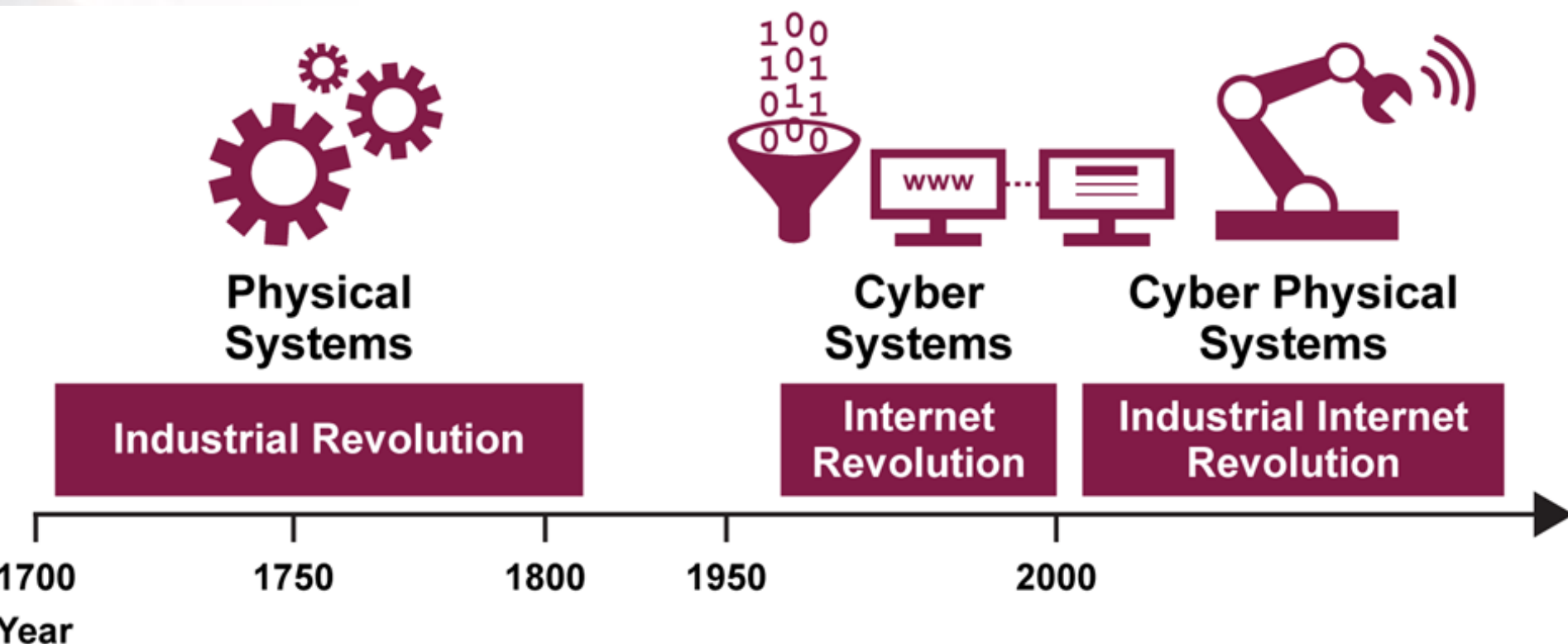


Connected sensors:

Internet of Things (IoT), Industrial Internet, and cyber-physical systems (CPS)^e

- ▶ Consumer items—wearables such as exercise trackers; connected vehicles; connected home items, such as smart thermostats^f
- ▶ Connected supply chains in manufacturing; connected sensors in agribusiness
- ▶ Connected government or public utilities—electricity, water
- ▶ Intelligent transportation—connected vehicles, smart traffic lights^g

The New Industrial Internet Revolution



Source: Adapted from Sunder 2016; GAO and Art Explosion (images). | GAO-16-659SP

AI Definitional Challenge

Stanford AI 100 Study:

“Artificial intelligence is that activity devoted to making machines intelligent, and intelligence is that quality that enables an entity to function appropriately and with foresight in its environment.”

...

“Ironically, AI suffers the perennial fate of losing claim to its acquisitions, which eventually and inevitably get pulled inside the frontier, a repeating pattern known as the “AI effect” or the “odd paradox”—AI brings a new technology into the common fold, people become accustomed to this technology, it stops being considered AI, and newer technology emerges.”

Three Waves of AI



First Wave

Expert knowledge or criteria and logical reasoning
The first wave of AI is represented by expert knowledge or criteria developed in law or other authoritative sources and encoded into a computer program in the form of an expert system.

Example: Online tax preparation

Second Wave

Machine/Statistical learning

Second-wave AI technology is based on machine learning, or statistical learning, and includes voice recognition, natural-language processing, and computer-vision technologies, among others.

Example: Face-recognition technology

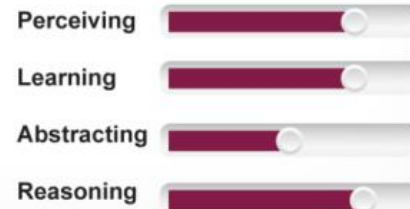
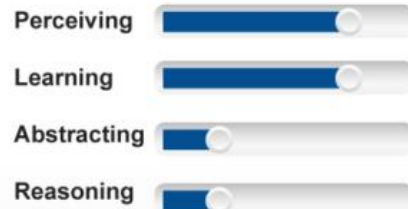
Third Wave

Contextual adaptation

Third-wave AI technology combines the strengths of first- and second-wave AI, and is also capable of contextual sophistication, abstraction, and explanation.

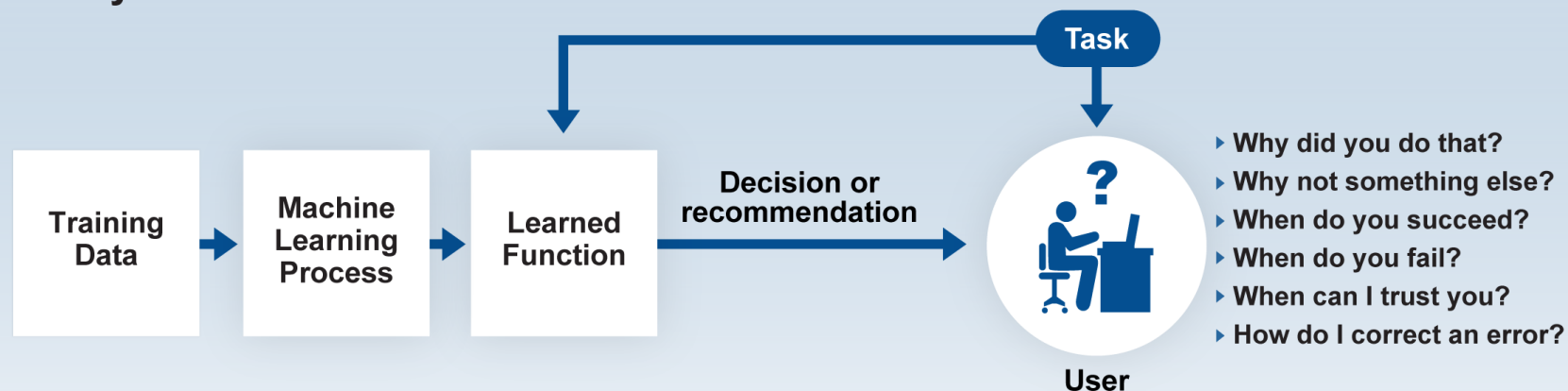
Example: Autonomous ships

Relative levels of capability

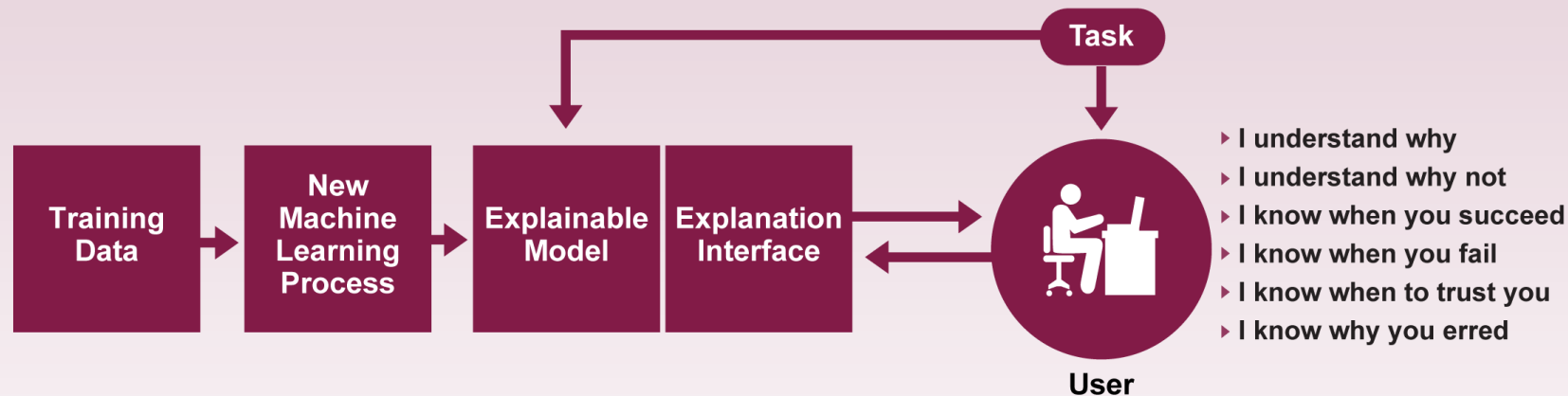


Key Issue: Explainable AI

Today



Explainable AI



GAO Risk of Counterintuitive Outcomes



GAO AI and High-Consequence Applications

Selected Questions



Cybersecurity

AI applications face threats from cybersecurity attacks, but AI also may be used as a tool for detecting and defending against attacks.

- ▶ How can autonomous systems be made secure, without stifling innovation?
- ▶ How useful is a risk-based approach to determining if machine-learning algorithms adhere to legal requirements or ethical norms?



Automated Vehicles

Automated vehicles hold promise for increasing driving safety and providing enhanced mobility, but pose challenges for assuring increased safety.

- ▶ What is the appropriate regulatory framework for automated vehicle safety assurance?
- ▶ What are the roles of federal, state, and local governments in infrastructure adaptation and addressing issues of liability and enforcement?

GAO AI and High-Consequence Applications



Criminal Justice

The use of AI in criminal justice may improve the allocation of law enforcement resources and has the potential to reduce crime and jail populations, but also raises concerns about privacy and civil rights violations.

- ▶ What are the options for assessing accuracy and the potential for bias in AI data and algorithms?
- ▶ What are solutions for safeguarding privacy in the collection and use of personal information by AI systems?

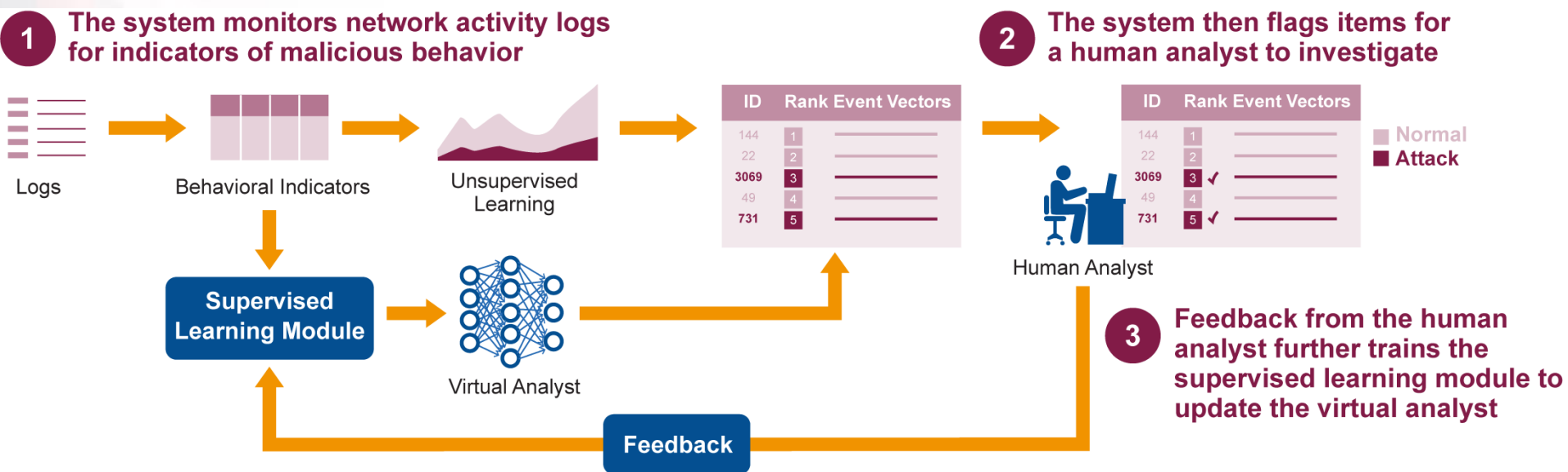


Financial Services

The use of AI in financial services could improve client services and enhance surveillance monitoring, but also poses challenges to ensuring fair lending, attracting and retaining staff with requisite skills, and maintaining hardware and software.

- ▶ What are the mechanisms to address ethical considerations, tradeoffs, and protections?
- ▶ How can regulatory sandboxes be used to test new AI products, services, and business models?

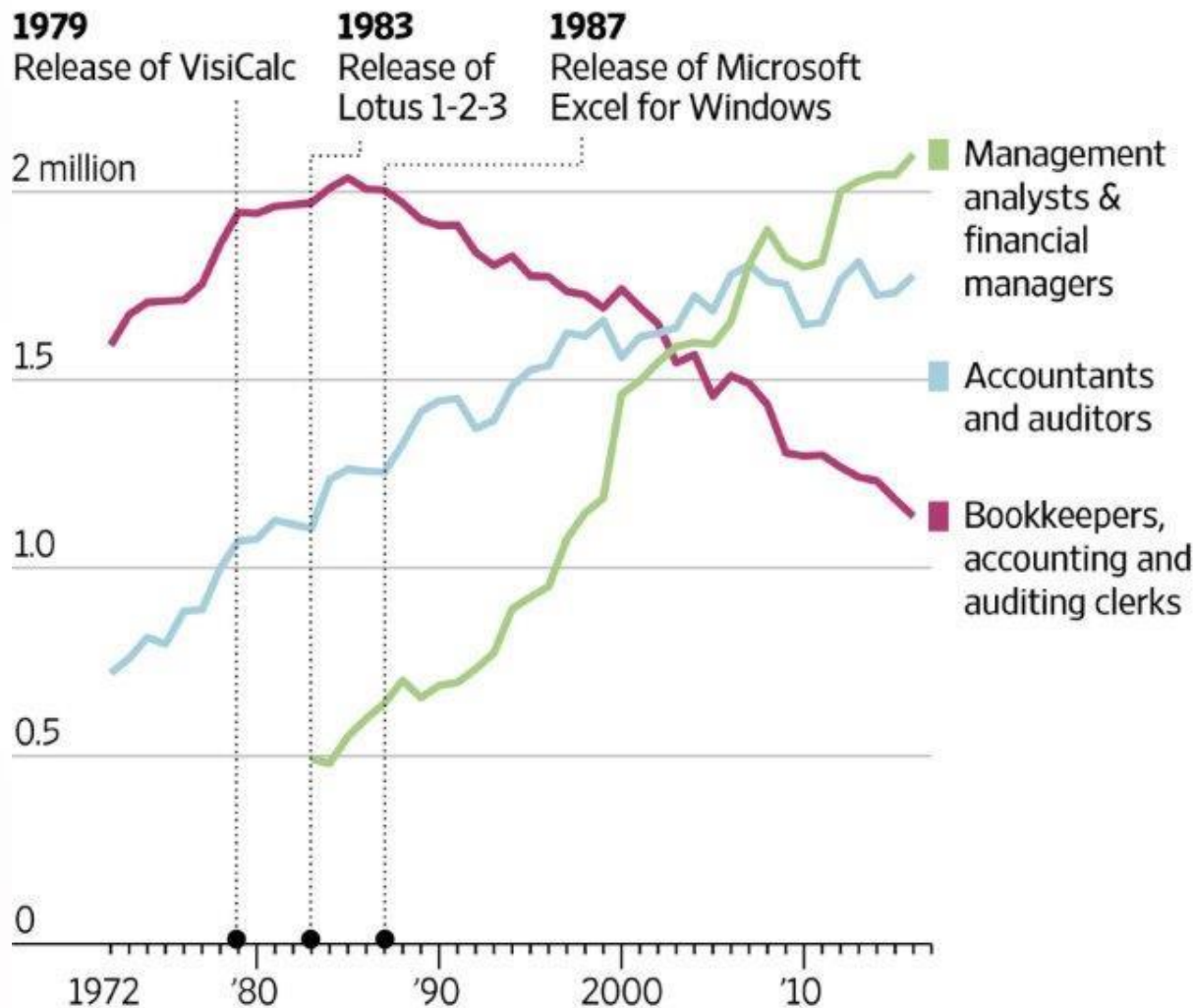
Machine Learning with Human Feedback for Cybersecurity



Source: GAO, adapted from video, Veeramachaneni, Arnaldo et al., *AI2: Training a Big Data Machine to Defend* (https://www.youtube.com/watch?v=b6Hf1O_vpwQ). | GAO-18-142SP

The Spreadsheet Apocalypse, Revisited

Jobs in bookkeeping plummeted after the introduction of spreadsheet software, but jobs in accounting and analysis took off.



Notes: There is no data for 1982. Changes in occupational definitions in 1983, 2000 and 2011 mean that data is not strictly comparable across time. There was no category for management analysts or financial managers prior to 1983.

Source: Bureau of Labor Statistics

THE WALL STREET JOURNAL.

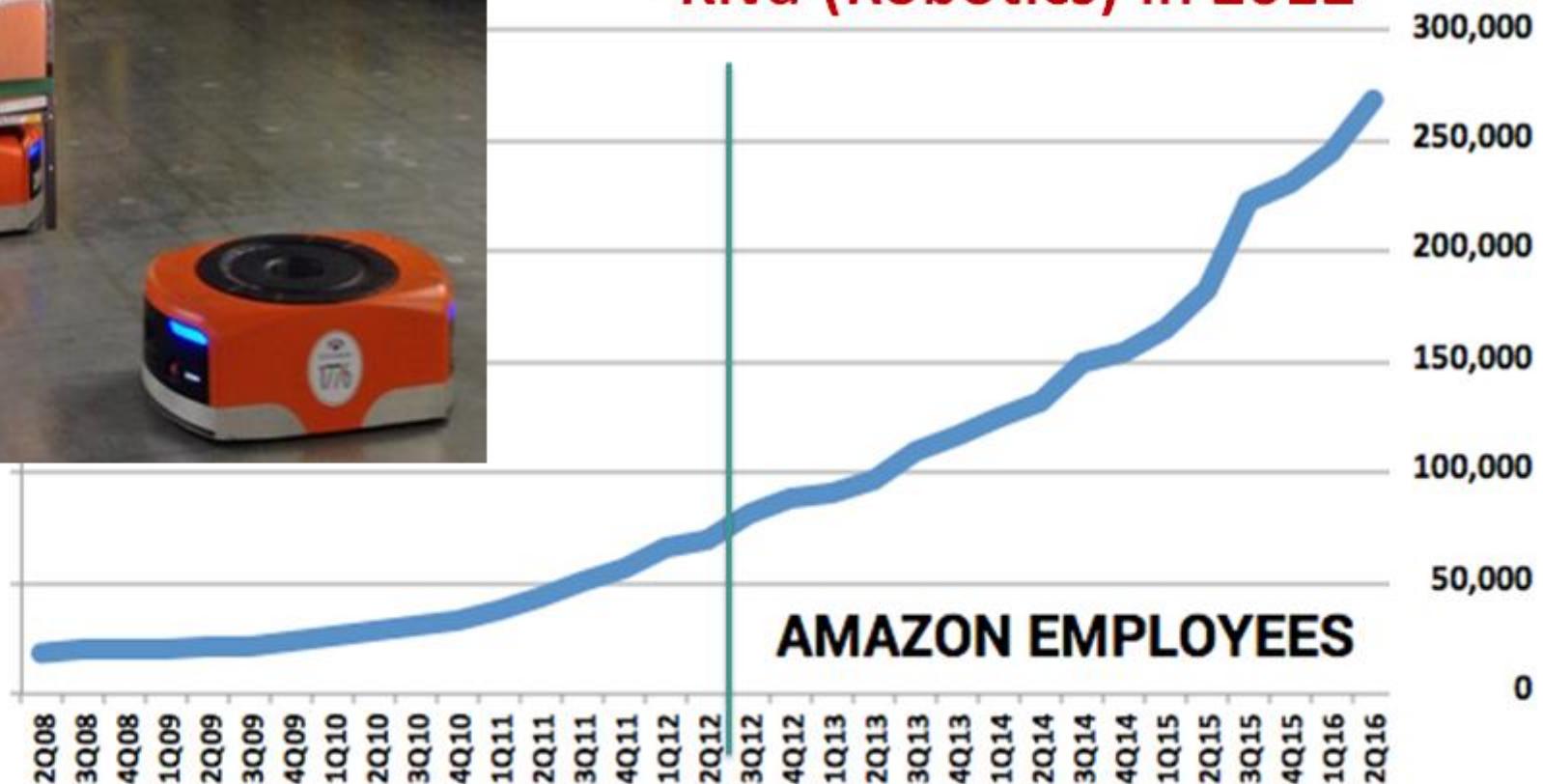


• More demand → More Supply

• An Example of more Jobs:

• Amazon's Acquisition of

• Kiva (Robotics) in 2012





What Jobs are Actually Under Threat?



Anticipated Impacts on Selected Job Tasks

Three types of job tasks			Anticipated differential DAI impacts	
Type of task and education level	Task features or characteristics	Occupational examples	Type of impact	Level of impact
Manual task with relatively low education required	<ul style="list-style-type: none"> tends to involve environmental adaptability tends to involve interpersonal adaptability 	flight attendant waiter cleaner	complementary or substitution	limited
Routine task with low to medium education required	<ul style="list-style-type: none"> is rules-based is codifiable is procedural 	bookkeeper assembly line worker	direct substitution; job loss	extensive
Abstract task with very high education required in many cases	<ul style="list-style-type: none"> tends to involve abstract problem solving tends to involve mental flexibility 	scientist attorney manager doctor	complementary; possible growth in jobs and wages	extensive

Source: GAO, based on forum discussions and literature (Richard 2016; Autor 2015; Autor et al. 2003; Katz 2015). | GAO-16-659SP

Re-Skilling and Up- Skilling (Current and Future)

MATH & STATISTICS

- ☆ Machine learning
- ☆ Statistical modeling
- ☆ Experiment design
- ☆ Bayesian inference
- ☆ Supervised learning: decision trees, random forests, logistic regression
- ☆ Unsupervised learning: clustering, dimensionality reduction
- ☆ Optimization: gradient descent and variants

DOMAIN KNOWLEDGE & SOFT SKILLS

- ☆ Passionate about the business
- ☆ Curious about data
- ☆ Influence without authority
- ☆ Hacker mindset
- ☆ Problem solver
- ☆ Strategic, proactive, creative, innovative and collaborative

PROGRAMMING & DATABASE

- ☆ Computer science fundamentals
- ☆ Scripting language e.g. Python
- ☆ Statistical computing packages, e.g., R
- ☆ Databases: SQL and NoSQL
- ☆ Relational algebra
- ☆ Parallel databases and parallel query processing
- ☆ MapReduce concepts
- ☆ Hadoop and Hive/Pig
- ☆ Custom reducers
- ☆ Experience with xaaS like AWS

COMMUNICATION & VISUALIZATION

- ☆ Able to engage with senior management
- ☆ Story telling skills
- ☆ Translate data-driven insights into decisions and actions
- ☆ Visual art design
- ☆ R packages like ggplot or lattice
- ☆ Knowledge of any of visualization tools e.g. Flare, D3.js, Tableau



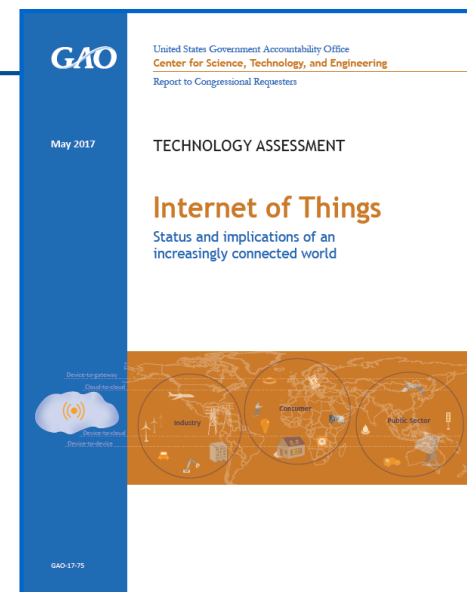
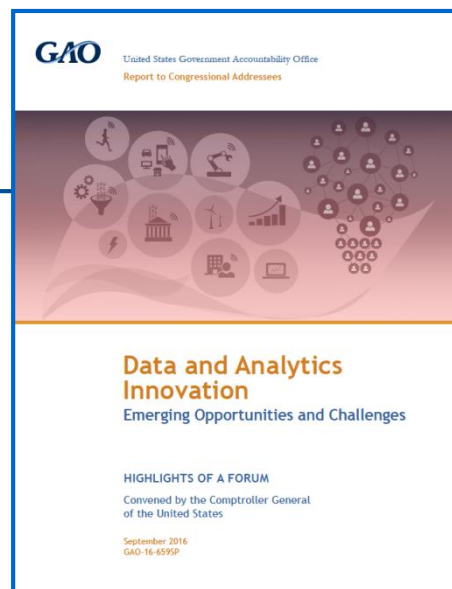
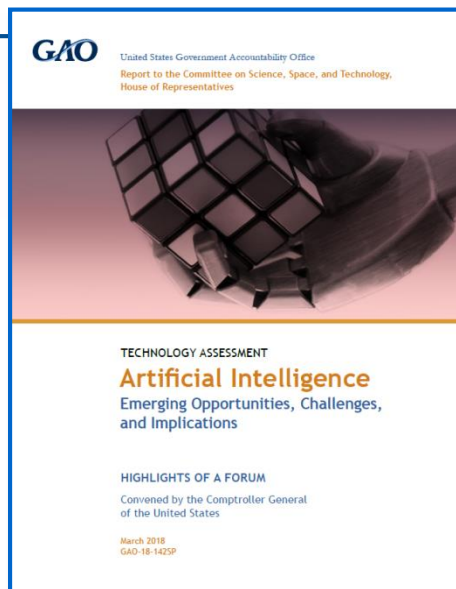
Key Cross-Sector Policy and Research Issues

- Safety and security
- Assessing acceptable risks & ethical decision making
- Updating regulatory approaches
- Incentivizing data sharing
- Computational ethics and explainable AI
- Regulatory sandboxes
- Effects on employment, training and education
- Role of high-quality data

Considerations Going Forward

- “Data are the new oil” – tremendous opportunities exists for all economic sectors to embrace key trends and shape them toward positive ends
 - Innovation “sandboxes” will be needed to identify issues and test the technologies in a realistic environment to determine the extent to which they enhance quality, timeliness, and ultimately, relevance.
 - Rumors of the deaths of institutions and vocations are greatly exaggerated...jobs will be lost, but others gained (possibly a net gain)
 - Human capital development will require fundamental reconsideration and will need transformation to meet the future demands of most professions
 - Vocations – including the Public Sector – will be required to adapt to the probabilistic (vs. deterministic) paradigm
 - The greatest challenges ahead are socio-cultural...not technical (*“culture eats strategy for breakfast”*)
-

Thank you



personst@gao.gov

+1 (202) 512-6412

@GAOChfScientist

LinkedIn: "Timothy M. Persons"

http://www.gao.gov/technology_assessment/key_reports