Integrating Humans & Autonomy: Achieving Smooth, Simple & Seamless

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3 March 2014
Autonomy Is An Underlying Theme Across Many Areas Of The Air Force Mission

Remotely Piloted Vehicles

Space

C2&ISR

Cyber Operations

Logistics
**Missed Opportunities, Needed Technology Developments**

- **Scenario Planning & Decision Making**
  - Section Leader, Team Lead, Team Members
  - Pilot, Sensor Operator

- **Scenario Assessment & Understanding**

- **Information/Network Management**

- **Contingency Management**

- **Mission Planning & Decision Making**

- **Failure Anticipation and Replanning**

- **Multi-agent, Communication, Collaboration**

- **GN&C**
  - Sensors & Weapons Management

- **Fault Detection & Vehicle Health Management**

- **Situational Awareness**
  - Communications

**Under-utilized existing capability**  **Open technical challenges needing investment**

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

Automated Tasking

Logic for pre-defined situations & classes

Information Fusion

Intelligent Agents

Learning & Adaptation

Autonomous Systems
Need Effective Synergy of the Human/Automation Team

- Main benefits of autonomous capabilities are to extend and complement human performance, not provide a direct replacement of humans
  - Extend human reach: perception, action, speed, persistence, size, scale, fatigue
  - Permit delegation and reduction of cognitive load – if explicitly designed to do so
  - Expand the adaptive capacity of the warfighter (e.g., more options, more flexibility)
  - Synchronize activities of UxS, software, and warfighter over wider scopes and ranges
  - Provide operations with denied or degraded comms links

- Synergistic human & automated agent team is critical to success
  - Overseeing what system is doing
  - Intervening when needed
  - Coordination and collaboration on functions
Relative Advantages

- Novel situations
- Moderate repeatability
- May be inconsistent
- Unpredictable

- Constrained situations
- Reliable
- Consistent
- Predictable

Humans

Autonomous Systems

- Autonomous systems can extend operating environment & provide unique capabilities while protecting human assets
  - Often brittle – poor ability to rapidly adjust to situations outside programming
- Humans provide most robust decision making for unexpected events & situations inherent in warfare
Challenges In Effective Use Of Autonomy

- Traditional approaches to automation lead to out-of-the-loop errors
  - Slow to detect problems and slow to diagnose
  - Loss of situation awareness
    - Vigilance & complacency, changes in information feedback, active vs. passive processing
    - Often do not result in desired workload reductions
- Previous systems have led to poor understanding of the system’s behavior and actions
  - System complexity, interface design, training
- Can increase time required for decision making
- Lack of trust in automation limits its use
Trust Will Only Occur With Meaningful Changes in the Design of the Autonomy

- Provide automation transparency
  - Assumptions & goals of the system
  - Current and projected actions of the automation
  - Confidence in the specific, situationally relevant data & algorithms
- Provide adaptable, flexible levels of automation
  - Facilitate shifts between human and automation
- Keep operator in control and in the loop
  - People do better as active participants in decision making
- Provide integrated SA rather than decisions
  - Autonomy can help with integration of plethora of data into meaningful SA
- Keep the system understandable
  - Minimize use of modes, made modes and states salient
Flexible Autonomy is Best

- **Supervised, Flexible Autonomy**
  - Human in ultimate control - can oversee, modify behavior as needed
  - Range of levels of autonomy available that can shift over time as needed

- **Level of Autonomy – How much autonomy is applied to a given task**
  - Significant benefit from automation that carries out tasks
  - Significant benefits from automation that transfers, integrates & transforms information to that needed (Level 2 SA)
  - Significantly degraded by automation that generates options/strategies
  - Filter with great care – can bias attention, deprive projection (Level 3 SA)
  - Intermittent LOAs provide best SA to human

- **Adaptive Autonomy – Ability to switch tasking from human to automation and back over time**
  - Provides maximum aiding with advantages of human
  - Must be supported through the interface
    - Keep humans in the loop
Synergistic Human-Autonomy Integration

Human – Autonomy Integration that is Smooth, Simple, & Seamless…
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
SA is critical to Autonomy
Oversight & Interaction

SA

System Environment
Task State
Automation State
Informed Trust Requires SA

- Oversight
- Intervention

How much confidence do I have in the system?
- Generically
- Situationaly
  - Is it working?
  - Is it getting good data?
  - Is it within its programmed envelope?
  - Will its actions meet my intended goals?
Failures in SA of Automation

- Perception of System State (Level 1 SA)
  - e.g. Automation induced complacency
  - L-1011 crash in Everglades

- Understanding of System State (Level 2 SA)
  - Detroit – NW255
  - Power Grid Blackout of 2003
  - American Airlines – Cali, Columbia

- Projection of System State (Level 3 SA)
  - Air France – Brazil
  - Upset over the Atlantic
Failure to communicate

What’s it doing?
Why did it do that?
What is doing now?

Ability to project behavior of system is key to successful team work
Model of Team SA

(Endsley & Jones, 1997)

Team SA Requirements
- Data
  - system
  - environment
  - other team members
- Comprehension
  - status relevant to own goals/requirements
  - status relevant to other’s goals/requirements
  - impact of own actions/changes on others
  - impact of other’s actions on self & mission
- Projection
  - actions of team members

Team SA Devices
- Communications
  - Verbal
  - Non-verbal
- Shared Displays
  - Visual
  - Audio
  - Other
- Shared Environment

Team SA Mechanisms

Team SA Processes
- Self-checking
  - checked against others at each step
- Coordinated
  - to get information from each other
- Prioritized
  - set-up contingencies
  - re-joining
- Questioning
  - as a group
Building Team SA

Mental Models

Goals

Displays
Environment

SA

Mental Models

Goals

Displays
Environment

SA

Computer Models

Goals

Sensors
Inputs

SA

Environment

Computer Models
Shared SA Requirements

- **Data**
  - system
  - environment
  - other team members

- **Comprehension**
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- **Projection**
  - actions of team members

Shared SA Needs
From Shared Goals
Shared SA Requirements

**Human**

- Data validity
- Automation Status
- Task Assignments
- Task Status
- Current Goals
- Impact of Tasks on Auto Tasks
- Impact of Tasks on System/Environment
- Impact of Tasks on Goals
- Ability to Perform Assigned Tasks
- Strategies/Plans
- Projected actions

**Autonomy**

- Data validity
- Automation 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
Added complication of Learning Systems

- **Validity/verification**
  - Did it learn the right things and what did it learn?

- **Repeatability**
  - How will it behave the next time?

- **Standardization**
  - Is my understanding of how it works valid across different units? Across different sessions over time?

Will seriously challenge need for predictability of system behavior
Future Aviation Environment:
Air, Space & Cyber Combined in an
Integrated C2 & ISR System

Integrated
Networked
Operations

Trusted
Resilient
Software &
Cyberspace

Effective
Human &
Automation
Teams

Data Transformed
Into Higher Levels
Of Situation Awareness

Built on a platform for rapid innovation, prototyping and testing