Autonomous Horizons

System Autonomy in the Air Force

Dr. Greg Zacharias
Air Force Chief Scientist (AF/ST)

Outline

- Background and context
- Challenges to overcome
- Approaches to solutions
- Next steps

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- **Background and context**
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Categories

- HOT Products
- Highly Recommend
- High Power Jammer
- Portable Cell Phone Jammers
- Cell Phone Jammers
- 4G Jammer
- GPS Jammers
- WIFI Jammer
- Audio Jammer
- RF Jammers
- UHF/VHF Jammers
- Wireless Video Jammer
- LoJack and XM radio Jammer
- Jammer Accessories
- Cell Phone Signal Booster
- Radio Frequency

Home › GPS Jammers

Sort by: Featured Items

GPS Jammers

GPS Jammers Filter By Isolating Frequency

GPSL2:1220-1230MHz GPSL3:1200-1210MHz GPSL4:1250-1280MHz GPSL5:1170-1180MHz GPSL1:1500-1600MHz

GPS Jammers Effective Radius Range

GPS Jammers Jamming Functions

Show All GPS Jammers

Pages: 1 2 3 4 5 6 Next »

8 Bands Selectable Man-

10 Antenna 10 Band 3G 4G GPS

15W 6 Antenna Mobile Phone GPS

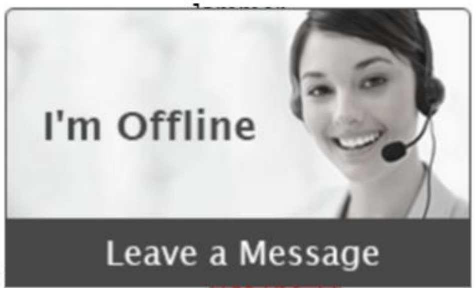
20W Powerful Desktop GPS 3G

Current Top Sellers

Mini GPS jammer for Car
US$57.90

2 Mini GPS Satellite Isolator
US$64.99

3 Mini Portable Cell phone & GPS



Autonomy Could Transform Many Air Force Missions

Remotely Piloted Vehicles

Manned Cockpits

Space

Cyber Operations

C2&ISR

Air Traffic Control

DSB 2012 Autonomy Study: Recommendations

- **The Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) should work with the Military Services to establish a coordinated S&T program with emphasis on:**
  - **Natural user interfaces and trusted human-system collaboration**
  - **Perception and situational awareness to operate in a complex battle space**
  - **Large-scale teaming of manned and unmanned systems**
  - **Test and evaluation of autonomous systems**
- **These emphasis areas have driven DoD's Autonomy Community of Interest Tier I Technology Areas*:**

Human/Autonomous System Interaction and Collaboration (HASIC)

Machine Perception, Reasoning and Intelligence (MPRI)

Scalable Teaming of Autonomous Systems (STAS)

Test, Evaluation, Validation, and Verification (TEVV)

*Dr. Jon Bornstein, "DoD Autonomy Roadmap: Autonomy Community of Interest", NDIA 16th Annual Science & Engineering Technology Conference, Mar 2015.

DSB 2015 Autonomy Study: Terms of Reference

- **The study will ask questions such as:**
  - What activities cannot today be performed autonomously? When is human intervention required?
  - What limits the use of autonomy? How might we overcome those limits and expand the use of autonomy in the near-term as well as over the next two decades?
- **The study will also consider:**
  - Applications to include:
    - Decision aids, planning systems, logistics, surveillance, and war-fighting capabilities
  - The international landscape, identifying key players (both commercial and government), relevant applications, and investment trends
  - Opportunities such as:
    - Use of large numbers of simple, low cost (ie, "disposable") objects
    - Use of "downloadable' functionality (e.g., apps) to repurpose basic platforms
    - Varying levels of autonomy for specific missions rather than developing mission-specific platforms
- **The study will deliver a plan that identifies barriers to operationalizing autonomy and ways to reduce or eliminate those barriers**

DSB 2015 Autonomy Study: Status

- **Still awaiting release of the Report**
- **But we can infer some conclusions from DepSecDef (Mr. Work) from his comments last December's CNAS Inaugural National Security Forum**

*Third Offset Building Blocks**

- **Autonomous deep learning systems**
  - **Coherence out of chaos: Analyzes overhead constellation data to queue human analysts (National Geospatial Agency)**
- **Human-machine collaboration**
  - **F-35 helmet portrayal of 360 degrees on heads up display**
- **Assisted human operations**
  - **Wearable electronics, heads-up displays, exoskeletons**
- **Human-machine combat teaming**
  - **Army's Apache and Gray Eagle UAV, and Navy's P-8 aircraft and Triton UAV**
- **Network-enabled semi-autonomous weapons**
  - **Air Force's Small Diameter Bomb (SDB)**

*Keynote by Defense Deputy Secretary Robert Work at the CNAS Inaugural National Security Forum, December 14, 2015

A Spectrum of Autonomous Solutions*

- **Assisted/enhanced human pe… e**
  - **Wearable electronics, heads-… s, exoskeletons**
  - **711th HPW enhanced sensory… motor architecture**
- **Human-machine collaboration… n-aiding)**
  - **Humans teaming with autono… ems**
  - **Cyborg Chess; Pilot's Associ… elmet**
- **Human-machine collaboration… teaming)**
  - **Humans teaming with autono… forms**
  - **AFSOC Tactical Off-board Se… anced Technology Demonstration (…**
- **Autonomous "deep learning"…**
  - **Autonomous systems that lea… ne and "big data"; tactical learning, emergent behavior, …**
  - **AFRL's Autonomous Defensiv… perations (ADCO)**
- **Cyber-secure and EW-harde… onomous weapons**
  - **AF's Small Diameter Bomb (SD… PS-denied operation**

Autonomy

711th Human Performance Wing BATMAN project

Altius UAV Demo

* Based on Keynote by Defense Deputy Secretary Robert Work at the CNAS Inaugural National Security Forum, December 14, 2015

Need Effective Synergy of the Human/Autonomy Team

- **Main benefits of autonomous capabilities are to extend and complement human performance, not necessarily provide a direct replacement of humans**
  - **Extend human reach (e.g., operate in more risky areas)**
  - **Operate more quickly (e.g., react to cyber attacks)**
  - **Permit delegation of functions and manpower reduction (e.g., information fusion, intelligent information flow, assistance in planning/replanning)**
  - **Provide operations with denied or degraded comms links**
  - **Expand into new *types* of operations (e.g., swarms)**
  - **Synchronize activities of platforms, software, and operators over wider scopes and ranges (e.g., manned-unmanned aircraft teaming)**
- **Synergistic human/autonomy teaming is critical to success**
  - **Coordination and collaboration on functions**
  - **Overseeing what each is doing and intervening when needed**
  - **Reacting to truly novel situations**

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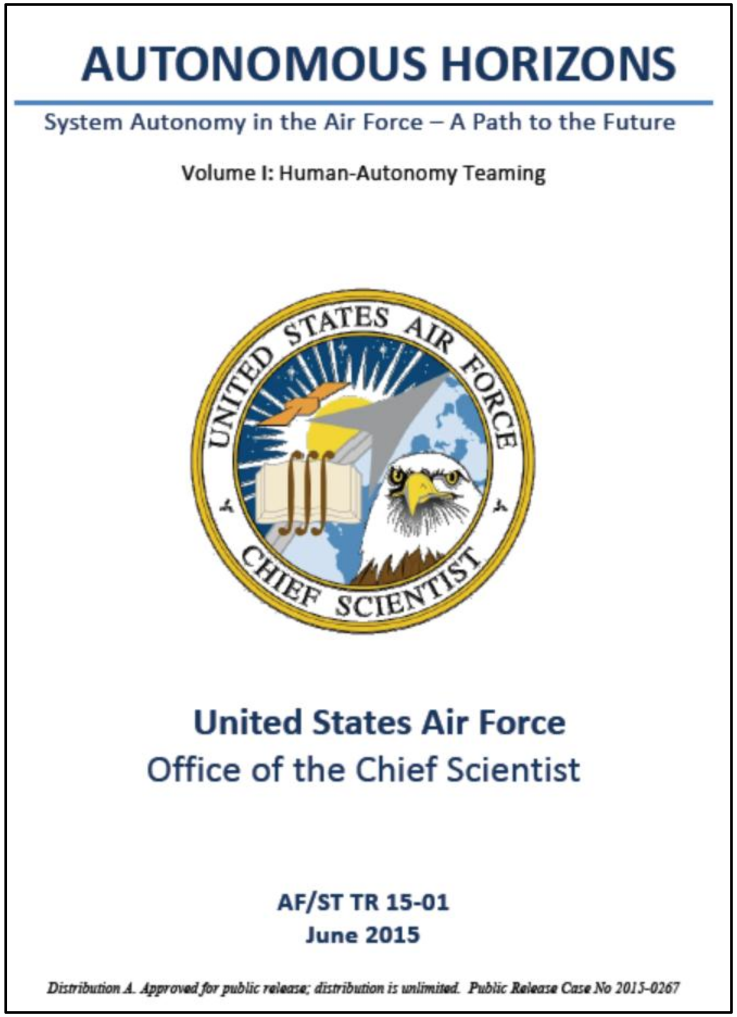
AUTONOMOUS HORIZONS

System Autonomy in the Air Force – A Path to the Future

Volume I: Human-Autonomy Teaming

United States Air Force
Office of the Chief Scientist

AF/ST TR 15-01
June 2015

Distribution A. Approved for public release; distribution is unlimited. Public Release Case No 2015-0267

Lessons Learned from Automation

- Traditional approaches to automation lead to "out-of-the-loop" errors (low mission SA)
  - Loss of situation awareness
    - Vigilance and complacency, changes in information feedback, active vs. passive processing
  - Slow to detect problems and slow to diagnose
- Previous systems have led to poor understanding of the system's behavior and actions (low system SA)
  - System complexity, interface design, training
  - Raft of "mode awareness" incidents in commercial aviation after flight management systems (FMS) introduced
- Can actually increase operator workload and/or time required for decision-making
- Trust and its impact on over- and under-usage

Does Automation Reduce Workload?

- Automation of least use when workload highest (Bainbridge, 1983)
- Pilots report workload same or higher in critical phases of flight (Wiener, 1985)
- Initiation of automation when workload is high increases workload (Harris, et al, 1994; Parasuraman, et al, 1994)
- Elective use of automation not related to workload level of task (Riley, 1994)
- Subjective workload high under monitoring conditions (Warm, et al, 1994)

Trust in Autonomous Systems

- **Autonomous decisions can lead to high-regret actions, especially in uncertain environments → Trust is critical if these systems are to be used**
  - **Current commercial applications tend to be in mostly benign environments, accomplishing well understood, safe, and repetitive tasks. Risk is low.**
  - **Some DoD activity, such as force application, will occur in complex, unpredictable, and contested environments. Risk is high.**
- **Barriers to trust in autonomy include those normally associated with human-human trust, such as low levels of:**
  - **Competence, dependability, integrity, predictability, timeliness, and uncertainty reduction**
- **But there are additional barriers associated with human-machine trust:**
  - **Lack of analogical "thinking" by the machine (e.g., neural networks)**
  - **Low transparency and traceability; system can't explain its own decisions**
  - **Lack of self-awareness by the system (system health), or environmental awareness**
  - **Low mutual understanding of common goals, working as teammates**
  - **Non-natural language interfaces (verbal, facial expressions, body language, …)**

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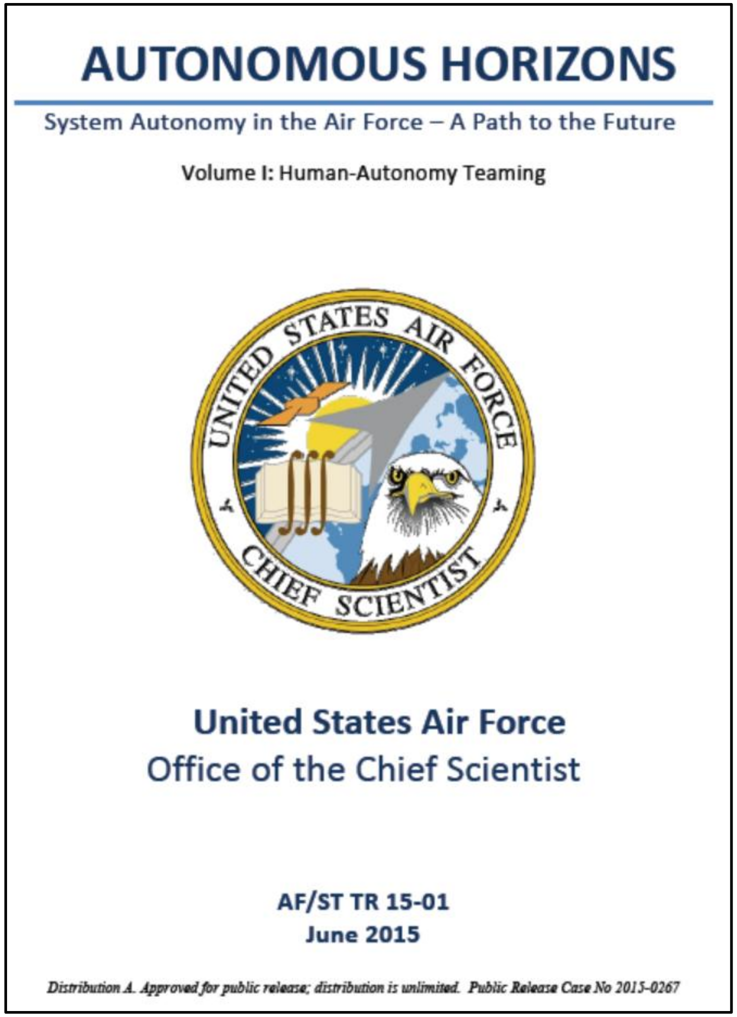
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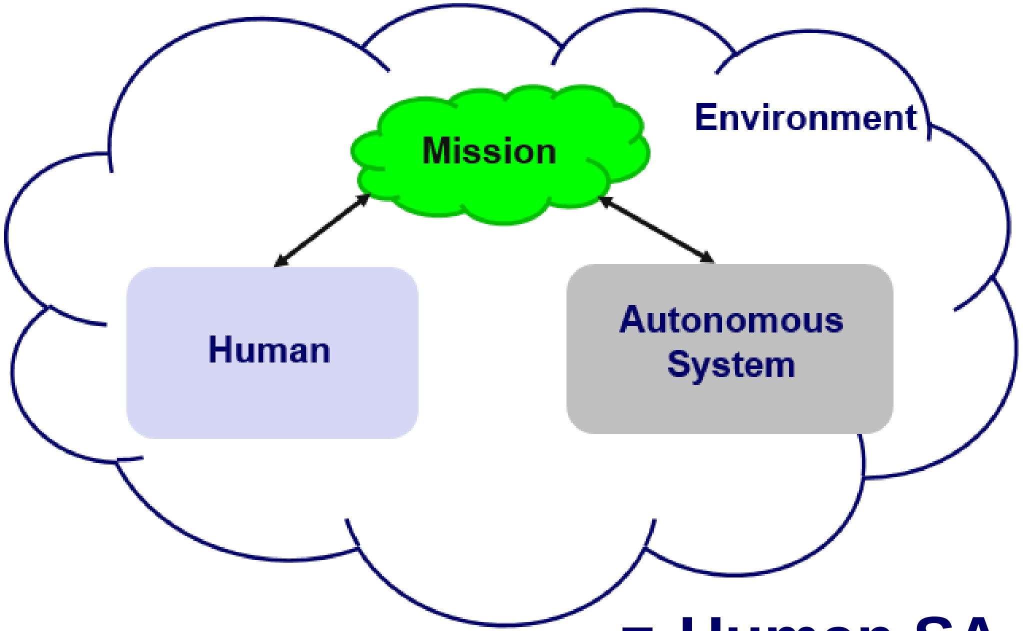
SA is Critical to Autonomy Oversight and Interaction



- **Human SA of**
  - Environment
  - Mission
  - Self
  - System
- **System SA of**
  - Environment
  - Mission
  - Self
  - Human

SA Levels and their Components

Human

- Data validity
- Automation Status
- Task Assignments
- Task Status
- Current Goals

- Impact of Tasks on Autonomy Tasks
- Impact of Tasks on System/Environment
- Impact of Tasks on Goals
- Ability to Perform Assigned Tasks

- Strategies/Plans
- Projected actions

Perception

Comprehension

Projection

Autonomy

- Data validity
- Human Status
- Task Assignments
- Task Status
- Current Goals

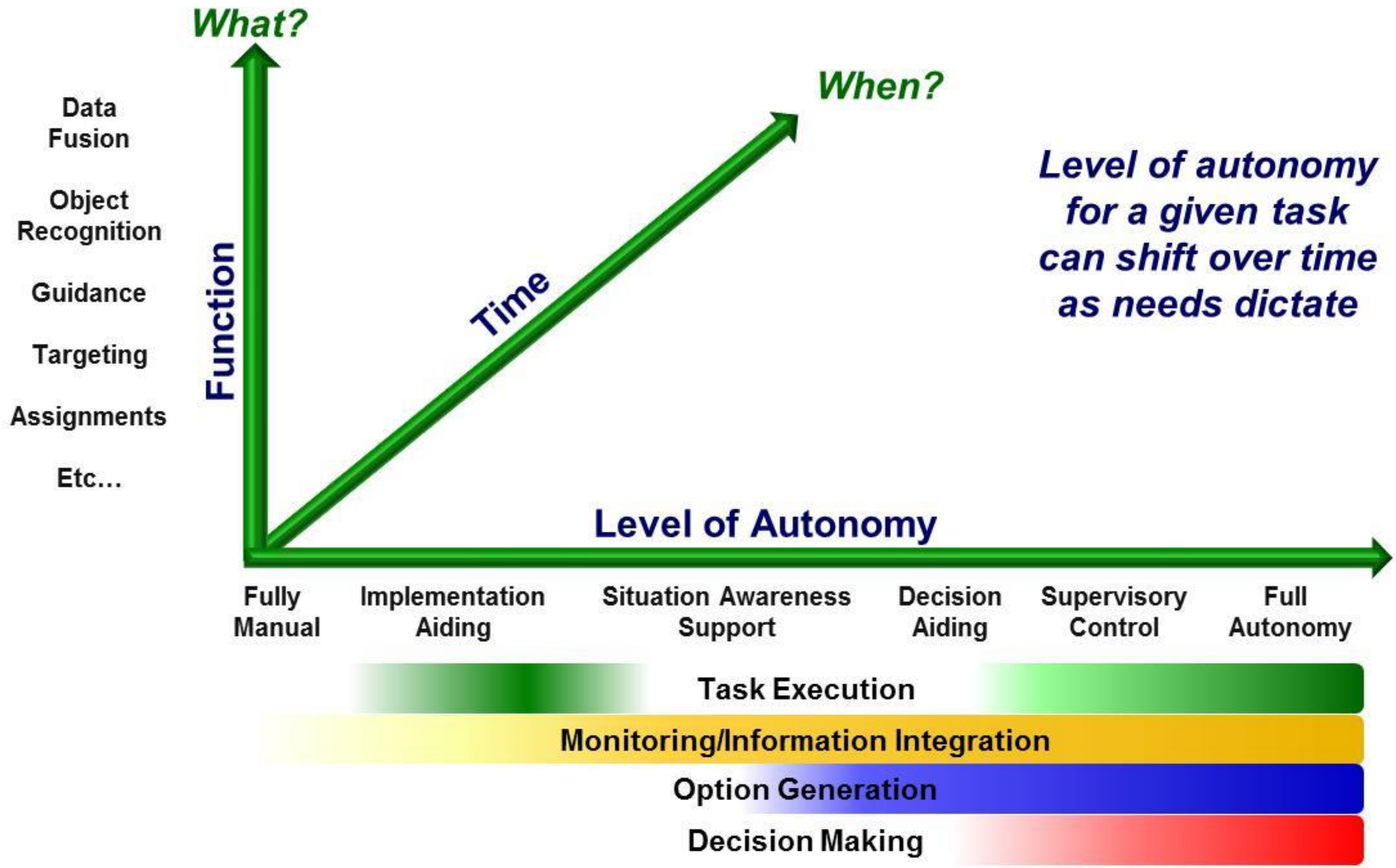
- Impact of Tasks on Human Tasks
- Impact of Tasks on System/Environment
- Impact of Tasks on Goals
- Ability to Perform Assigned Tasks

- Strategies/Plans
- Projected actions

Reducing Workload and Reaction Time, and Improving Performance

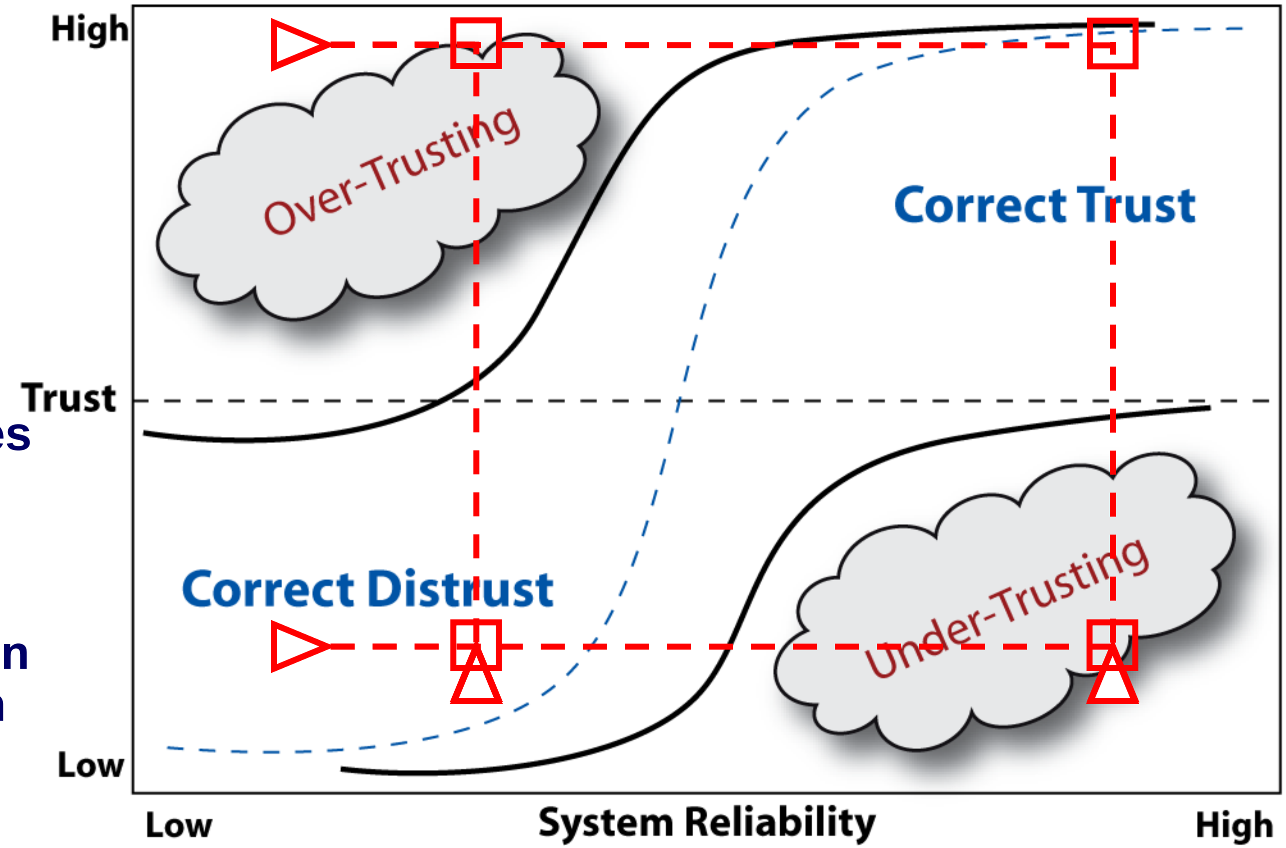
- **Supervised, flexible autonomy**
  - **Human in ultimate control: Can oversee, modify behavior as needed**
  - **Autonomy levels available that can shift over time as needed**
- **Benefits of autonomy depend on where applied**
  - **Significant benefits from autonomy that transfers, integrates, and transforms information to that needed (Level 1 and Level 2 SA)**
  - **But filtering can bias attention, deprive projection (Level 3 SA)**
  - **Significant benefit from autonomy that carries out tasks**
  - **Performance can be degraded by autonomy that simply generates options/strategies**
- **Flexible autonomy: Ability to switch tasking from human to automation and back over time and changes in mission tasks**
  - **Provides maximum aiding with advantages of human**
  - **Must be supported through the interface**
  - **Keep humans in the loop**

Flexible Autonomy



Trust: Over, Under, and Just Right

- **Simple model showing partitioned trust/reliability space***
- **Can use to explore transitions in trust and reliability over time**
- **But trust depends on many other factors**
- **And trust, in turn, drives other system-related behaviors, particularly usage by the operator**
- **But there's more we can do in the way of design and training…**



*Kelley et al, 2003

Ways to Improve Human Trust of Autonomous Systems (1 of 2)

- **Cognitive congruence or analogical thinking**
  - Architect the system at the high level to be congruent with the way humans parse the problem
  - If possible, develop aiding/automation knowledge management processes along lines of the way humans solve problem
  - Example is convergence of Endsley's SA model with the JDL fusion model
- **Transparency and traceability**
  - Explanation or chaining engines
  - If the system can't explain its reasoning, then the human teammate should be able to drill down and trace it
  - Context overviews and visualizations at different levels of resolution
  - Reducing transparency by making systems too "human-like" has the *added* problem of over-attribution of capability by the human user/teammate
    - Visually, via life-like avatars, facial expressions, hand gestures, ...
    - Glib conversational interface (e.g., Eliza)

Ways to Improve Human Trust of Autonomous Systems (2 of 2)

- **“Self-consciousness” of system health/integrity**
  - **Metainformation on the system data/information/knowledge**
  - **Health management subsystems should monitor the comms channels, knowledge bases, and applications (business rules, algorithms, …)***
  - **Need to go far beyond simple database integrity checking and think in terms of consistency checkers at more abstract levels, analogs to flight management health monitoring systems, …**
- **Mixed initiative training**
  - **Extensive human-system team training, for nominal and compromised behavior**
  - **To understand common team objectives, separate roles and how they co-depend**
  - **To develop mutual mental models of each other, based on expectations for competence, dependability, predictability, timeliness, uncertainty reduction, …**

*Yes, it’s turtles all the way down

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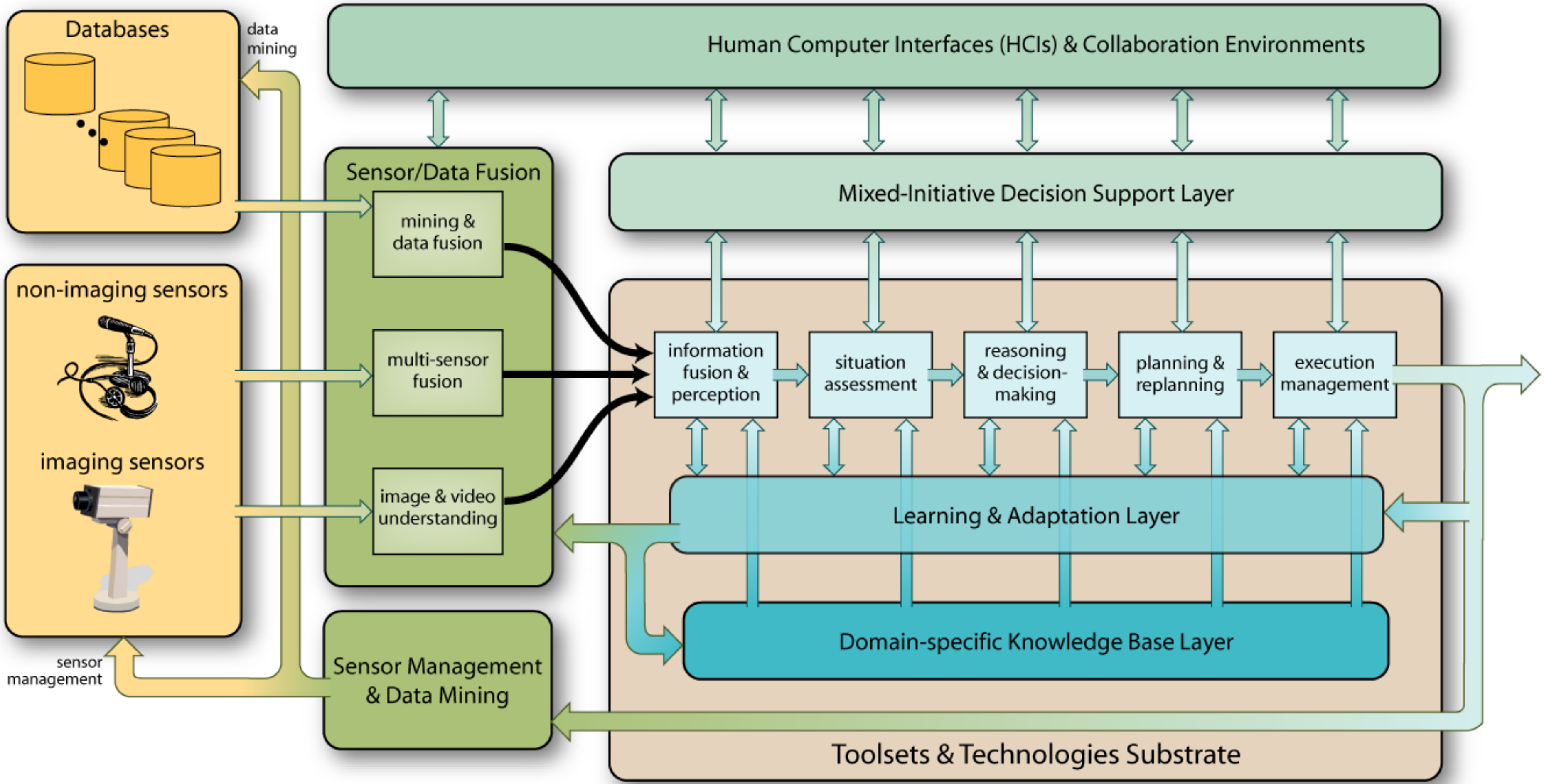
Four Tracks Towards Autonomy (1 of 2)

- **Cybernetics**
  - 1940's: *The scientific study of control and communications in the animal and the machine* (Norbert Weiner)
  - 50's – 70's: Manual control (e.g., flight simulators)
  - 70's – 90's: Supervisory control (e.g., FMS)
  - 90's – present: Cognitive models with a systems bent (e.g., COGNET, SAMPLE)
- **Symbolic Logic ("hard" AI)**
  - 50's: Turing Test, "Artificial Intelligence" Dartmouth Symposium, General Problem Solver (Newell and Simon)
  - 60's – 80's: Symbolic/linguistic focus, expert systems, logic programming, planning and scheduling
  - 80's – present: Cognitive models with a logic bent (e.g., Soar)

Four Tracks Towards Autonomy (2 of 2)

- **Computational Intelligence ("soft" AI)**
  - 40's: Artificial Neural Networks (ANNs)
  - 50's: ANNs with Learning (Turing again, Hinton, LeCun)
  - 60's – present: Genetic/Evolutionary Algorithms (Holland, Fogel)
  - 60's – 90's: Fuzzy Logic (Zadeh)
  - 80's – present: Deep Learning
    - *We've ceased to be the lunatic fringe. We're now the lunatic core.* (Hinton)
    - Merging architectures for Big Data and Deep Learning, to influence cognitive architectures
- **Robotics**
  - ~1900's: Remote control of torpedoes, airplanes
  - 30's – present: "Open loop" in-place industrial robots
  - 40's – 70's: Early locomoting robots
  - 70's – present: "Thinking" locomoting robotics
    - Actionist approach (e.g., Brooks' iRobot, Google Cars, …)
    - Sensor-driven mental models of "outside" world; drive to "cognition"

Potential Framework for Autonomous Systems R&D



Next Steps for AF/ST and AFRL

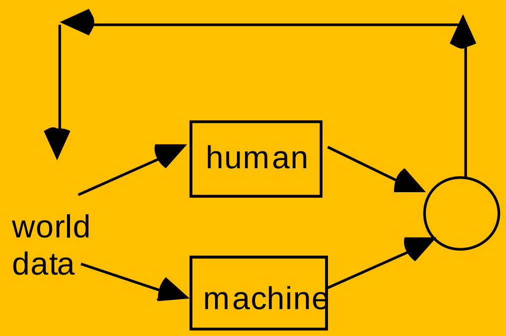
- **Autonomous Horizons Volume II**
  - Focus on developing a framework that will reach across communities working autonomy issues
    - Identify high payoff AF autonomous systems applications
    - Identify technical interest groups working these problems, via Autonomy COI, others
  - Specify key "under the hood" functions included in that framework (e.g., planning)
  - Evaluate key technologies that can support implementation of these functions (e.g., optimization)
  - Lay out a research strategy and demonstration program
- **Autonomous Horizons Volume III**
  - Focus on critical implementation issues, including: cyber security, communications vulnerability, V&V

Independent, Objective, and Timely
Science & Technology Advice

Does Automation Reduce Response Time?

People take the recommendation as another information source to combine with their own decision processes

Parallel Systems

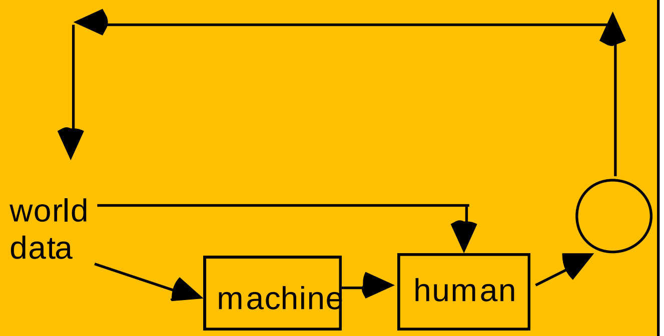


Reliability =1- (1-HR)(1-MR)

ex. HR = 90%
MR = 85%

= 1- (1-.9)(1-.85) = 1 - .02 = 98%

Serial Systems



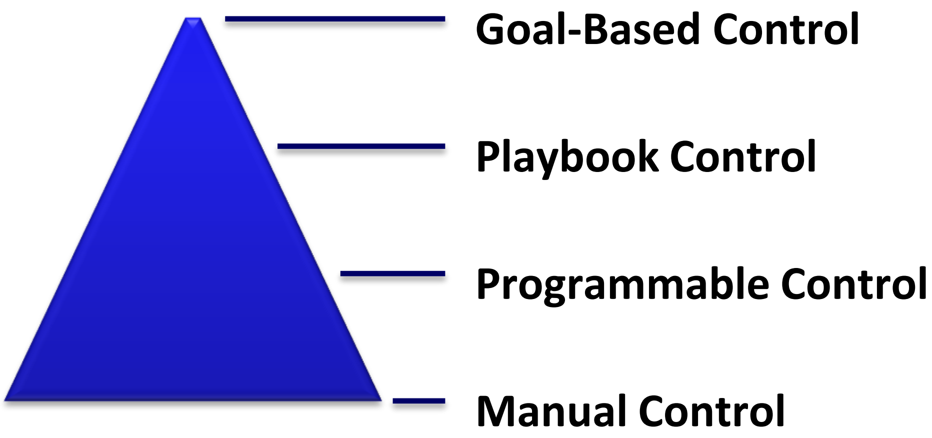
Reliability = (HR)(MR)

ex. HR = 90%
MR = 85%

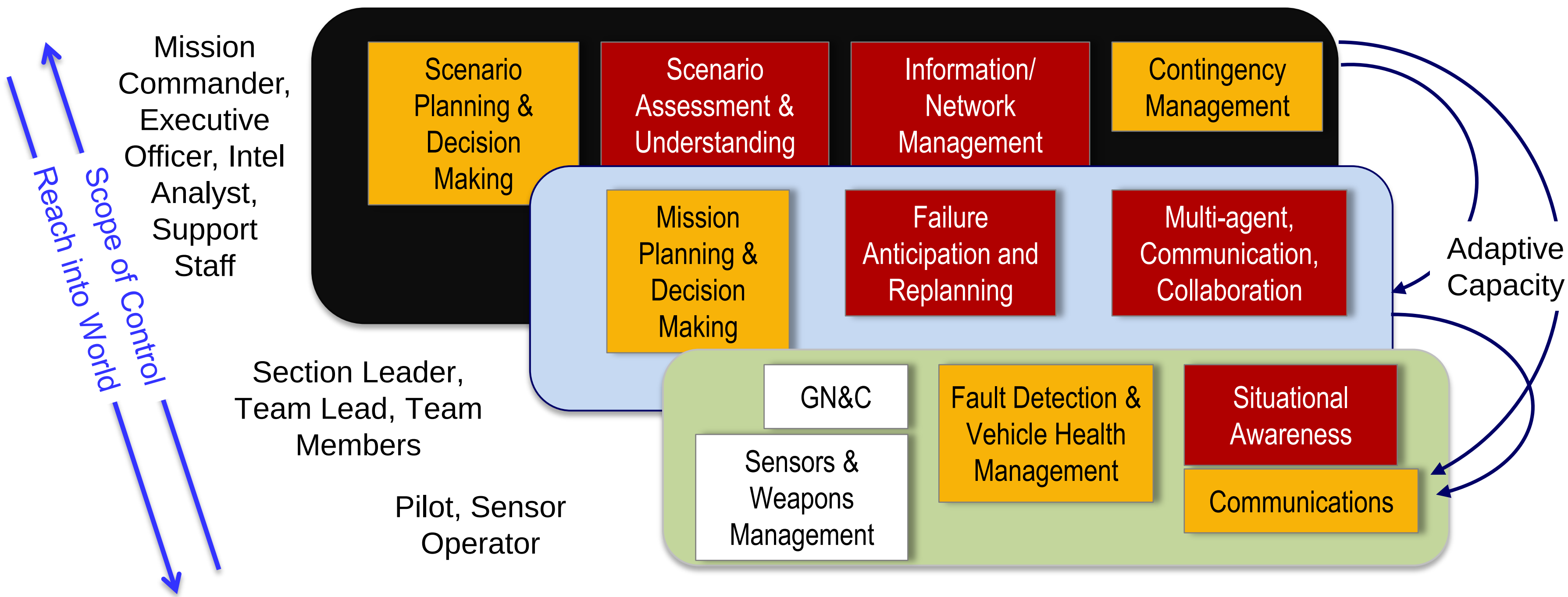
= (.90)(.85) = .77

Human-Autonomy Interaction

- **Robustness**
  - The degree to which the autonomy can sense, understand, and appropriately handle a wide range of conditions
- **Span of Control**
  - From only very specific tasks for specific functions, up to autonomy that controls a wide range of functions on a system.
- **Control Granularity**
  - Level of detail in the breakdown of tasks for control



Missed Opportunities and Needed Technology Developments



Under-utilized existing capability

Open technical challenges needing investment

Defense Science Board , Task Force on the Role of Autonomy in the DoD Systems, 2012

(Bad) Human-System Teaming in the Commercial Cockpit (1 of 2)*

- **Overtrust**
  - A DC-10 landed at Kennedy Airport, touching down about halfway down the runway and about 50 knots over target speed. A faulty auto-throttle was probably responsible. The flight crew, who apparently were not monitoring the airspeed, never detected the over-speed condition.
  - In 1981 a DC-10 crashed into Mt. Erebus in Antarctica. The accident was primarily due to incorrect navigation data that was inserted into a ground-based computer, and then loaded into the on board aircraft navigation system by the flight crew. The inertial navigation system (INS), erroneously programmed, flew dutifully into the mountain.
- **Misuse**
  - While climbing to altitude, the crew of a DC-10 flying from Paris to Miami programmed the flight guidance system to climb at a constant vertical speed. As altitude increased, the autopilot dutifully attempted to comply by constantly increasing the pitch angle, resulting in a high-altitude stall, and loss of over 10,000 feet of altitude before recovery.

*Ciavarelli, 1997

(Bad) Human-System Teaming in the Commercial Cockpit (2 of 2)

- **Differing intentions across teammembers**
  - In a China Airlines Airbus A300 accident at Nagaya Japan, the autopilot continued to fly a programmed go-around, while the crew tried to stay on glide slope. The autopilot applied full nose-up trim and [the] aircraft pitched up at a high angle, stalled, and crashed.*
  - Confusion over flight mode was the cause of a fatal A320 crash during a non-precision approach into Strasburg-Entzheim Airport in France. The crew inadvertently placed the aircraft into 3300 feet per minute descent when a flight crewmember inserted 3.3 into the flight management computer while the aircraft was in vertical descent mode instead of the proper flight path control mode. Pilots intended to fly a 3.3 glide slope.*
  - The DHL B757 and Tu154M mid-air over Germany in 2002 might have been avoided if both crews had followed their onboard TCAS advisories: the B757 was told to dive, the Tu154M to climb. ATC, unaware of the advisories, told the Tu154M to dive. The B757 crew, trusting TCAS in a close conflict situation, dove. The Tu154 crew, trusting ATC, did also.**

*Ciavarelli, 1997; **Weyer, 2006

Building Trust in Autonomous Systems

- Understanding autonomous system capability and limitations
  - Develop models, tools, and datasets to understand system performance
  - Experimentation with systems that change over time with the environment, and because of learning
- Understanding the boundaries within which the system is designed to operate, and the systems "experience"
  - Boundaries are situational, may evolve, and may violate the original system design assumptions
  - Systems will change over time because of learning, changing operator expectations
- Supporting effective man-machine teaming
  - Provide mutual understanding of common goals
  - Support ease of communication between humans and systems
  - Train together to develop CONOPS and skilled team performance, across wide range of mission, threat, environment, and users
- Assuring the operator of the system's integrity
  - Provide for transparency, traceability, and "explainability",
  - Support machine self-awareness, including boundary operation violations
  - Performance within boundaries must be reliable and secure
  - Awareness of operating outside the boundaries
- Identifying and addressing potential vulnerabilities
  - Red teaming early and often

Hierarchy for Supporting Collaboration

- **Goal Alignment**
  - Desired goal state actions need to support
  - Requires active goal switching based on prioritization
- **Function Allocation/Re-allocation**
  - Assignment of functions and tasks across team
  - Dynamic reassignment based on capabilities, status
- **Decision Communication**
  - Selection of strategies, plans and actions needed to bring world into alignment with goals
- **Task Alignment**
  - Coordination of inter-related tasks for effective overall operations

Shared Situation Awareness

Autonomy Functions

- Machine Perception
  - Vision
    - Image Processing and Computer Vision
    - Image Understanding
  - Tactile Sensing
  - Specialized Sensor Processing
    - EO, IR, Radar, Sonar,…
- Event Detection
- Situation Assessment
  - External Environment
  - Internal Environment
    - Health Awareness
  - Confidence specification (of assessments)
- Reasoning

Autonomy Functions

- Planning and Scheduling
- Motor Control
  - Locomotion
  - Motor Control (manipulation)
  - Sensor control
- Learning
  - Knowledge Acquisition
  - Adaptation/Learning
- Performance Monitoring/assessment
  - Performance awareness
  - Capability awareness (operating envelope)
- Reconfiguration/repair (of self)

Autonomy Functions

- Human Computer Interface
  - Auditory Channel
    - Alarms
    - Natural Language Processing
      - Signal Processing
      - Speech Recognition
        - Signal Processing
        - Computational Linguistics
      - Speech Synthesis
  - Haptic Channel
  - Visual Channel
    - Image Processing
      - Face recognition
      - Gesture Recognition
      - Object Recognition
    - Display/Visualization