Brief on Autonomy Initiatives in the US DoD

8 November 2012

Autonomy Priority Steering Council

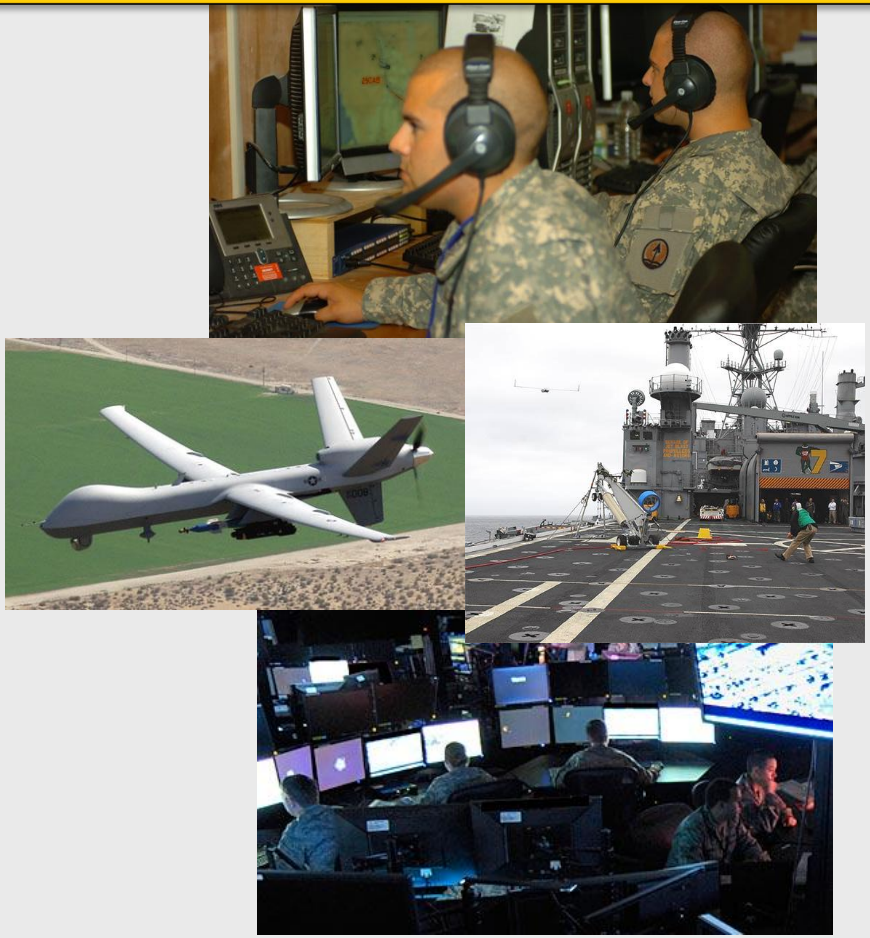
Key DOD Challenges Addressed by Autonomy

Decentralization, Uncertainly, Complexity…Military Power* in the 21st Century will be defined by our ability to *adapt – this is THE hallmark of autonomy

<u>Manpower efficiencies</u>: Insufficient manpower to support complex missions such as command and control and surveillance across relevant battlespace

<u>Harsh environments</u>: Operational environments that do not reasonably permit humans to enter and sustain activity

<u>New mission requirements</u>: Need adaptive autonomous control of vehicle systems in face of unpredictable environments and challenging missions



DoD Science & Technology Initiatives--Preparing for the Future

- **Operational missions with:**
  - Expanded duration
  - Intermittent communication disruptions
  - Complex, contested, and dynamic environments/situations
  - Highly populated environments
  - Larger array of asset capability
    - Cross domain (air, land, sea, space, cyber)
    - Multiple autonomous systems working as a team

Autonomy is not about making widgets…
It is making existing/future systems more self-governing

What is "Automated" Technology?

Automation: Using machines to accomplish tasks traditionally performed by humans. Automated systems are most effective in predictable environments. Automation is not limited to simple tasks, but rather to well defined tasks with predetermined responses to all operational contingencies.

Historic Challenges Associated with Automated Technology:

Technical	*Computer processing speed* *Sensor development/integration* *Cyber/mechanical teaming*
Social	*Human trust in automation* *Impact upon work force/political* *Human-machine teaming*
Economic	*Significant initial investment/maintenance*

What is "Autonomous" Technology?

Autonomy: Having the capability and freedom to self-direct to achieve mission objectives. An autonomous system makes choices and has the human's proxy for those decisions.




Challenges Associated with Autonomous Technology:

Technical

Human/Autonomous System Interaction and Collaboration
Scalable Teaming of Autonomous Systems
Machine Reasoning and Intelligence
Testing and Evaluation (T&E), Verification and Validation (V&V)

Social

Human-machine teaming
Public perception of unmanned vehicles (land, sea, air)

Economic

Potential game-changing opportunity for many industries, including transportation, healthcare, security

The Automation-Autonomy Continuum

Automation

Autonomy

Primary sources of automation brittleness:

1. ***Dynamic and complex mission <u>requirements</u>***
2. ***Dynamic and complex operational <u>environments</u>***

In a static environment, with a static mission, automation and autonomy converge. However, in reality, where dynamic environments collide with dynamic missions, automation can only support a small fraction of autonomy requirements.

DoD Technology Research and Development Strategy: Establishment of 7 Priority Steering Councils (PSC)

Complex Threats

- Electronic Warfare/Electronic Protection
- Cyber Science and Technology
- Counter Weapons of Mass Destruction

Force Multipliers

Unique Synergy

- Data-to-Decisions
- **Autonomy**
- Human Systems
- Engineered Resilient Systems

Autonomy Priority Steering Council Linkages

White House Office of Science and Technology Policy Robotics Group

NDIA

National Defense Industrial Association

COCOM USERS

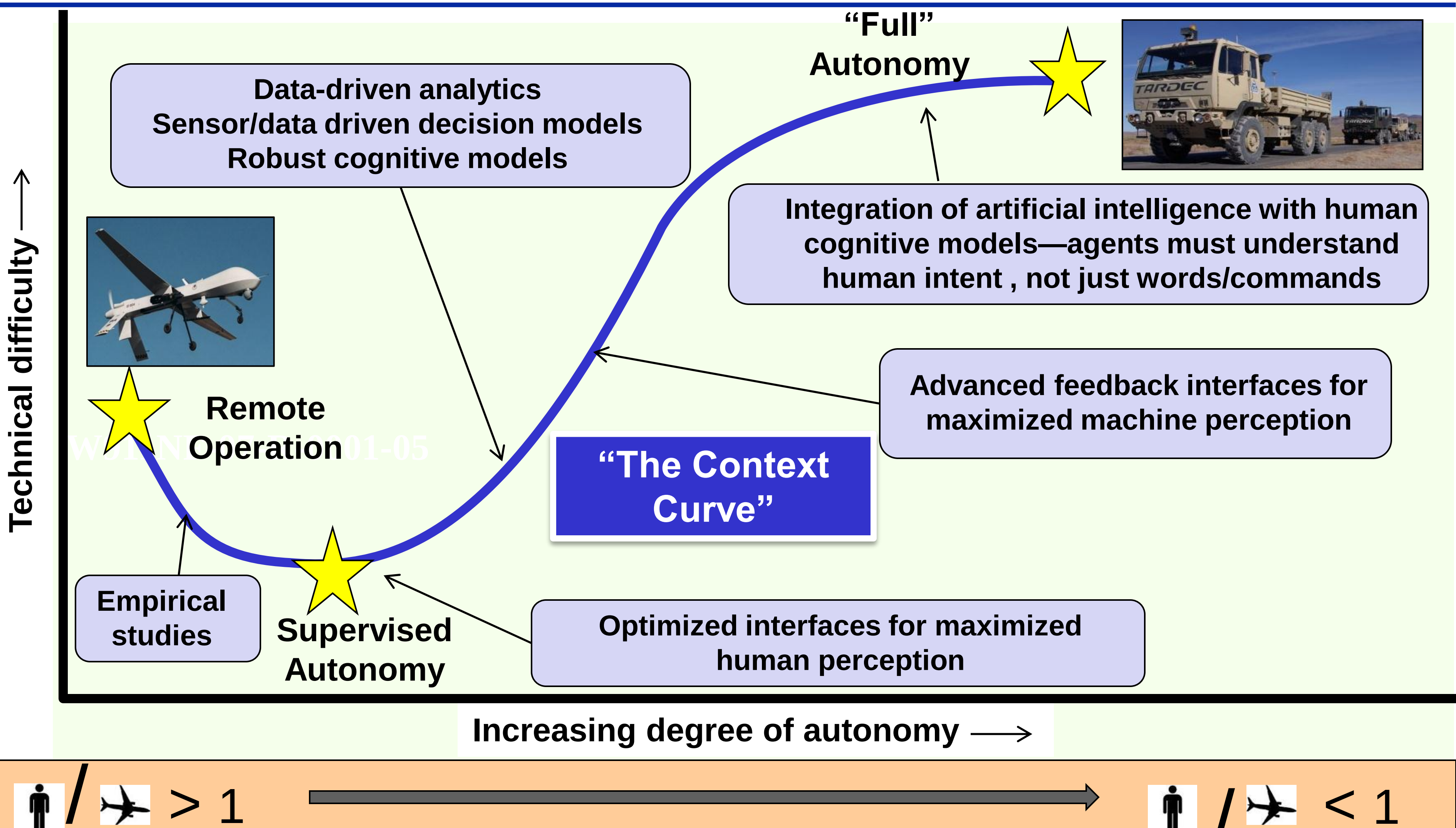
Academic Collaborations

FEDERAL AVIATION ADMINISTRATION

NASA

Other Federal Agencies

Autonomy Capability Curve



Data comprehension (that of the human and his agent) drives functionality

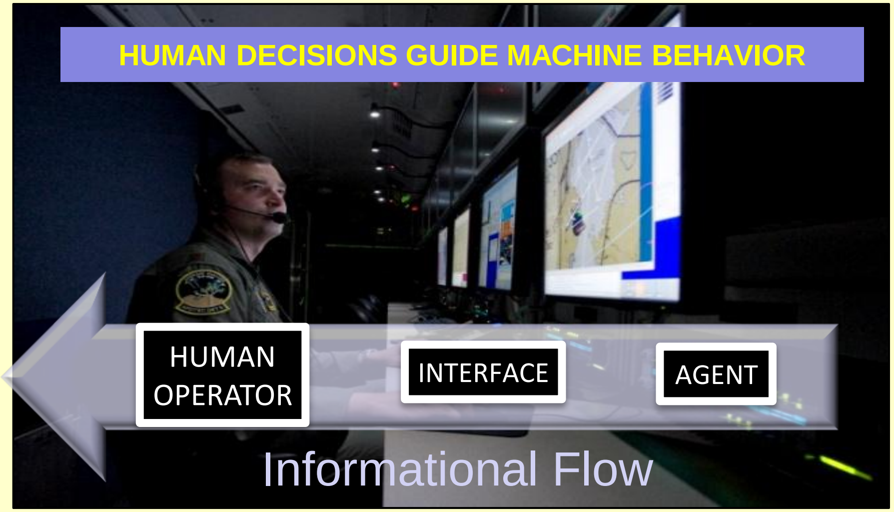
Autonomy PSC
Technical Challenge Areas and Gaps

- **Human/Autonomous System Interaction and Collaboration**
  - ***Human and machines understanding mission context, sharing understanding and situation awareness, and adapting to the needs & capabilities of another.***
- **Scalable teaming of Autonomous Systems**
  - ***Self-organizing teams, initiating and completing complex mission tasks (as a team or individuals).***
- **Machine Reasoning and Intelligence**
  - ***Ability to sense, perceive, plan, decide and act***
- **Test, Evaluation, Validation, and Verification**
  - ***Methods & facilities to test responses and decisions to various environmental stimuli***

Man-Machine Common Perception

DoD must approach autonomy as a unique human/machine or machine/machine system where decision-making is shared.

If decision-making is shared, there must be some level of shared perception.



Current Status

Future Status

Autonomy PSC Emphasis:
Advanced Test & Evaluation and Verification & Validation

Advanced LVC Test Beds Addressing:

- -- Performance in Contested Environments
- -- Human-Agent Teaming
- -- Scalable Teaming of Autonomous Agents (Including Cross Domain)
- -- Machine Reasoning and Intelligence
- -- Computer Model and Algorithm Analysis

Autonomy Priority Steering Council

Morley Stone, Chair

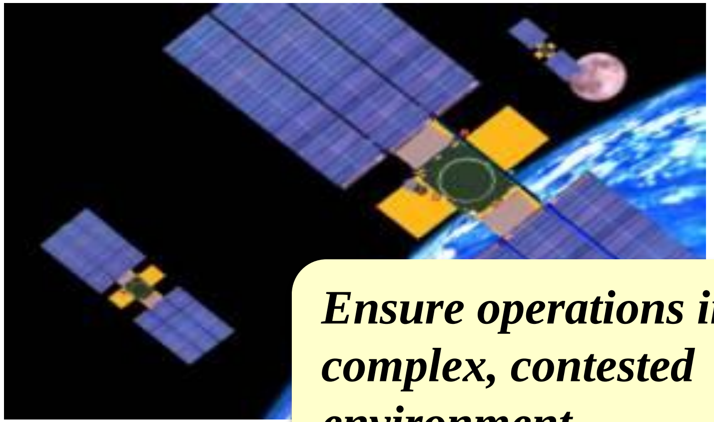
US Air Force Research Laboratory

US Army--Army Research Lab and TARDEC

US Navy--Office of Naval Research and Naval Research Laboratory

Defense Threat Reduction Agency

AFRL Autonomy Vision

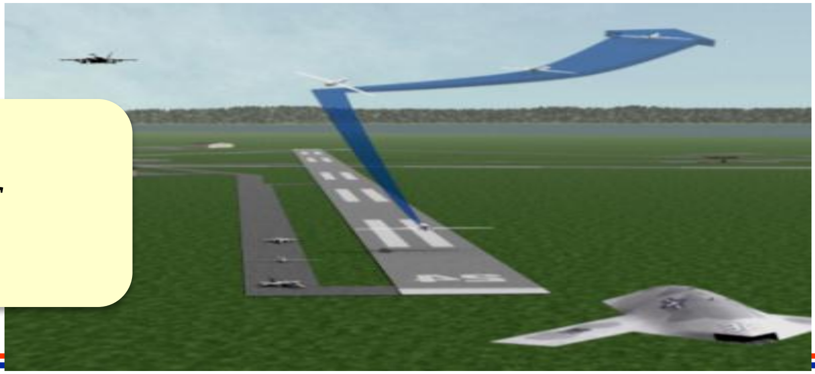


Ensure operations in complex, contested environment

Demonstrate highly effective human-machine teaming

Intelligent machines seamlessly integrated with humans - maximizing mission performance in complex and contested environments

Create actively coordinated teams of multiple machines



Autonomy S&T Missions Across AFRL

Human-Automation Interaction
- Supervisory Control
- Enhanced Training
- Trust in Automation

Autonomous Space Vehicles
- Constellation Management
- Cooperative Tactics for Dynamic Teams

Autonomous Aerospace Systems
- Airspace Integration
- Intelligent / Adaptive Flight Control
- Cooperative Teaming
- Systems of Systems Interactions
- Verification / Validation

Automated Sensor Data Fusion & Interpretation
- Sensor Resource Management
- Performance-Driven Sensing
- Automated Exploitation and Analysis
- Trusted Autonomous Exploitation

Common Challenges
- Machine reasoning and intelligence
- Human/System Interaction
- Scalable Teaming
- Testing and Evaluation (T&E) and Verification and Validation (V&V)

Autonomous Munitions
- Systems of Systems Interactions
- Verification / Validation
- Command and Control Systems
- Position, Navigation and Timing

Principles of USAF Autonomy Human Factors Research

One design approach: “Leftover” Principle

- Automate as much as possible: human does ‘leftover’ tasks
- Automation does what it does and human adapts

- Rigid, inflexible interaction
- Little automation transparency
- Mode confusion
- Lacks bi-directional intent understanding
- Automation complacency & bias
- Vigilance decrement
- Miscalibrated trust

Operator-preferred approach: “User-Centered” Design

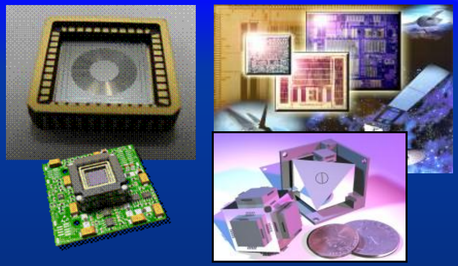
vs.

Challenge: Precision Navigation and Timing (PNT) Sources

- Small Unmanned Air Systems may have Greater Vulnerability to GPS Jamming Due To:
  - Support of Close-in Ops
  - Unable to Support Large 'Traditional' Military GPS Equipment
- AFRL, partnered with others, is Developing Technology Solutions that:

Decrease PNT SWaP

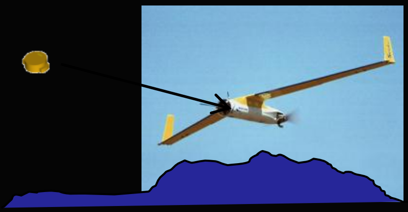
Developing Miniature Anti-Jam Military GPS Receivers



Shrinking Navigation Grade Gyroscopes (Partnered with DARPA)

Small GPS Antenna Arrays and Distributed Element Anti-Jam

Increases PNT Availability

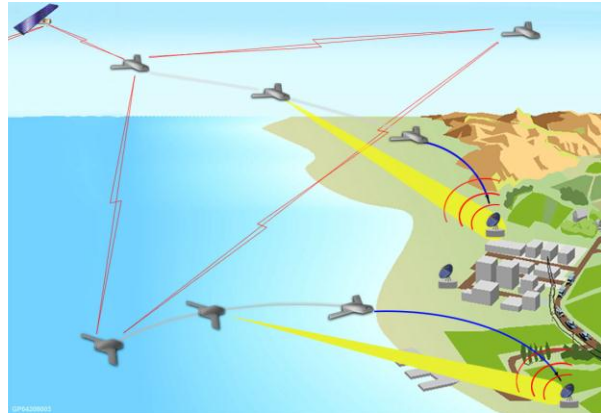


Inertial/GPS/Sensor Augmentation (e.g. vision-aided nav)

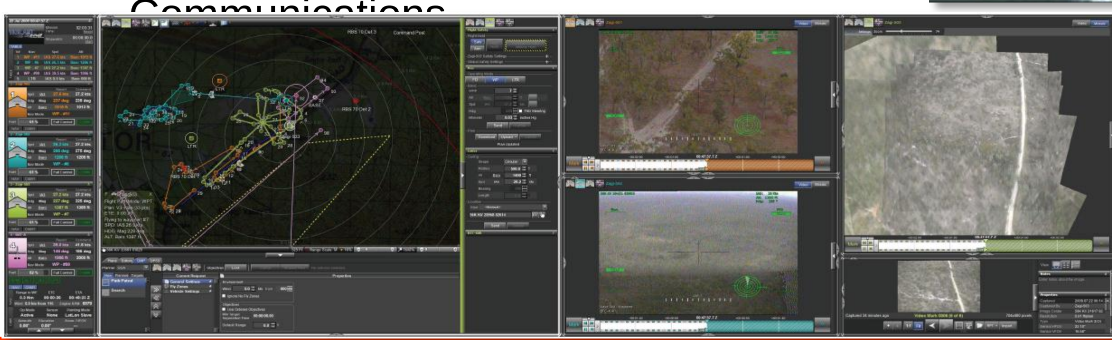
Challenge: Cooperation & Teaming

Desired Capability:

- **UAV teams working together in pursuit of common mission goals**
- **Ad-hoc collaboration**
- **Adaptation & learning**
- **Key sub-challenges:**
  - Uncertainty
  - Coupling
  - Communications



Vandenberg AFB perimeter surveillance demo



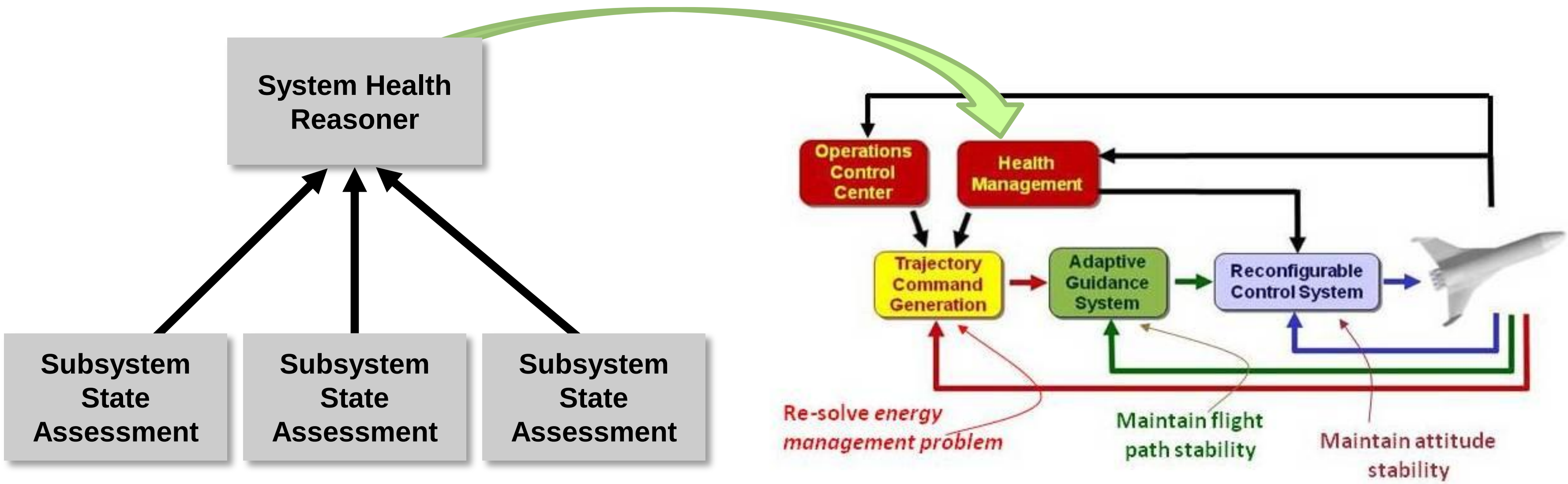
Talisman Saber 2009 Participation

- **71 sorties, 64 flight hours, 12 days**

Challenge: Adaptation to Degradations in Systems Health

<u>Motivation</u>: Autonomous Systems need to be responsive to systems health

- Determination of failure, or impending failure
- Reconfiguration of control to allow for safe recovery, or
- Adaptation to enable continued mission operations



Hierarchical health diagnosis architecture with feedback and reasoning for disambiguation

Adaptive inner-loop (stability) and outer-loop (trajectory) control to recover from failures

Autonomy Priority Steering Council

US Air Force Research Laboratory--Morley Stone, Chair

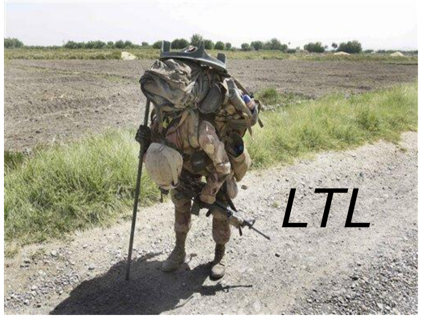
US Army--Army Research Lab and TARDEC

US Navy--Office of Naval Research and Naval Research Laboratory

Defense Threat Reduction Agency

US Army Ground Robotics Realities

- **Robotics benefits…**
  - Robots can extend the reach of the soldier
  - Robots can reduce the load of the soldier
  - Robots can go into some dangerous places
  - Robots are better at doing some tasks
- **The current realities of 'fielded' mobile ground robotics…**
  - Robots are mostly remotely controlled or tele-operated
  - Robots are difficult to control
  - Robots work best in benign, structured environments
  - Robots are slow and can't keep up with the operation tempo
  - Robots are expensive
  - Robots break down frequently
  - Robots that are 'intelligent' aren't fielded because we can't guarantee their behavior under all conditions



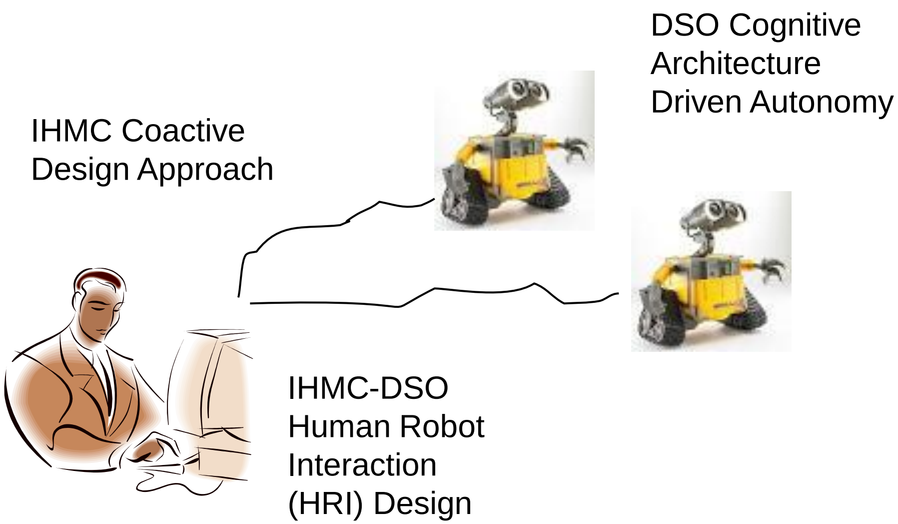
A Vision for the Army:
The Robot is a Member of the Unit

- **Understand the mission**
  - Receive and correctly interpret orders
  - React to changing situations
- **Understand the environment**
  - Recognize “rubble pile by lamppost”
  - Observe person fleeing checkpoint
  - Spot suspicious activity near intersection
- **Move in a tactically correct way**
  - Move downrange to IED – and return
  - Check intersection before manned units pass through it
  - Maintain tactical integrity moving through urban environment
- **Communicate clearly & efficiently**
  - Ask for assistance when needed
  - Report salient activity – e.g., insurgent entering building, fleeing checkpoint
- **Perform missions**
  - Monitor activity at checkpoint
  - Navigate autonomously to combat outpost
  - Inspect and neutralize IED
  - Perform ISR in urban setting

Able to function in a world designed for humans, to grasp small objects, to open doors, to carry the wounded, etc.

DSO-IHMC: Human-Robot Peering System for Challenging Surveillance Missions

Objective : Develop a system to improve performance of a team, composed of a human and two robotics platforms, during a challenging surveillance mission



Proposed R&D Approach

1. Employ IHMC's Coactive Design Approach to study how human and robots can work together during surveillance missions.
2. Robot's autonomy driven by DSO Cognitive Architecture with the ability to adapt and learn from human input.
3. HRI design that support mission interdependence between human and robots and leverages advanced interface concepts, such as exploiting both focal and ambient vision to enable human multi-tasking (e.g. Joint IHMC-DSO patent on Ambient Obstacle Avoidance)

Example Scenario – Robot perceptual imitations prevent classification of an object. Human participation not only enables correct classification, but the DSO CA also learns from this assistance and the learned knowledge will improve future autonomous perception.

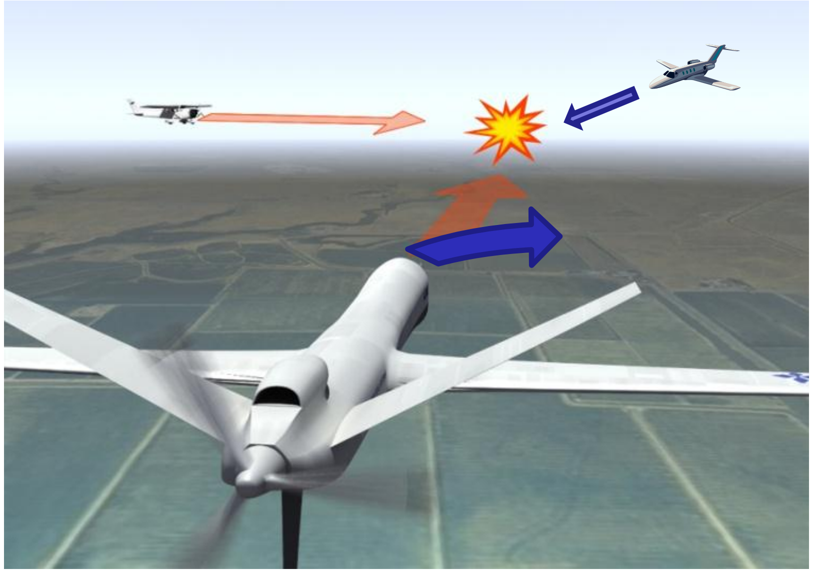
What We will Achieve ?

Improved partnering of the human and robots through better support for interdependence in surveillance missions. The human will supplement robot autonomy to reduce robot frailty and the automation and interfaces will be designed to leverage unique human capabilities to be brought to bare on the surveillance mission. Improved partnering will result in a more effective human-robot team.

Next Steps

1. To jointly work out a detailed proposal by Mar 2013 for funding consideration.

Questions/Comments?



Morley Stone, ST
Chair, DoD Autonomy PSC
Chief Scientist, AFRL/711th HPW
Morley.stone@wpafb.af.mil
937-255-8222