Astronauts and IoT: Toward True Human-Autonomy Teaming

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Nordic Digital Business Summit 2016

Helsinki, Finland

22 September 2016

Overview

Three Themes

- Robotics and human interfaces progressing quickly but real AI not so much
- Human intelligence will remain unique and of great value for decades
- Not designing autonomous systems to interact with humans increases costs

Machine Intelligence

We appear to be at an exciting time with respect intelligent machines (again).

- **Four Related Areas of Development**
  1. Big Data - volume, velocity and variety
  2. Deep Learning
  3. Networked operations and cyber-physical systems
  4. Moore's Law (exponential growth, doubling of components on an integrated circuit every two years): faster, bigger computers driving change with increasing velocity
- **Stephen Hawking, Bill Gates and Elon Musk have all recently warned about the potential dangers of AI.**
- **Also interesting time in terms of self-driving cars and companies with robotic operations/factories like Amazon, Tesla and Toyota**
- **Big Blue, Watson, Pokerbot**
- **Google DeepMind AI Division beats human at GO (Jan 2016)**
- **First AI investment software hits Wall St. (Feb 2016)**

Manpower Reduction: Start with the Human (Not the Technology)

The Autonomy Paradox

(Blackhurst, Gresham & Stone, 2011)

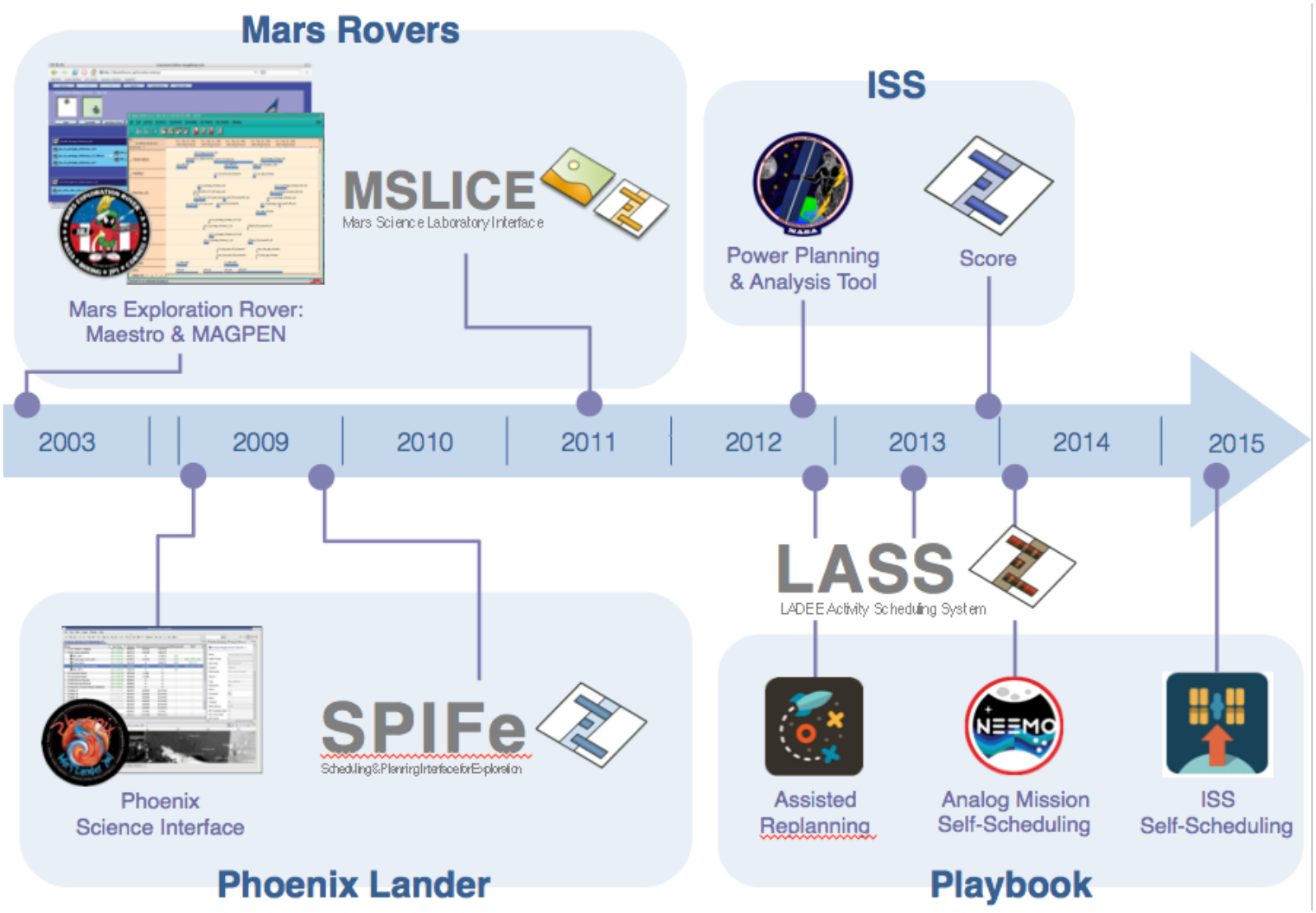
- Autonomy doesn't get rid of humans, it changes their roles
- DoD has shifted from Levels-of-Automation to Cognitive Echelons
- As machine intelligence advances, the need for better human interfaces increases

The Littoral Combat Ship

Built to be operated by 45 sailors

Dr. Larry Shattuck, NPS (pg. 13-15)
http://human-factors.arc.nasa.gov/workshop/autonomy/download/presentations/Shaddock%20.pdf

Path to Collaborative, Human-in-the-Loop Planning Systems



Toward Human-Autonomy Teaming?

Domesticated Robots

Caged Robots

Robots Designed for Teaming

…but still mostly caged ***autonomy***

Generative, Adaptive Expertise

Toyota replacing some robots on the factory floor with humans

Rio Tinto working to integrate humans in with robotic mining systems

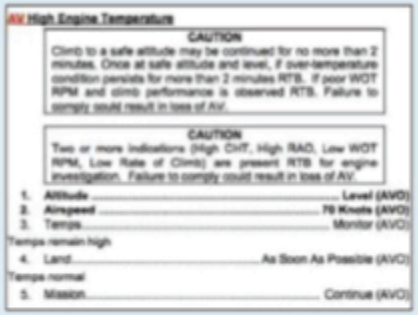
- **When a robot is doing the work, the process stops improving.**
- **Improvement in non-deterministic environments requires adaptive expertise**

Self-Driving Cars

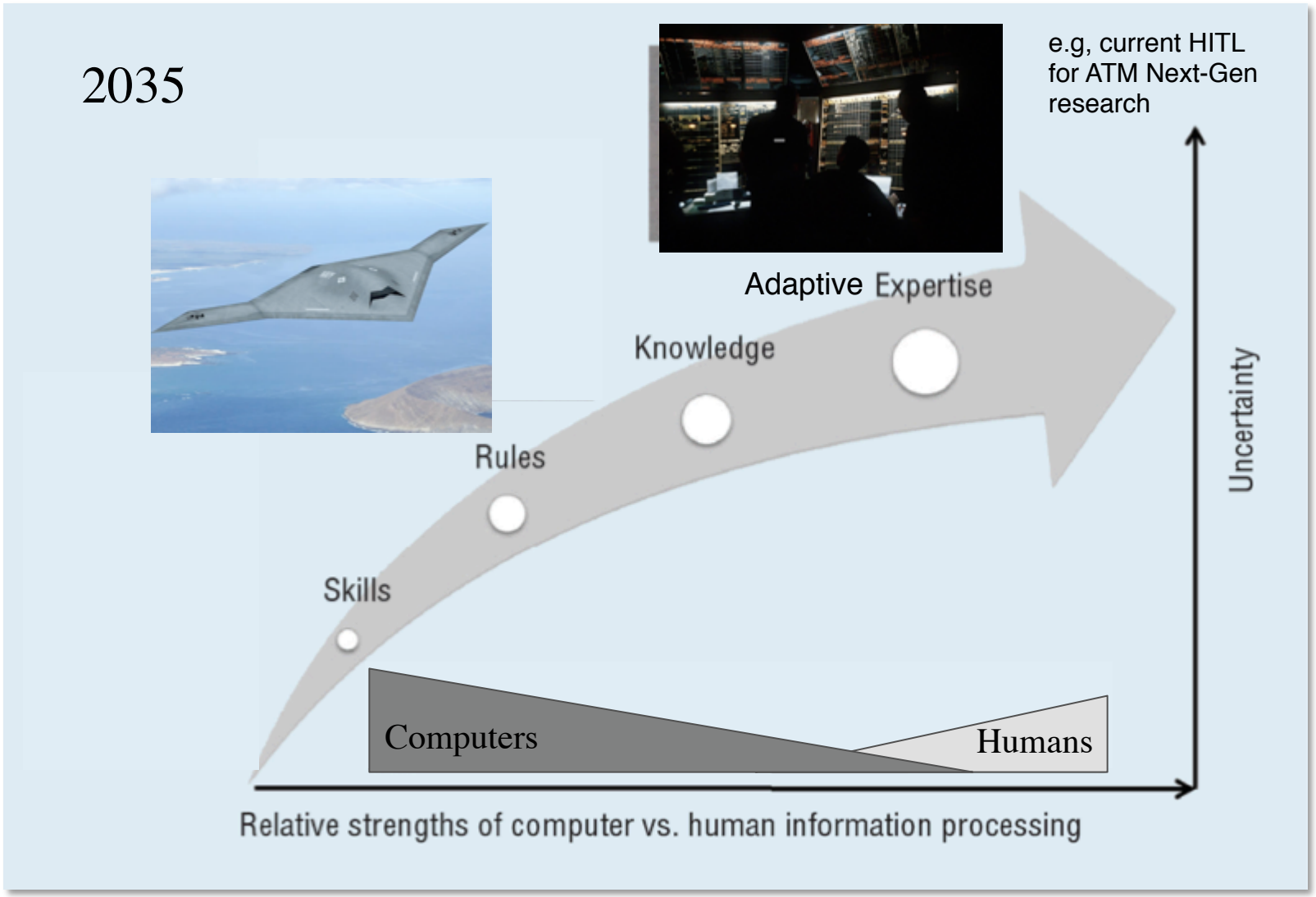
Driving: Low Cognitive Demand Task

- **Does not necessarily indicate progress in machine intelligence relevant to performance in more complex decision-making and reasoning along the lines of expert humans.**
- **Last 5% challenge**
- **Control room v. return of control**

2015



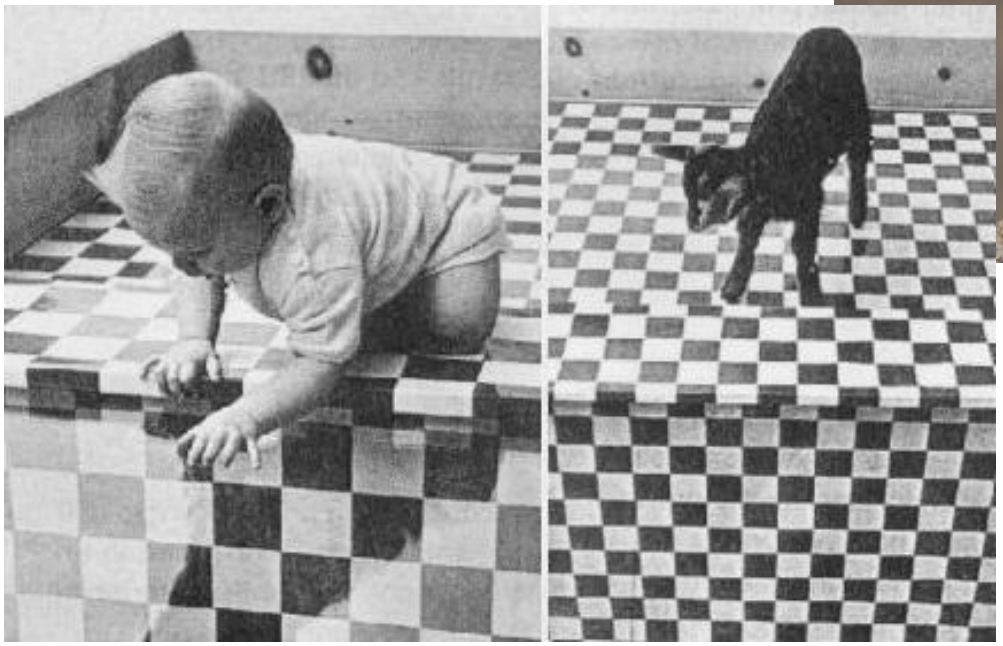
From Cummings, M.L., "Man vs. Machine or Man + Machine?" *IEEE Intelligent Systems*, (2014) 29(5), p. 62-69.



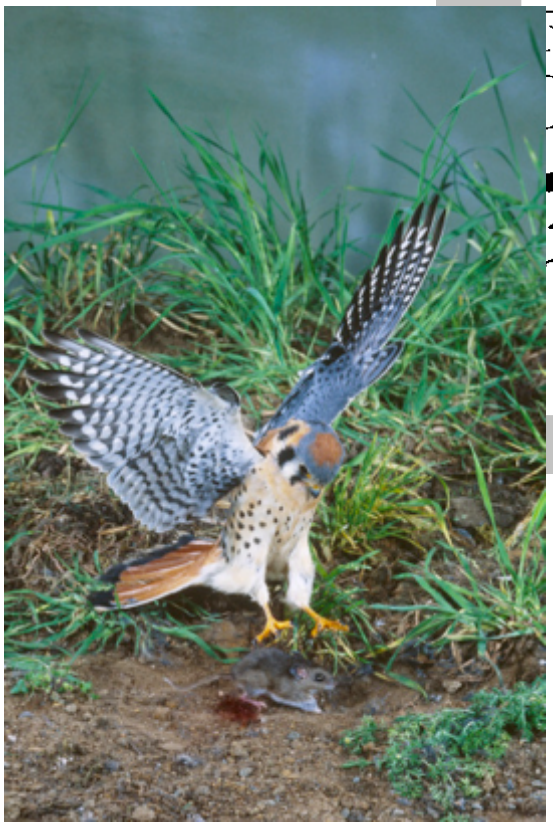
Architecture based on autonomy performing all skill and rule-based roles, as well as most knowledge-based roles. Manpower reduced by two orders of magnitude with remaining expert humans teaming with machine intelligence to solve complex problem solving under uncertainty. Machine intelligence for airspace management evolves from the outset to support teaming with small set of expert humans to support cooperative problem-solving.

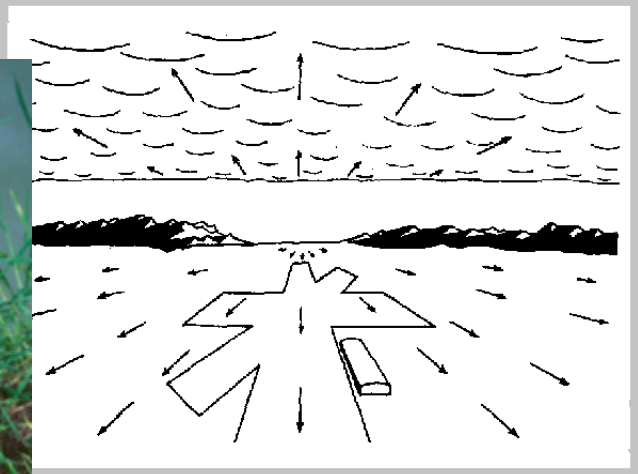
Tabula Rasa?

- **Animal perceptual systems attend to specific information from the visual environment**



Affordances from the Environment





idealised flowfield (after Gibson, 1950)

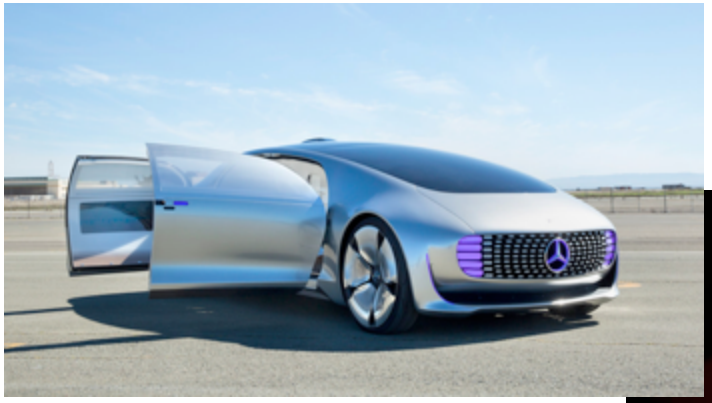
Human Cognitive Architecture not Tabula Rasa nor Randomly Constrained

- **Key characteristics of human problem solving: "Why did this happen?" and "Can this be done better?"**
  - Induction rather than deduction
  - More than knowing the answer to a question: what is the right question
- **Heuristics and biases**

80 billion neurons

100,000 neurons

Using Affordances



- **Application of Gibsons' Ecological Psychology**
  - Alternatives to using human central attention resource
  - A car more like a horse

Big Data

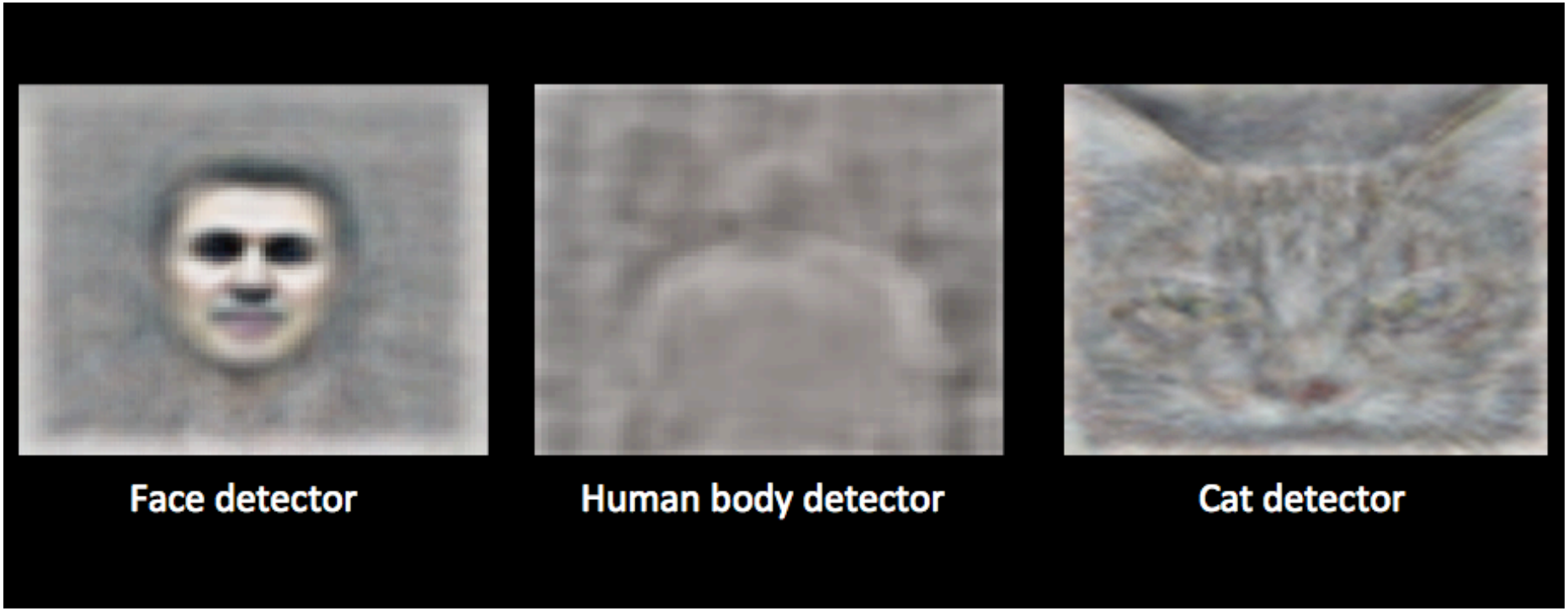
Natural Language translation

- **“Will Big Data spell the end of Theory?”**

NASA has big data on the science side. Unfortunately, on engineering side, NASA has a big problem with data but not a big data problem.

Deep Learning

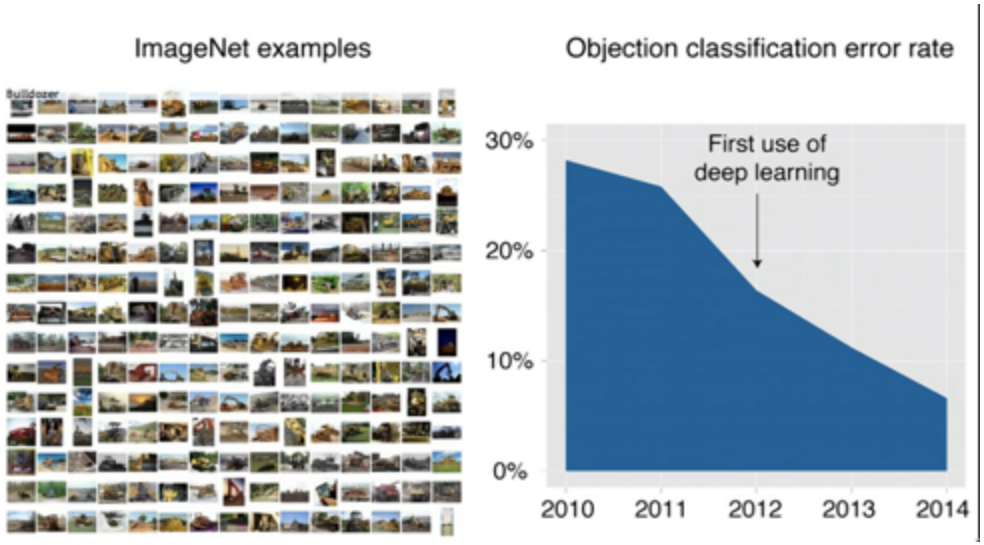
Neural Nets plus big data

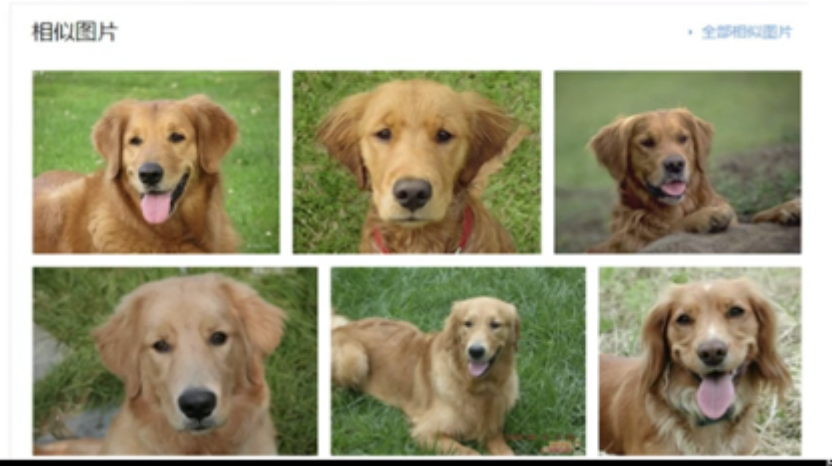


Google Deep Learning Experiment: emergent images from YouTube image analysis

Deep Learning for Pattern Recognition

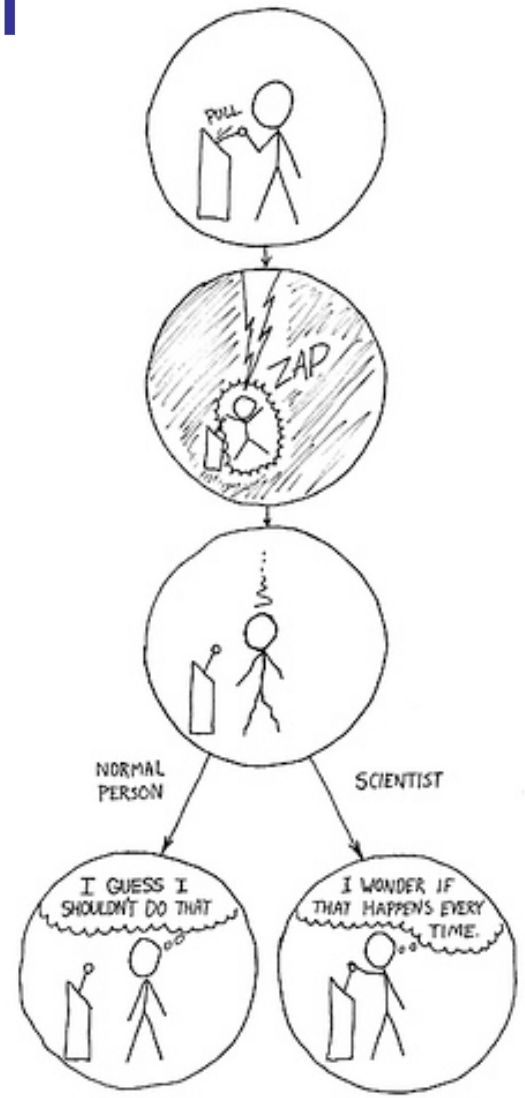
From Jeremy Howard's TED Talk in Dec. 2014





Correlation v. Causation

- **Humans: Causal reasoners based on contentful understading**
- **Machines: Correlational reasoners (a lot of data really helps)**
- **Human are poor at fast, systematic assessment of large data sets**
- **Humans are good at solving slow (hours to days) complex problems under uncertainty, where the outcome is based on successfully generating and evaluating causal explanations**
- **For humans, remarkably little exposure to data is needed to learn language in the first two years**
  - Internet of Things, Cyber-Physical Systems



Adaptive v. Associative Expertise

From Newell, 1990

- **Human and machine intelligence can arrive at equivalent solutions via different paths for certain classes of problems**

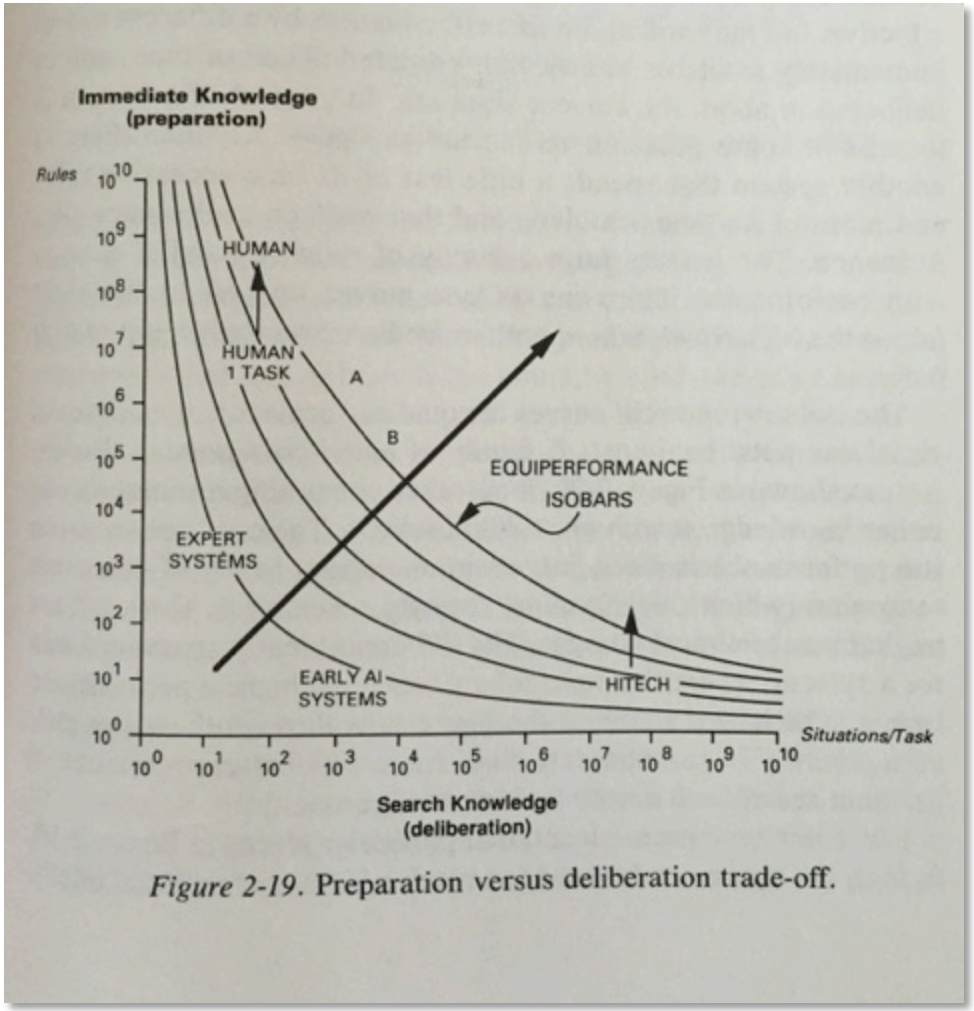


Figure 2-19. Preparation versus deliberation trade-off.

Skills, Rules, Knowledge and Expertise

Adaptive Expertise: Problem Solving under uncertainty

- **Differentiate skill-based expertise, like driving and chess from adaptive expertise like innovative engineering or real-time control of complex systems.**
- **Using schemas, selective attention, chunking information, automaticity and more reliance on top-down information.**
- **10,000-20,000 hours on task**
  - This is one reason we start driving at 14-15 years old
- **Expertise in the performance of complex, knowledge rich tasks under a great deal of uncertainty not well understood. We know some humans do it well some of the time, but not how or why.**

Teaming of Human and Machine Intelligence

- **Even as computers get very "intelligent", it is very likely that the nature of the their intelligence will be different than that of humans (unless they become omniscient or we program them to function just like humans)**
- **Humans are particularly good at adaptive problem-solving and discovery, areas where there has been little machine intelligence progress**
- **Successful efforts going forward will be those that wrap new machine intelligence capabilities around human competencies in order to get the most out of each**

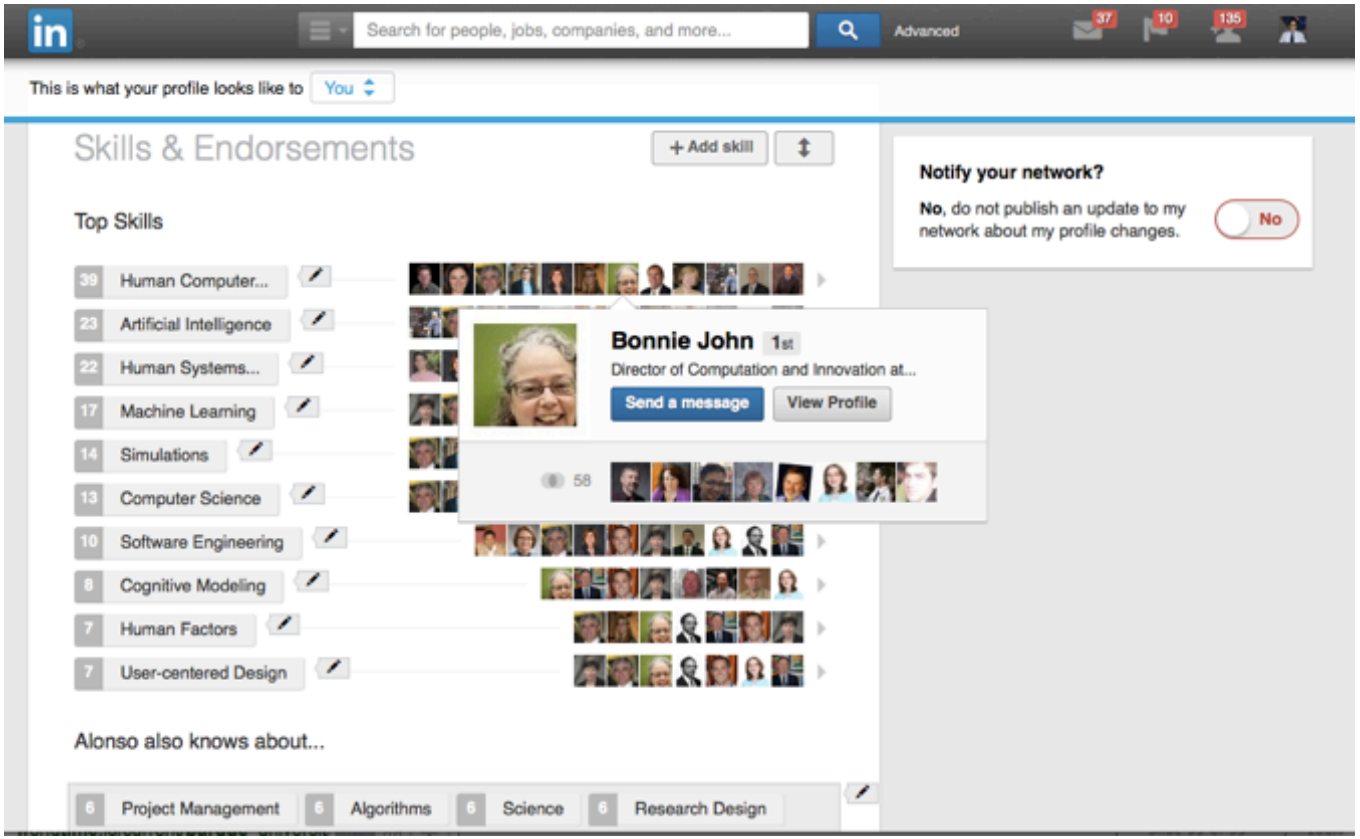
Goal: Design the human into the process. Focus on how the system will communicate it's state to the human so that the human can help in un-anticipated situations.

What data and how it is presented such that you can impose human intuition on it.

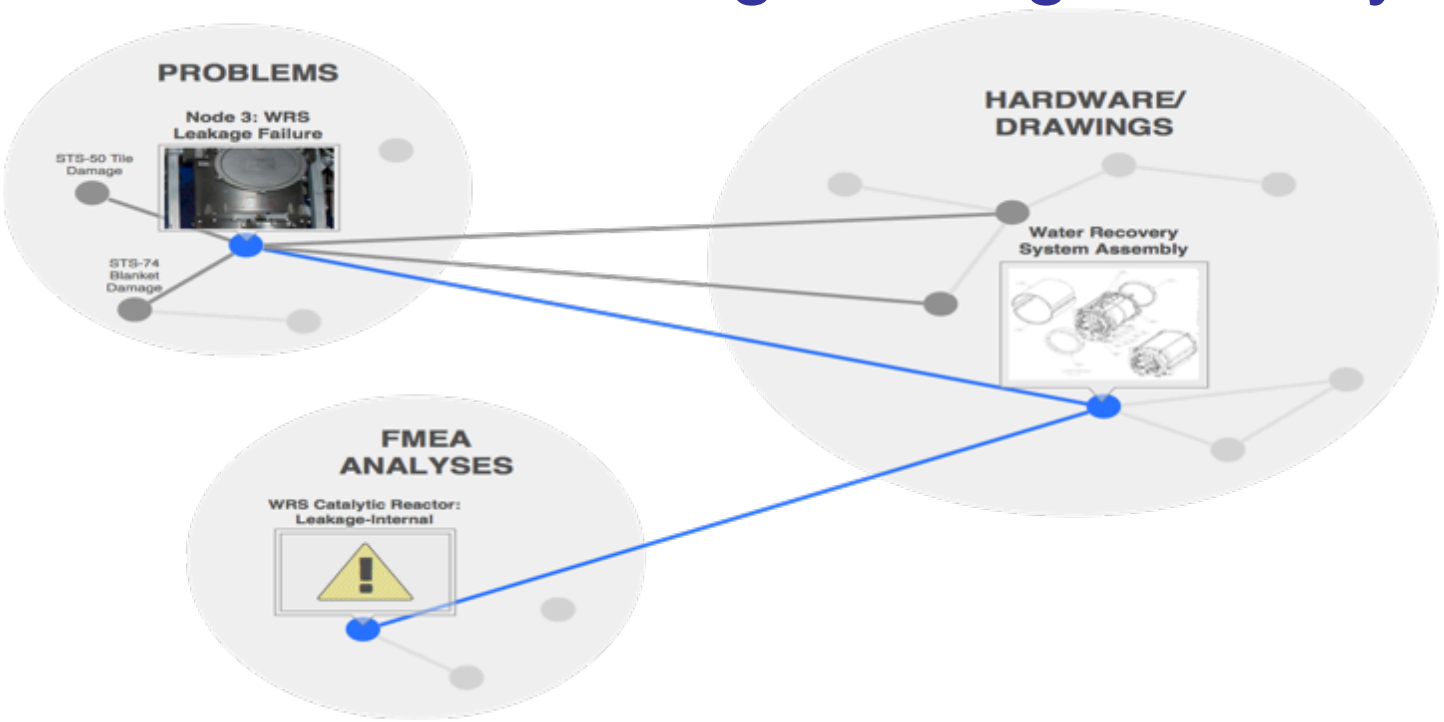
Expertise and Big Data

Endorsements on LinkedIn:

- From free text string skills “HCI” to a structured taxonomy of skills and suggestion capability
- To more consistently define skills across users and set up the infrastructure to support endorsements

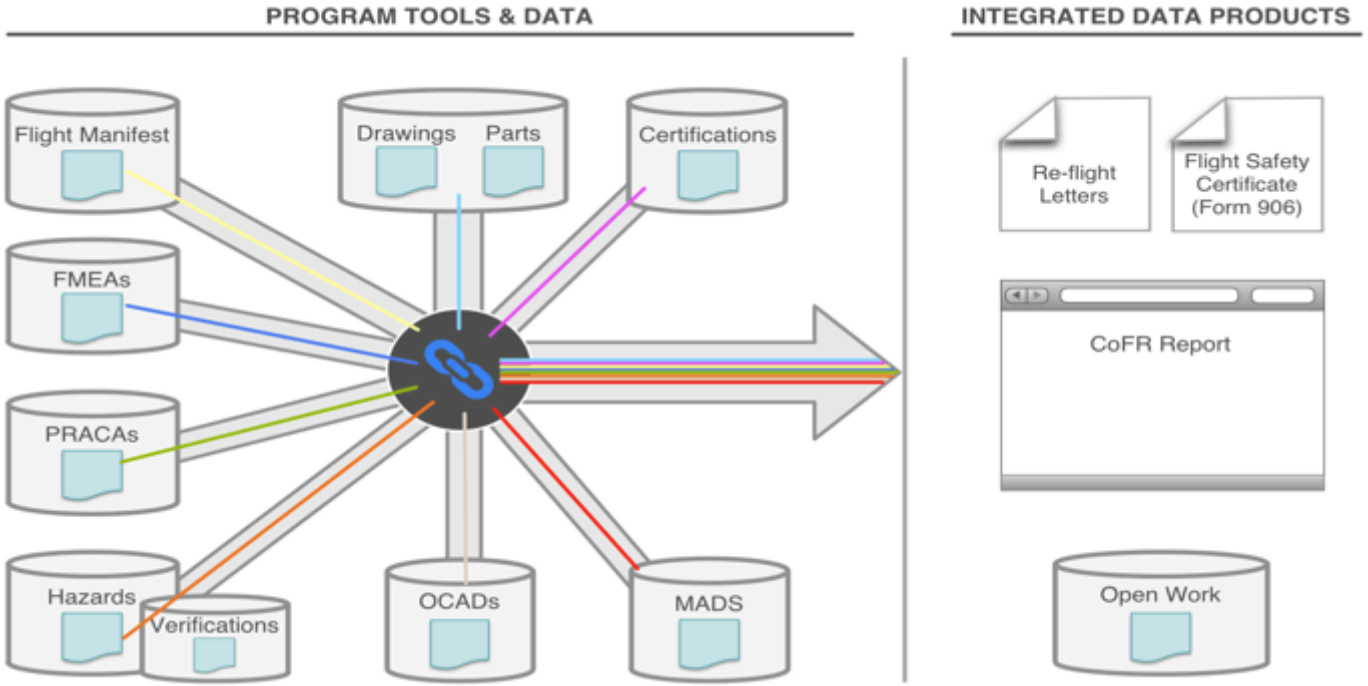


NASA's Small Data: Engineering & Safety



- *If a failure occurs on a piece of hardware, what similar PRACAs have been filed in the past? What FMEAs and Hazards were related to that hardware — why were they not successful in mitigating the failure?*

NASA's Small Data: Engineering & Safety



- Enabling application and capture of human expertise to NASA's systems engineering processes
  - Structuring data and creating *persistent* links **as part of existing engineering processes**
  - Providing efficient access to data and knowledge over mission lifecycle, enabling **reuse** of output of ongoing engineering processes

The Economics of Human-Centered Automation

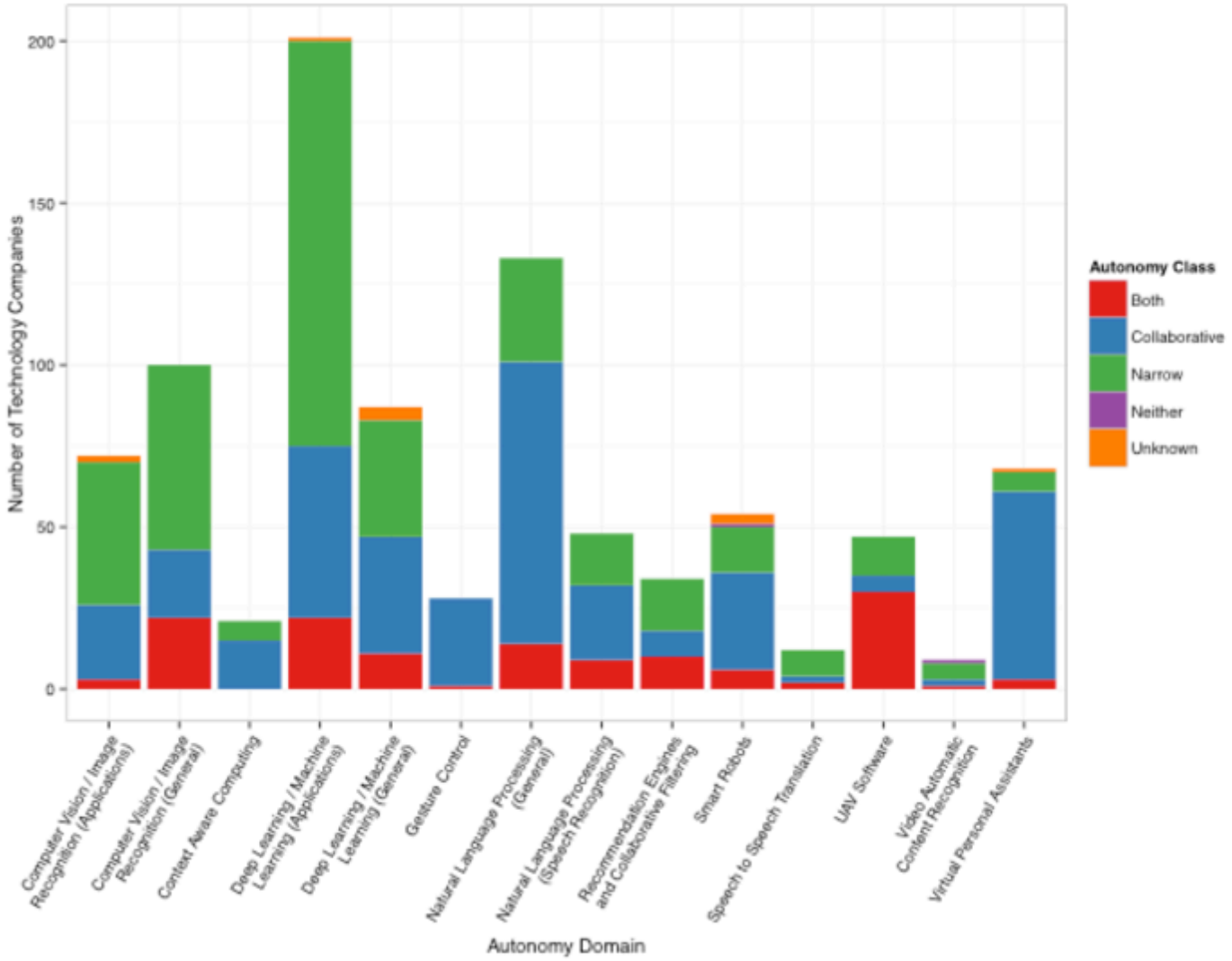
- **For lower costs, higher efficiencies and overall improved system performance:**
  - Characterize nature of human roles (skills, rules, knowledge, expertise) and tasks (e.g., proportion of hard and soft constraints)
  - Wrap autonomy around remaining human roles from the beginning

Critical to shape the autonomy industry

- **e.g., Apple v. Littoral Combat Ship**

Dr. Jon Bornstein, DoD Autonomy Roadmap Autonomy Community of Interest
http://www.defenseinnovationmarketplace.mil/resources/AutonomyCOI_NDIA_Briefing20150319.pdf

Investment in Artificial Intelligence



Venture Scanner - Nov. 2015 http://insights.venturescanner.com/tag/artificial-intelligence/

Autonomy in Non-Deterministic Environments

- **Mars Rovers 5-25 meters**
- **Challenges for self-driving cars: the last 5%**
  - What is the role of humans in control centers and what information do they need to have?
- **Communicating with humans**
- **Putting humans in the context**
  - "Most of the information pilots have comes from their rear end"
- **Keeping humans in the loop**

Final Thoughts

- **Humans will remain important components of complex systems**
- **Use human adaptive expertise as much as possible**
- **Use human perceptual system as much as possible in interactions with big data sets**
- **Robotics progressing faster than AI**
- **Be aware of areas where you don't have big data**
  - Not all problems are associative in nature
- **Don't assume search will solve all problems**

Thank you