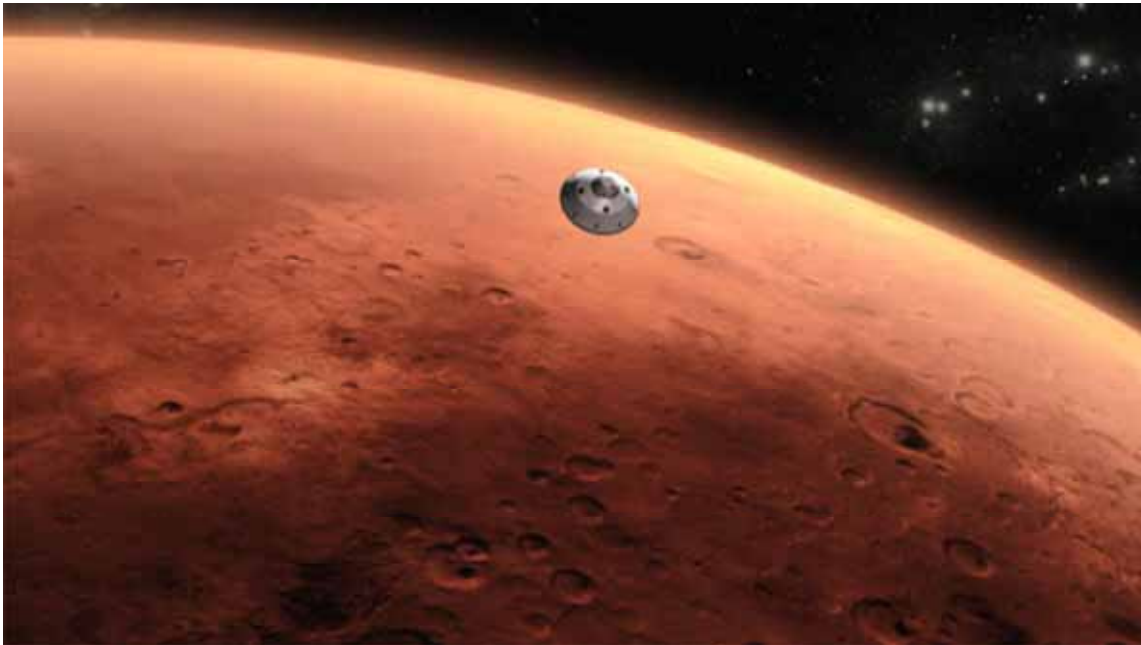


Embodied Cognition for a Mission to Mars



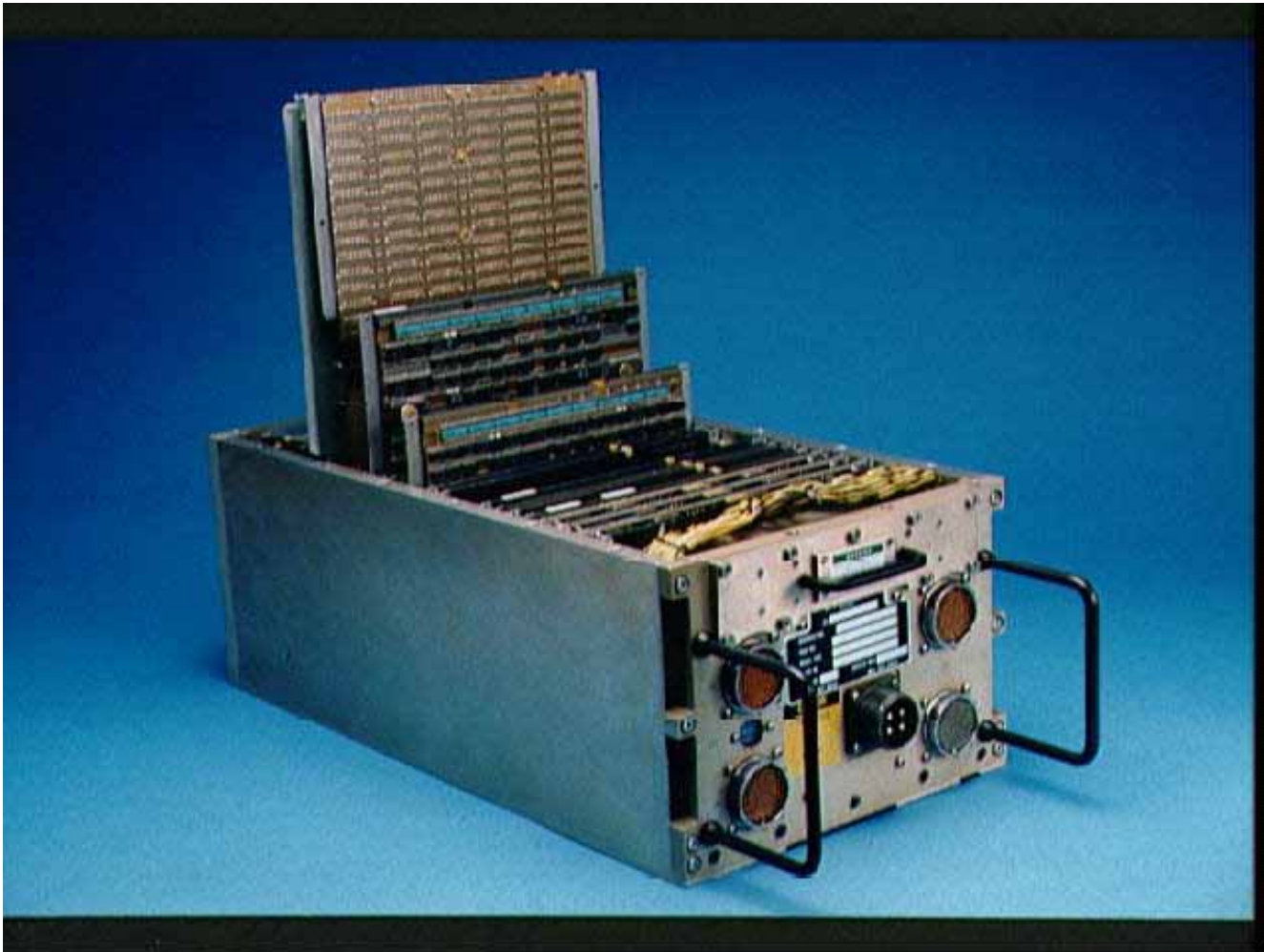
*Grady Booch
IBM Fellow
Chief Scientist, Project Intu*

*Dr. Chris Codella
IBM Distinguished Engineer
CTO Government Cognitive*









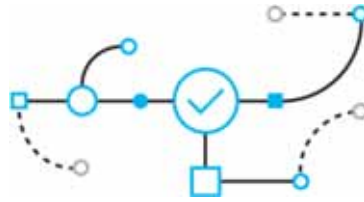


Three capabilities differentiate cognitive systems from traditional programmed computing systems...



Understanding

Cognitive systems understand like humans do.



Reasoning

They reason. They understand underlying ideas and concepts. They form hypothesis. They infer and extract concepts.



Learning

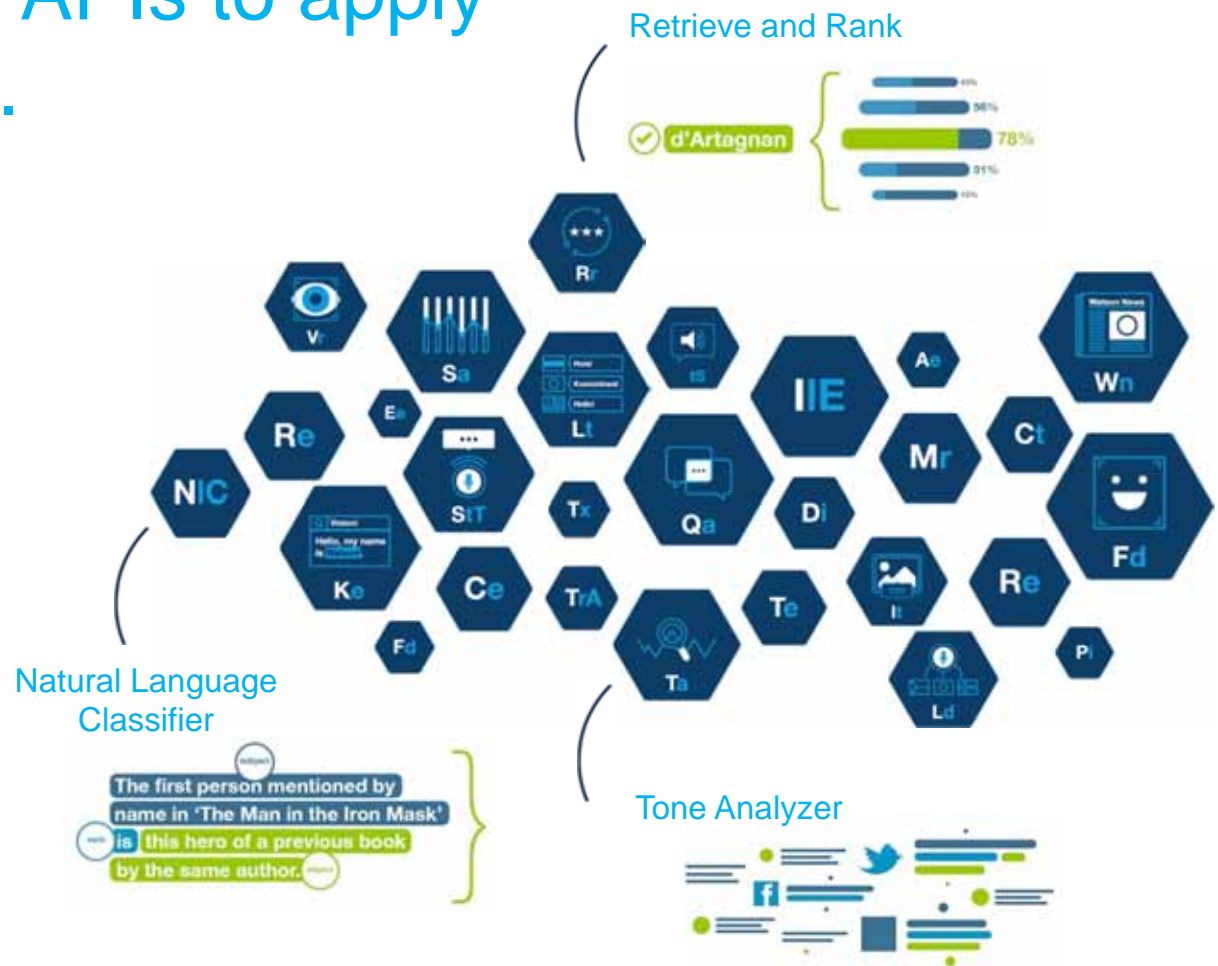
They never stop learning getting more valuable with time. Advancing with each new piece of information, interaction, and outcome. They develop “expertise”.

.... allowing them to interact with humans.

We leverage Watson APIs to apply cognitive capabilities.

50 underlying technologies

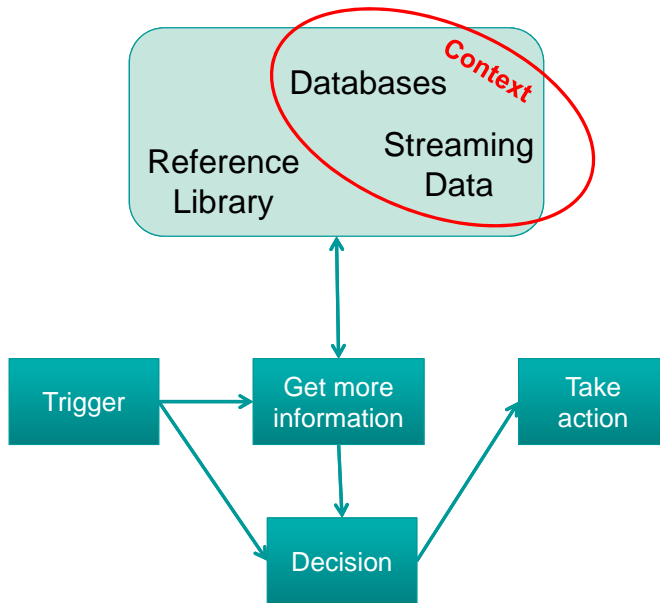
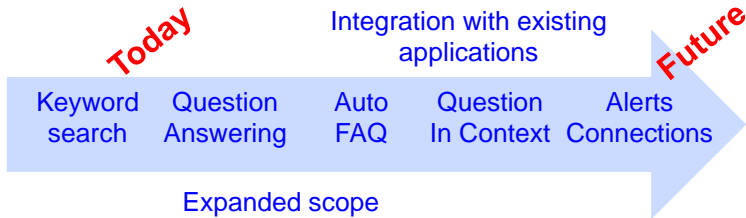
- | | |
|-------------------------|-----------------------------|
| Entity Extraction | Natural Language Classifier |
| Sentiment Analysis | Personality insights |
| Emotion Analysis (Beta) | Relationship Extraction |
| Keyword Extraction | Retrieve and Rank |
| Concept Tagging | Tone Analyzer |
| Taxonomy Classification | Emotive Speech to Text |
| Author Extraction | Text to Speech |
| Language Detection | Face Detection |
| Text Extraction | Image Link Extraction |
| Microformats Parsing | Image Tagging |
| Feed Detection | Text Detection |
| Linked Data Support | Visual Insights |
| Concept Expansion | Visual Recognition |
| Concept Insights | AlchemyData News |
| Dialog | Tradeoff Analytics |
| Document Conversion | |
| Language Translation | |



How Can Watson Help With Decision Making?



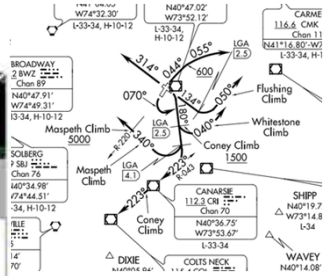
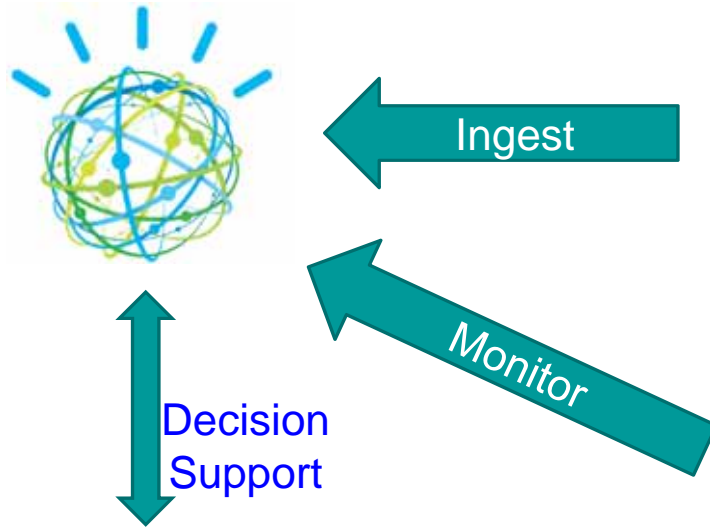
Flight Operations Advisor – Ames, Armstrong



Aerospace Innovation Advisor - Langley



Pilot Advisor – Langley, Armstrong



Pilot Advisor (Objectives)

- Goal:
 - Develop and demonstrate a pilot expert advisory system – a **human-autonomy teaming system** - which monitors and assesses in real-time the human, vehicle, and automation systems to ensure safe and efficient operations

- Principles:
 - Advance state-of-the-art in Human-Autonomy Teaming (HAT), Increasingly Autonomous Systems (IAS)
 - Create unique capabilities in Aerospace, exploiting Artificial Intelligence.
 - Address a present / emerging need in aviation operations.

- Initial Steps: Pilot Expert Advisor
 - Watson represents a first step into cognitive systems - a new era of computing, in significant, unique ways.

Pilot Advisor (Use Case)

- Goal:
 - Examine Cognitive Computing as a means of Aviation Knowledge Corpus Information Extraction
 - Use a specific incident / accident
 - If Watson would have been on-board would the returned information enlighten the crew as to the on-going issues / root causes
- Loss-of-airplane state awareness incident
 - Flight: Midwest Express 490 (B717-200)
 - Visibility and Weather: Night, IMC, convective activity in the area
 - Injuries/Fatalities: None / None (76 PAX + 4 crew)



Pilot Advisor (Corpus)

- Pilot Advisor Proof of Concept (PoC) Use Case
 - **1,147 files** ingested from 6 different data sources

- General Aviation Knowledge:
 - Aviation Weather
 - e.g., FAA AC 00-6A, Aviation Weather
 - Transport Canada, The Adverse Aerodynamic Effects of Inflight Icing on Airplane Ops
 - Regulatory
 - Title 14 CFR, Parts 1-59
 - Title 14 CFR, Parts 6-109
 - Title 14 CFR, Parts 110-199
 - Recurrent Training – Skybrary.aero
 - Manufacturer Guidance / Bulletins
 - Aviation Safety Reporting System (ASRS)
 - Make/Model = B717 .OR. Weather=Icing .OR. Text contains “pitot heat” .AND. Date of Incident between Jan 1988 – Apr 2005

Advisor (Corpus)

- Aviating:
 - Aeronautical Information Publication USA (23rd Edition)
 - FAA Airman's Information Manual
 - Aeronautics for Naval Aviators (NAVAIR 00-80T)
 - Adv. Avionics Handbook (FAA-H-8083.6)
 - Aviation Maintenance Technician Handbook (FAA-H-8083.31)
 - Pilot Handbook of Knowledge (FAA-H-8083.25B)
 - Weight and Balance Handbook (FAA-H-8083.1)
 - Instrument Flying Handbook (FAA-H-8083.16)
 - Pilot-Controller Glossary of Terms
 - Air Traffic Organization Safety Management System Manual
 - Flight Safety Foundation-Approach and Landing Accident Reduction (ALAR)
 - Adv. Maneuvering and Upset Recoveries with Alternate Control Strategies
 - Flight Briefing Notes on CRM Aspects in Accidents
 - Airplane Upset Recovery Training Aid
- Type Specific
 - B717 Maintenance Manual
 - B717 Airplane Flight Manual
 - B717 Flight Crew Operations Manual
 - B717 Master Minimum Equipment List
 - B717 Quick Reference Handbook

Pilot Advisor (Results)

IBM Watson
IBM

Notional Watson Use Case Interaction*

1. The captain initially focuses on RUDDER LIM FAIL alert

Watson can augment a pilot's previous experience, knowledge, and instincts by providing vast amounts of information that no human could remember or read in the time needed to respond:

"The procedure has to be shorter than your life expectancy at the moment" (NASA Researcher)

The screenshot shows the IBM Watson Discovery Advisor interface. The search bar contains the query "What is cause of rudder lim alert?". The results are categorized under "Key passages" and are sorted by relevance. The first passage discusses external factors like wind and engine issues. The second passage mentions jamming the rudder and inadequate system awareness. The third passage discusses rapid roll rates and pilot overreaction. On the right, there are "Hypotheses" listed: Anti-ice, CONFIG, Autopilot, Yaw, Airspeed, and EAD. A "Test a hypothesis" link is also visible.

2. The captain instructs the first officer to ask Watson: "What is cause of rudder lim alert?"

3. Watson returns hypotheses and supporting passages that indicate anti-ice as an issue

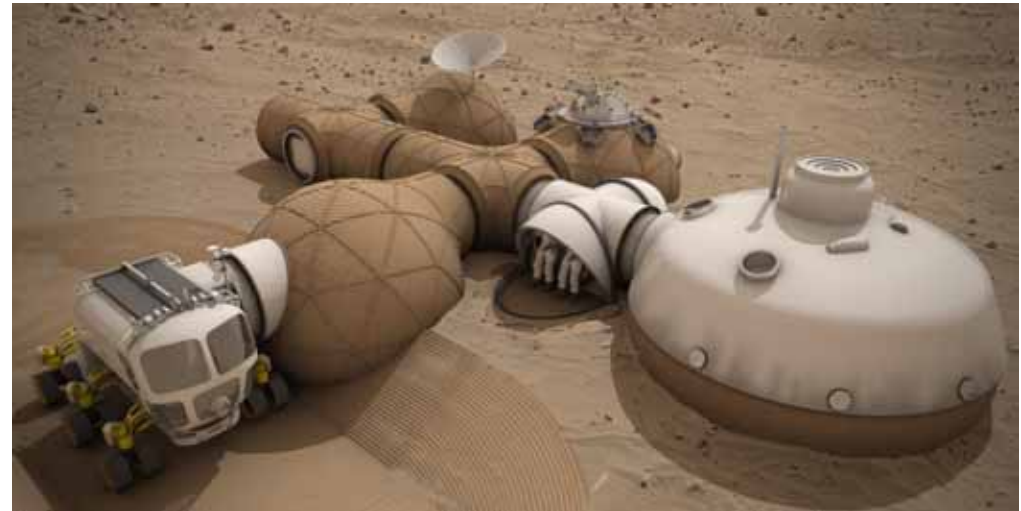
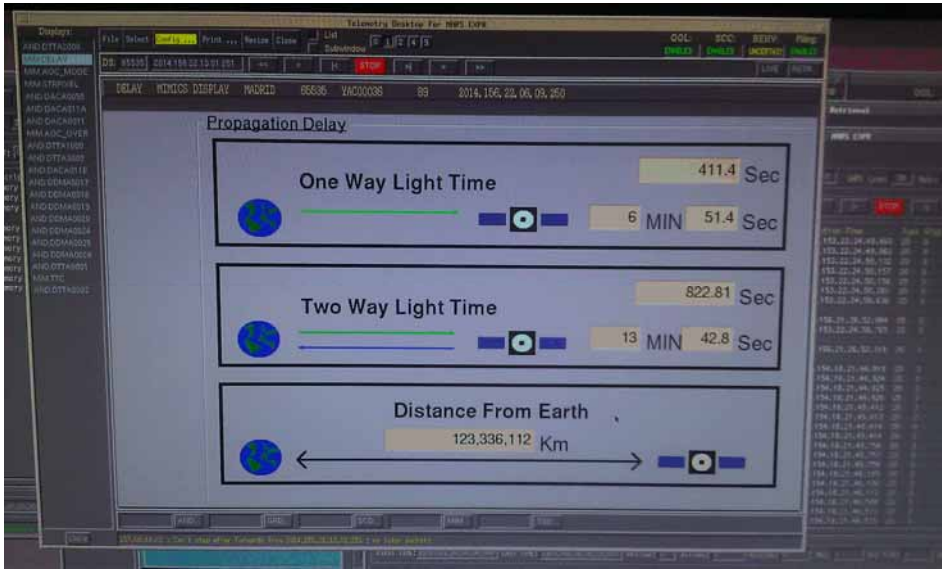
4. The captain uses his past experience with the hypotheses and passages from Watson to determine that he needs to engage the Air Data Heat (ADH) switch to prevent icing

7
kicon

Pilot Advisor (Future)

- Lexicon
 - Create a ‘natural language’ processor that is adapted to the ‘unnatural’ language of aviation.
 - Natural language processing of unstructured data is performed by the cognitive-computing pilot advisor, *but*:
 - Extensive use of acronyms and “spoken” acronyms;
 - Extensive use of “names” to associate geographical locations, e.g., waypoint identifier names;
 - Standardized radio communications phraseology, phonetics, and protocol;
 - Extensive list of “company” and “manufacturer” names which imply operational and capability constraints (e.g., “follow Boeing traffic, 3 miles at your 12 o’clock”); and,
 - Equipment (e.g., EICAS vs. ACAM)
- User Interface:
 - Meet pilot’s information requirements,
 - “The right information at the right time, the right way”
 - Not unique – Need to develop Human-Autonomy Teaming
 - Bi-Directional Communication
- Additional Watson Functionality / Capabilities
 - Deductive Reasoning / Root Cause Analysis





History of Project Intu

- March, 2015
 - Research begins regarding embodied cognitive architectures and their use cases.
- November, 2015
 - Grady Booch, Ray Chancey, and Rob High conceive of a system to support mission control, flight operations, and the scientific agenda of NASA's Mission to Mars.
- December, 2015 – November, 2016
 - In the context of several use cases across different form factors, Self is designed and built.
- November, 2016
 - Self (in binary form) is made public as an experimental release.
- July, 2017
 - Self (in open source form) is made public.

What Is Embodied Cognition?

- To be **embodied** means that an organism is in and of the world and that it can sense, react, and act in that world.¹
- To be **cognitive** means that an organism can reason and learn.
- An embodied cognitive organism has a identity that distinguishes itself from all other organisms (and is to a degree aware of its own identity).

¹ *To react means to behave in response to some (possibly complex) request or change of state in the world; to act means to behave in autonomous or semi-autonomous ways that take into account the pursuit of self-directed goals along with (possibly complex) immediate and historical context.*

Why Is Embodied Cognition Important?

- Cognitive processes develop when a tightly coupled system emerges from real-time, goal-directed interactions between organisms and their environment.¹
- True intelligence cannot emerge without embodiment.²
- Embodiment creates a sense of presence that contributes to a more natural augmentation of human intelligence.

¹ *Internet Encyclopedia of Philosophy* <http://www.iep.utm.edu/embodcog>

² *Booch*

What Is Project Intu?

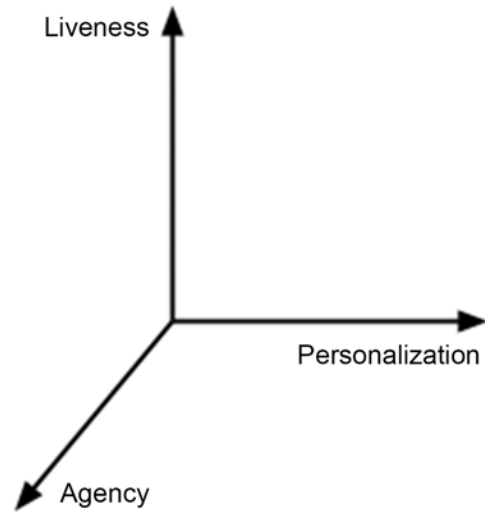
- **Project Intu** is an open source platform for embodied cognition, based on a cognitive architecture named Self.
- **Self** is an agent-based architecture that combines connectionist and symbolic models of computation, using blackboards for opportunistic collaboration.
- Project Intu provides a framework for orchestrating cognitive services in a manner that brings higher level cognition to an embodied system.

Motivation (Take One)

Imagine unleashing a cognitive system in the physical world. Give it eyes, ears, and touch, then let it act in that world with hands and feet and a face, not just as an action of force but also as an action of influence. This is **embodied cognition**: by placing a cognitive system in a robot, an avatar, an object in your hand, or even in the walls of an operating room, conference room, or spacecraft, we take the ability of a cognitive system to understand and reason and draw it closer to the natural ways in which humans live and work. In so doing, we augment individual human senses and abilities, giving us the ability to see a patient's complete medical condition, feel the flow of a supply chain, or orchestrate the tasks in a day in the life of an individual.

Motivation (Take Two)

We have seen incredible advances in the application of deep learning to natural language understanding, image understanding, decision making, planning, and even emotional interpretation. Assume for a moment that these components will become even more advanced...and that ultimately they will become commodities. How, then, might we combine the best of these diverse connectionist approaches with classical symbolic processing? This also is **embodied cognition**: by providing a platform that orchestrates different models of computation, we make it possible to leverage the strength of each in a manner that brings higher levels of cognition to systems with which humans may collaborate.



Resources

- Github <https://github.com/watson-intu/self>
- Slack¹ <https://intu-team.slack.com>
- Web² <http://projectintu.ai>

¹ Email egrady@booch.com for an invitation

² Under development

Platforms¹

- Linux
- Windows
- Mac OS
- Raspberry PI
- Softbank NAOQi OS²

¹ Project Intu is primarily designed to run on the edge, although it most certainly can run in the cloud; most often, Project Intu's kernel runs on the edge and accesses cognitive services in the cloud.

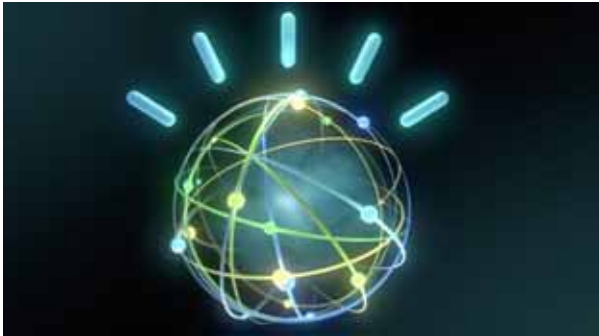
² Project Intu does not replace but may run on top of ROS, focused on providing higher cognitive functioning.

Form Factors (Robots)





Form Factors (Avatars)

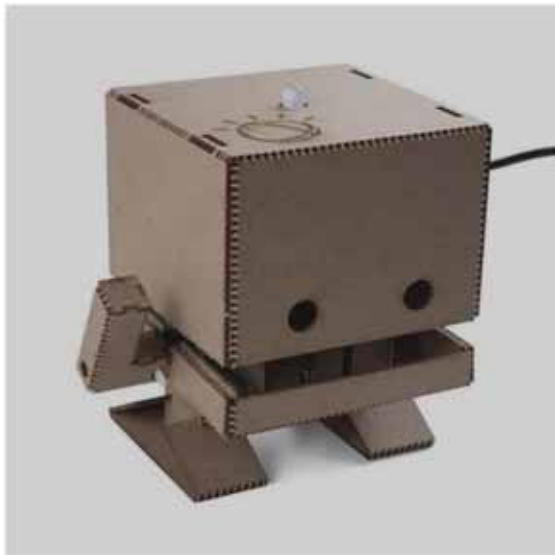




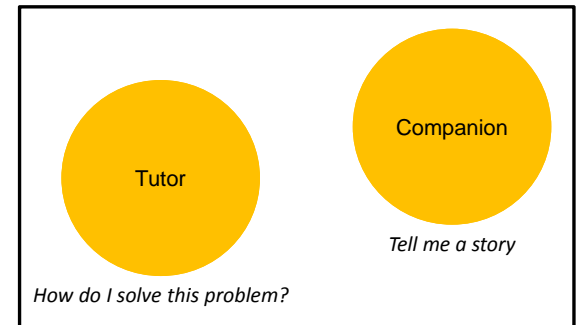
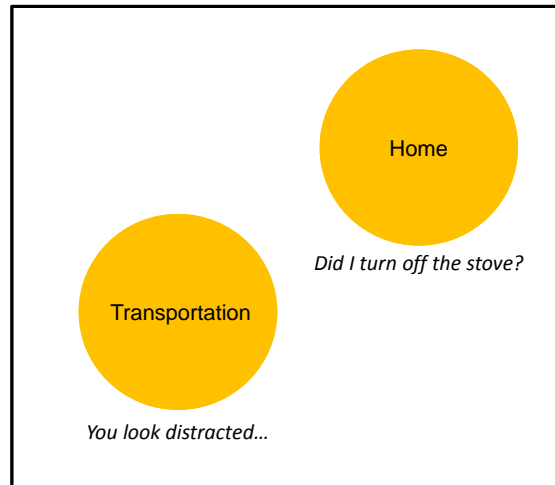
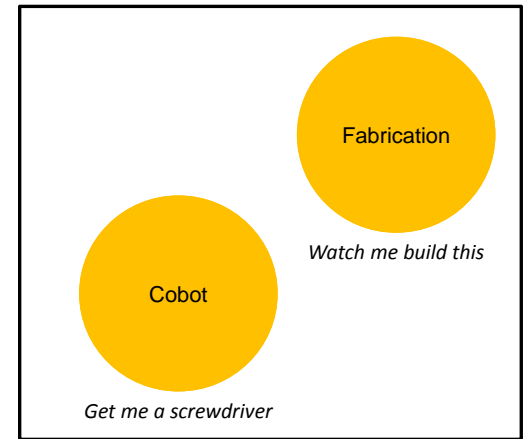
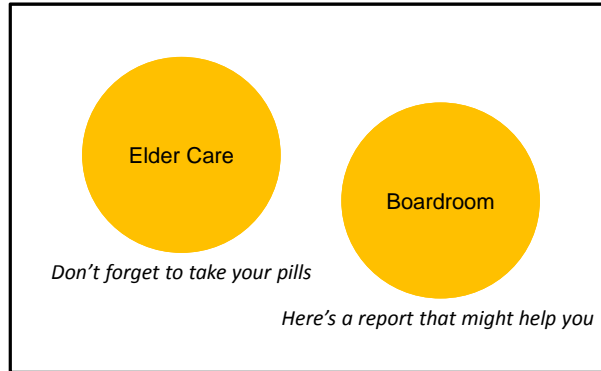
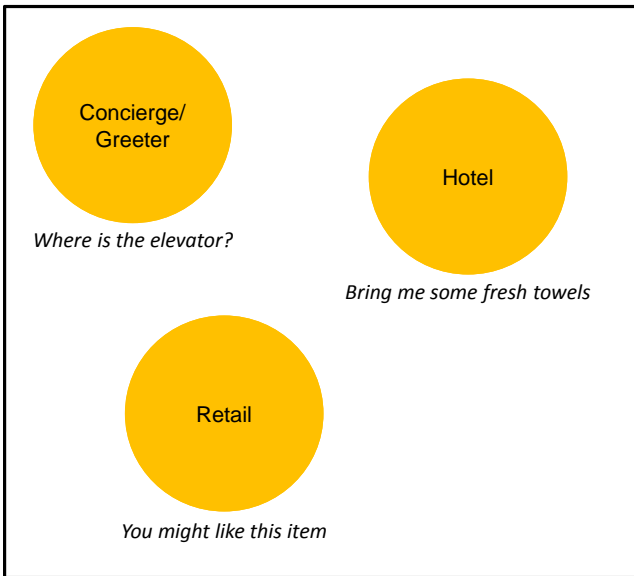
Form Factors (Spaces)



Form Factors (Objects)

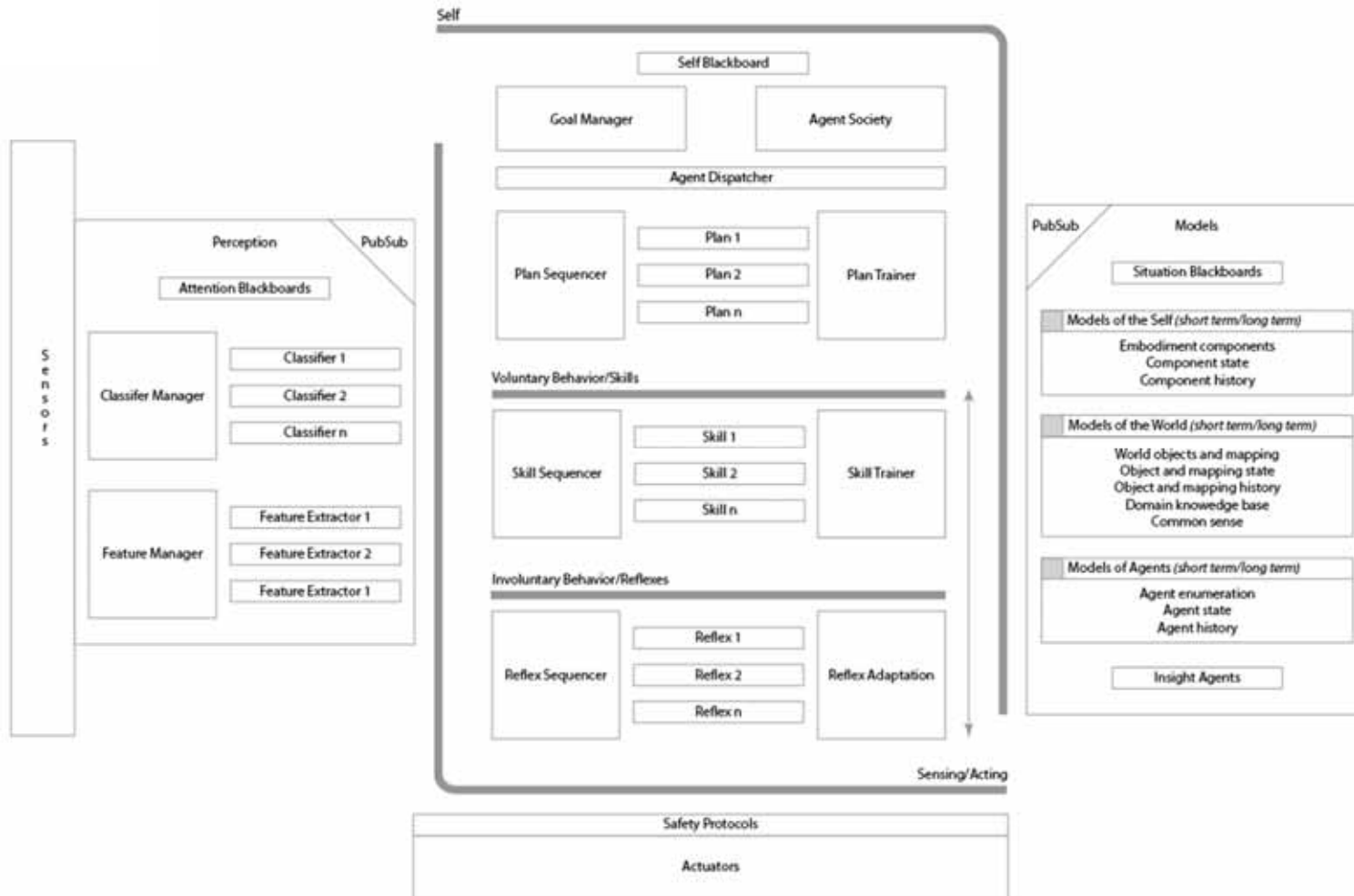


Use Cases

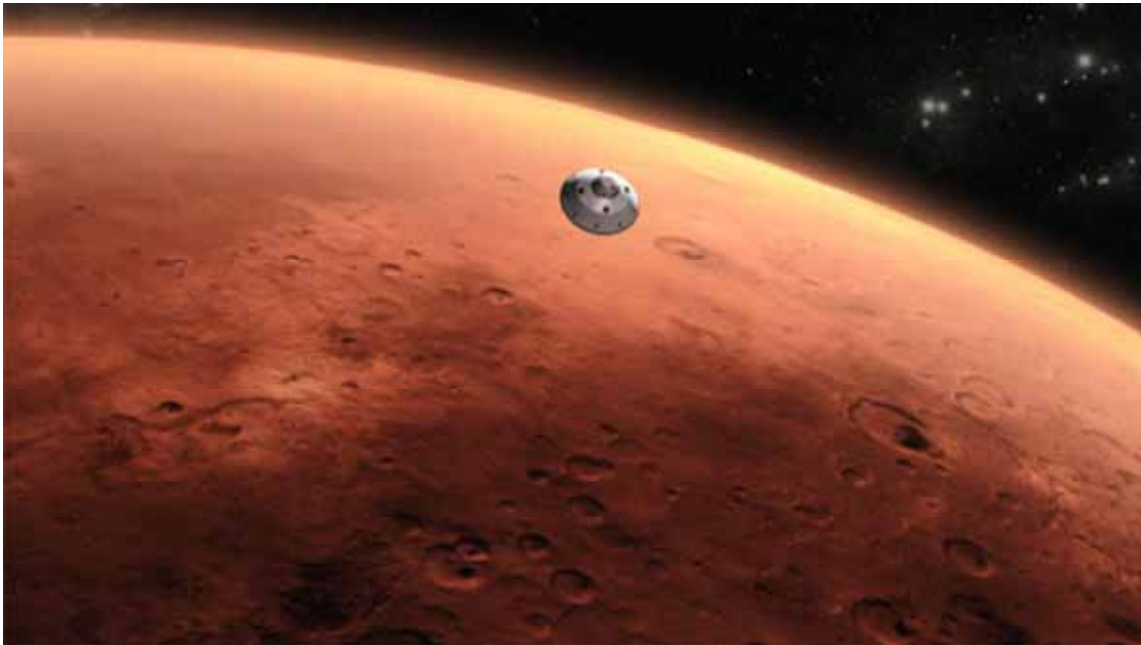


Self Architecture (Principles)

- Self is a hybrid architecture encompassing explicit symbolic computation at the center and neural networks at the edge.
- Inspired by Minsky's Society of Mind, behavior takes place in the context of multiple concurrent agents that communicate opportunistically via blackboards.
- Inspired by Brooks's subsumption architecture, behavior takes place in a hierarchy of cognition, from involuntary reflexes to voluntary skills to goals and planning.
- There is a clear separation of concerns among perception, actuating, models, and behavior.
- As much as possible, behavior is either taught or is learned, not programmed.
- As much as possible – driven by these separation of concerns, the needs of packaging, and performance – all components are made manifest as RESTful microservices.
- As much as possible, plans, skills, and reflexes are extensible.
- Self is intentionally full of strange loops: components of Self are also parts of the models of itself.
- Self is intentionally fractal: an instance of Self may have models of others, which themselves are other instances of Self.



Embodied Cognition for a Mission to Mars



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