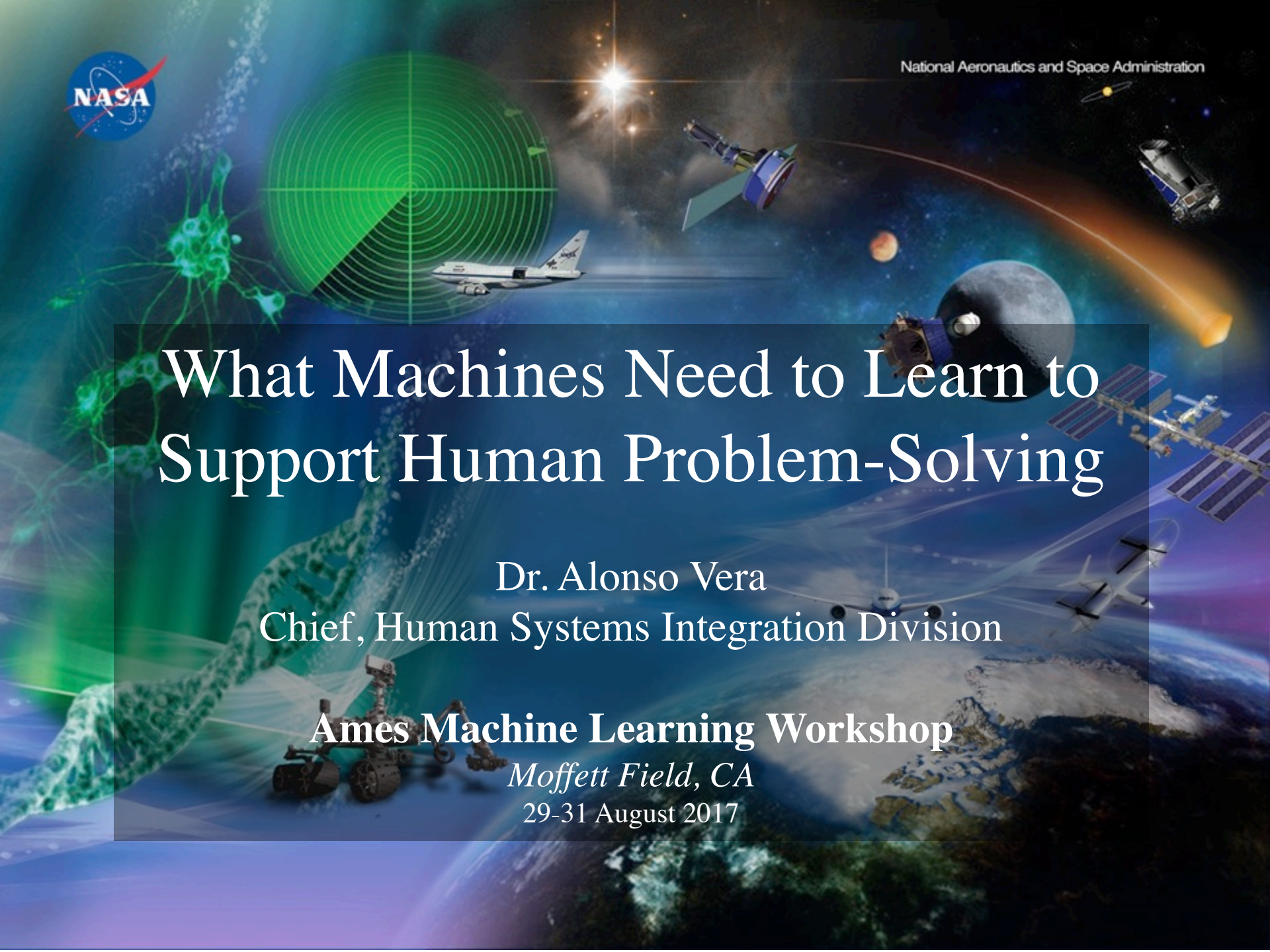


What Machines Need to Learn to Support Human Problem-Solving

Dr. Alonso Vera
Chief, Human Systems Integration Division

Ames Machine Learning Workshop

Moffett Field, CA

29-31 August 2017

Apple Research for Swimming App

- Characterizing calorie burn during swimming and using learning algorithms to tune the functionality to individual differences
- Developed novel experimental hardware and tested on 700 swimmers
- To develop a feature on one app for the Apple Watch

http://www.cultofmac.com/444551/why-apple-is-the-new-nasa/?&tc=em

Vision Science and Visual Technologies

Spatial Standard Observer

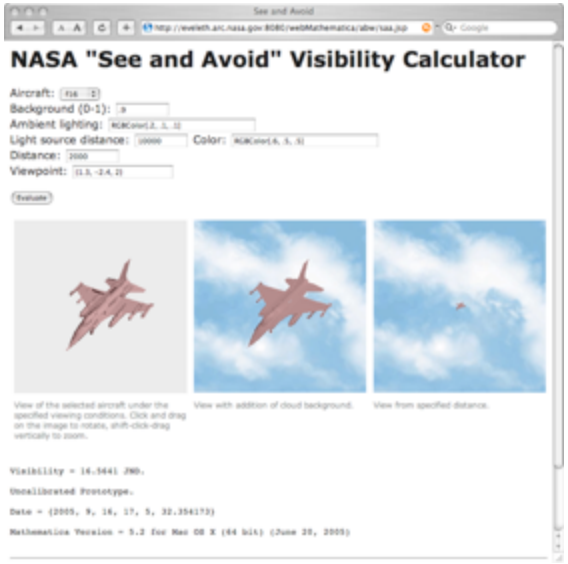
- Simple engineering tool to measure target visibility
- Replaces human observer in systems engineering
- Based on science model
- Prototype available
- Patented
- Users include FAA, ARL, industry
- Wide range of applications

Target Identification

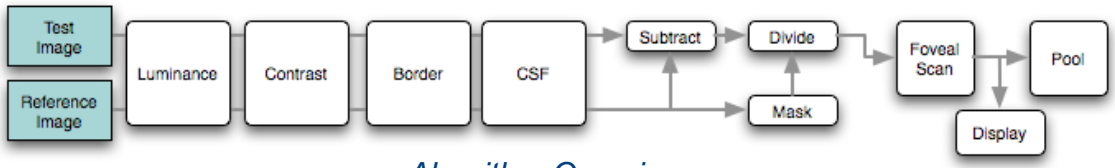
Orbiter Damage Inspection

Image compression

Aircraft/UAV Detection



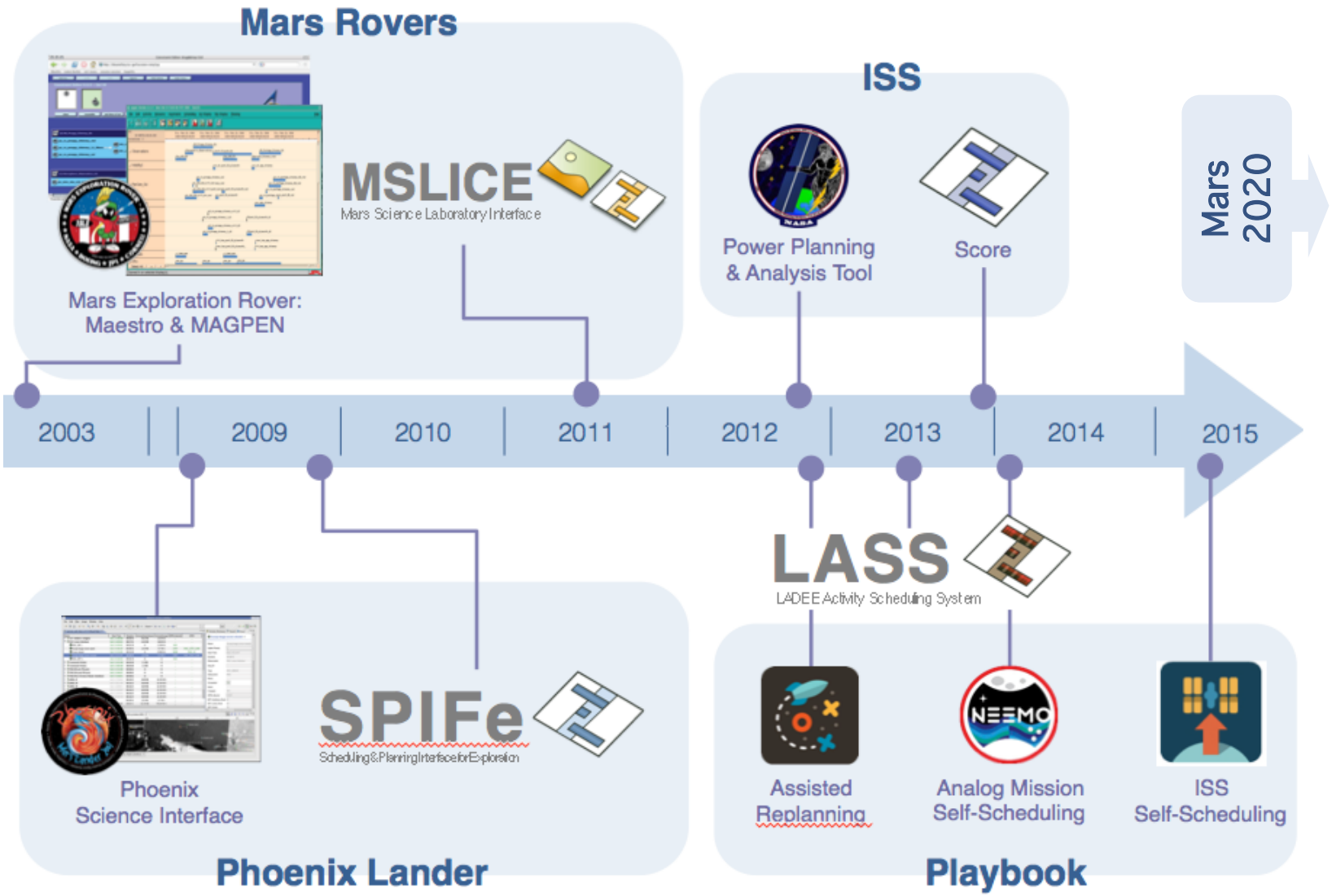
Night Vision Systems



Algorithm Overview

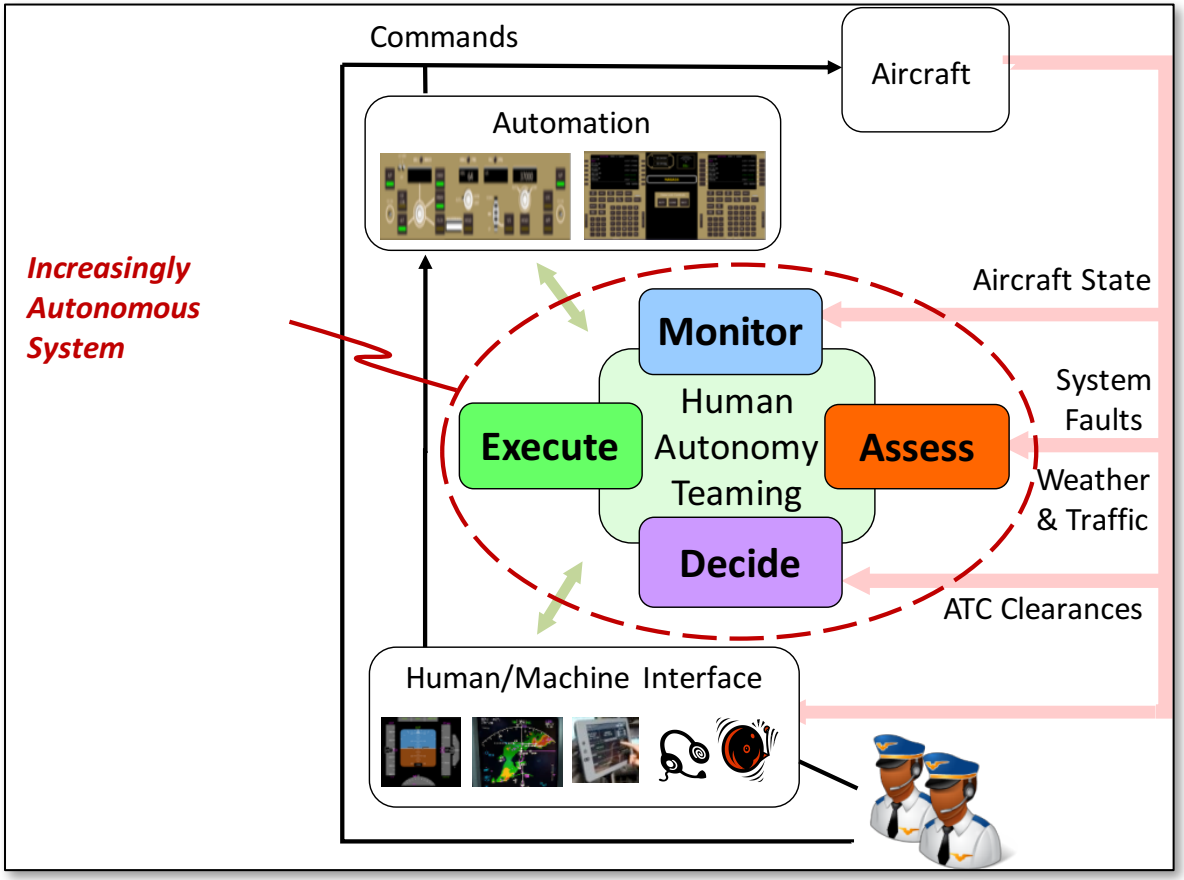
Watson, A. B., & Ahumada, A. J., Jr. (2005). Spatial Standard Observer for Visual Technology. Paper presented at the IEEE International Conference on Systems, Man, and Cybernetics (SMC).

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



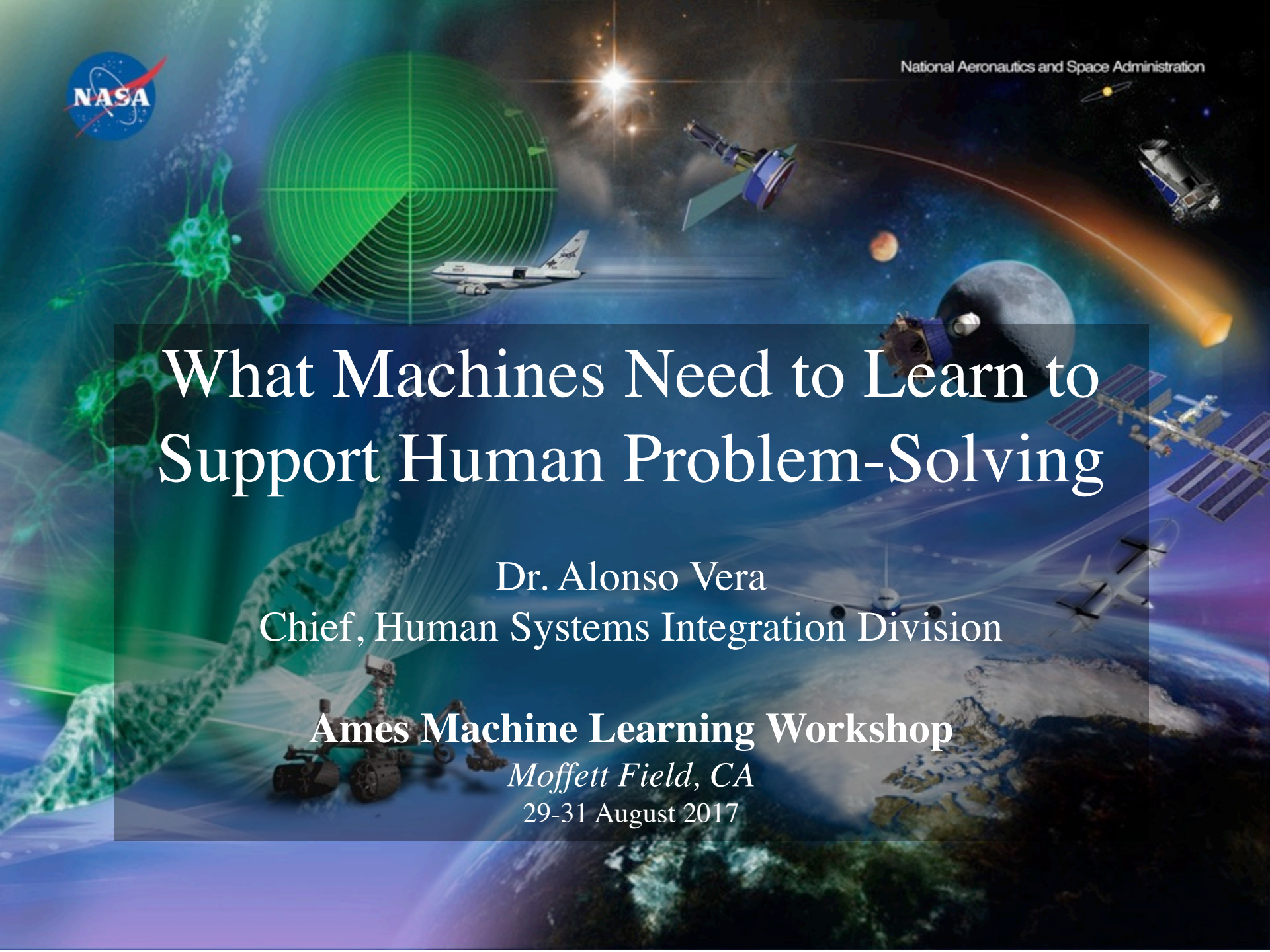
Intelligent Systems and Humans

Fundamental difference between developing machine learning to effectively support human problem solving and interfacing with human problem solvers. Work needed on both challenges.



Independent of how a system communicates with humans, its core functionality needs to be designed and around human capabilities, *yet we don't always know what those are.*

From SECAT briefing package, Aponsonet al., 09/2016



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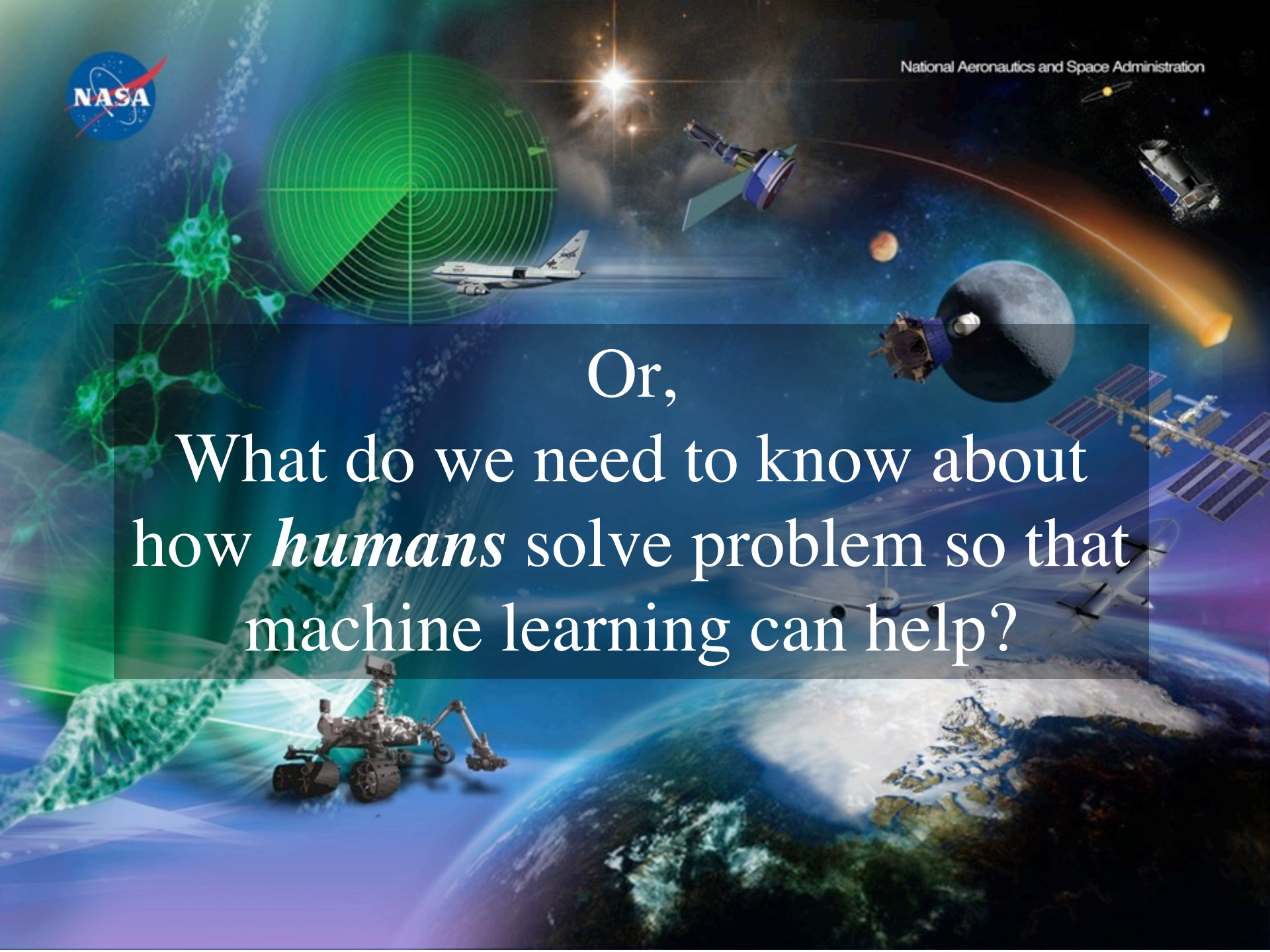
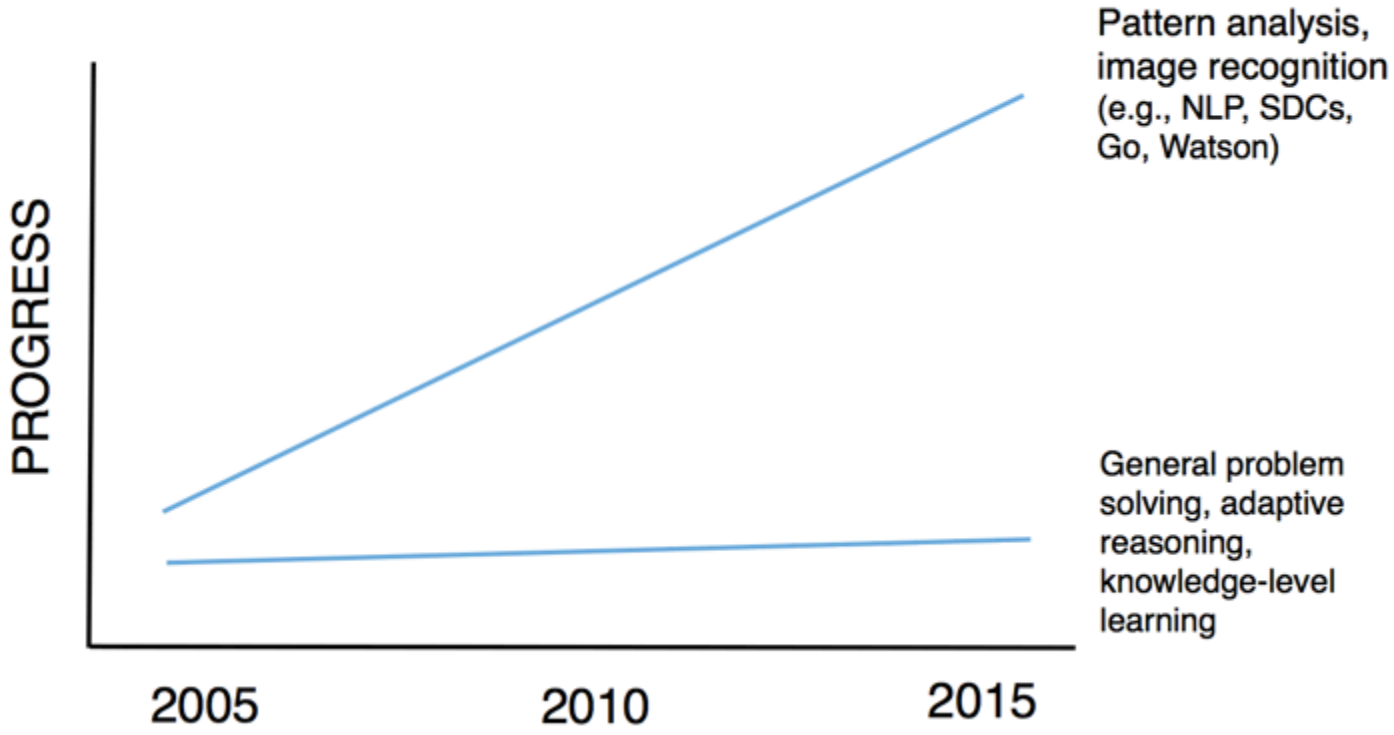

National Aeronautics and Space Administration
NASA
Or,
What do we need to know about how *humans* solve problem so that machine learning can help?

Three Underlying Assumptions

1. Machine learning is progressing down a different path than human learning
2. Humans are both the limiting and enabling elements of complex functional systems
3. Need to consider nominal and off-nominal situations separately

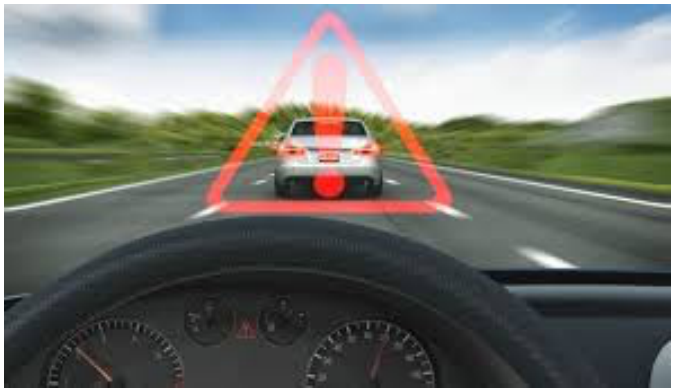
Machine Learning Path

- Machine learning is progressing down a different path than human learning



Self-Driving Cars

Driving is a low cognitive demand activity (most of the time)



- About 5 years of SDC trials
- Currently at around 1 critical disengage per 40,000 miles

- Humans Drivers:
  - 1.2 fatal accidents per 100,000,000 miles driven
  - 99 injury accidents per 100,000,000 miles driven ~ 1 injury accident per 1,000,000 m

- Control Center provides high-level goals when vehicle requires assistance
  - Time from software hand-back to human control ~ 1min

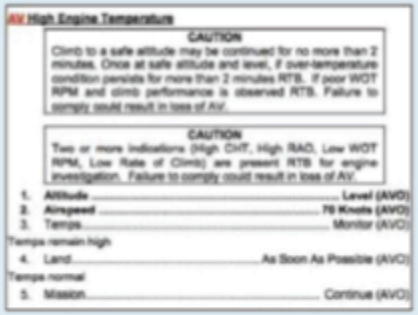
- *Vehicles can drive paths they "know"*
- Vehicle responsible for own safety
- Vehicle control not handed back to human in emergency

Humans as Limiting/Enabling

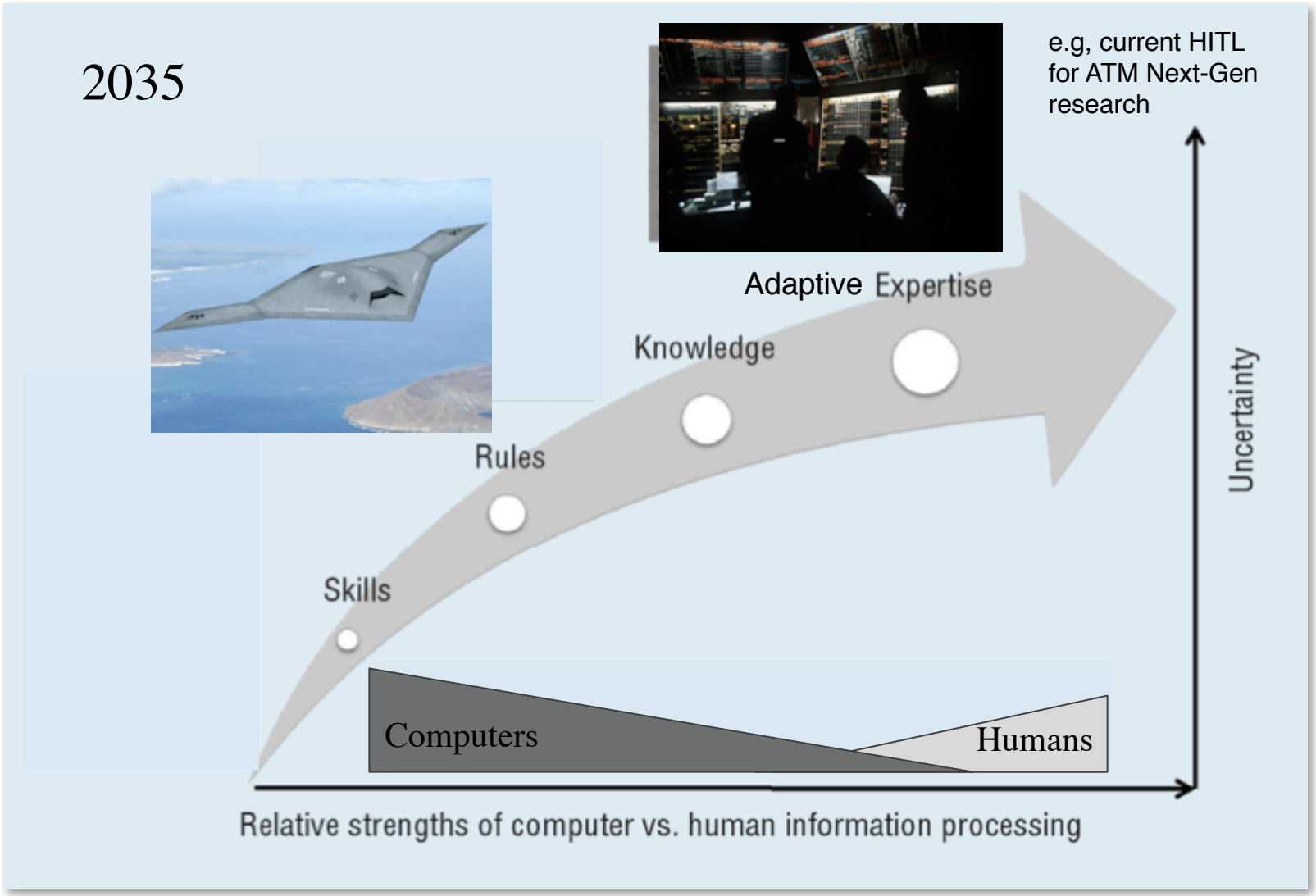
- **What kinds of problems are amenable to current machine learning approaches:**
  - NLP and translation
  - Recognition/classification tasks (e.g., melanoma detection)
- **Problems with Scarce data:**
  - Challenger, Columbia
- **Many have both: e.g., driving**

  Human learning system appears optimized for learning from little data combined with strong induction. E.g., language acquisition. Pilots report solving unexpected safety issues 20% of flights.

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.

Human Expertise & Problem-Solving

"In an information-rich world, the wealth of information means a dearth of something else: a scarcity of whatever it is that information consumes. What information consumes is rather obvious:

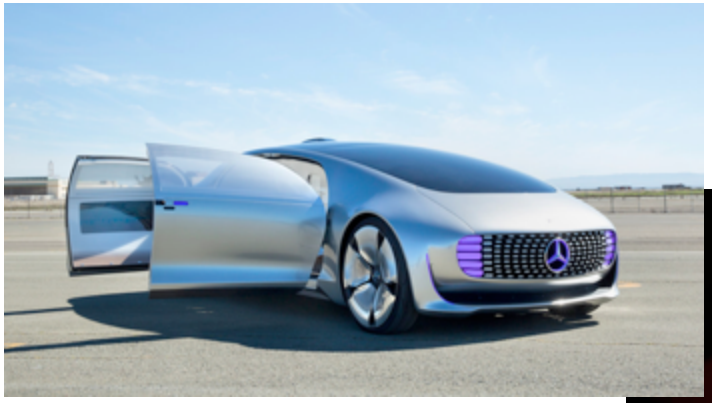
— *Herbert A. Simon*

Human Expertise & Problem-Solving

> "In an information-rich world, the wealth of information means a dearth of something else: a scarcity of whatever it is that information consumes. What information consumes is rather obvious: it consumes the ***attention*** of its recipients. Hence a wealth of information creates a poverty of attention and a need to allocate that attention efficiently among the overabundance of information sources that might consume it."

— *Herbert A. Simon*

Using Affordances



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

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 for Human-Systems Integration Researchers:

Help characterize those aspects of human performance that will allow the enabling capabilities of the human to function effectively when teamed with machine intelligence.

Final Thoughts

- **Humans will remain important components of complex systems**
- **Use human adaptive expertise as much as possible**
- **Understand where humans are limiting components of system performance and focus machine intelligence there**
  - Non-Bayesian
  - Limited working memory
  - Low, slow access to long-term memory
  - Single-threaded attention
  - Systematic reasoning biases
- **Be aware of areas where you don't have big data**
  - Don't assume pattern association can solve all problems (Not all problems are associative in nature)

Thank you