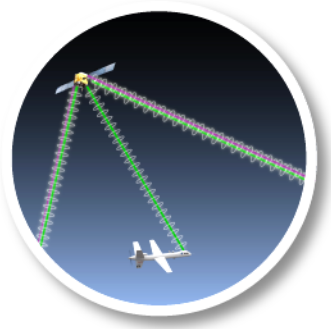


# Single Operator Control of Multiple UAS: A Supervisory Delegation Approach

Presented to UAS EXCOM Science and Research Panel (SARP)
Workshop on Single Operator Control of Multiple UAS

Jay Shively
NASA Ames Research Center

UAS INTEGRATION IN THE NAS

# Levels of automation of Decision and Action Selection (Sheridan & Verplanck, 1978)

1 The computer offers no assistance, human must take all decisions and actions

2 The computer offers a complete set of decision/action alternatives, or

3 Narrows the selection down to a few, or

4 Suggests one alternative, and

5 Executes that suggestion if the human approves, or

6 Allows the human a restricted veto time before automatic execution

7 Executes automatically, then necessarily informs the human, and

8 Informs the human only if asked, or

9 Informs the human only if it, the computer, decides to

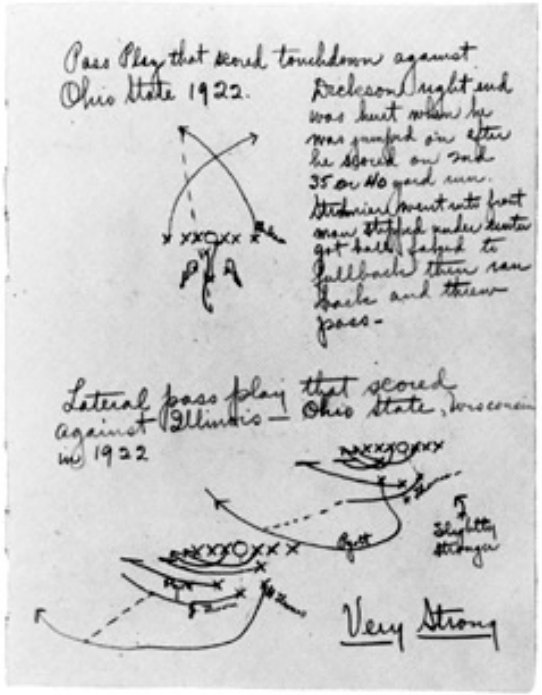
10 The computer decides everything, acts autonomously, ignores the Human

# Supervisory Control

Sheridan (2002) defined supervisory control as an arrangement in which "one or more human operators are intermittently programming and continually receiving information from a computer that itself closes an autonomous control loop," but he also accentuated the human system relationship underlying the definition: "Supervisory control derives from the close analogy between a supervisor's interaction with subordinate people in a human organization and a person's interaction with intelligent automated subsystems"

**Supervisory control** is a general term for control of many individual controllers or control loops, such as within distributed control system. It refers to a high level of overall monitoring of individual process controllers, which is not necessary for the operation of each controller, but gives the operator an overall plant process view, and allows integration of operation between controllers.

# Delegation Control: Playbook®




A page from Alonzo Stagg's 1927 Playbook

- Delegation: one way humans manage supervisory control with heterogeneous, intelligent assets
- Playbook®: ones means of delegation
- Plays: analogous to football
  - Quick commands – complex actions
- A Play provides a framework
  - References an acceptable range of plan/behavior alternatives
  - Requires shared knowledge of domain Goals, Tasks and Actions
  - Supervisor can further constrain/ stipulate
- Potentially facilitates intuitive cooperative control of Unmanned Systems
- Drill-down and modify as required by context

# Example: Troops in Contact Tango

# Levels of Automation Simulation

Example: Prosecute Target

**Tools**:

Arm laser ➔ Lase target ➔ Send coordinates to weaponized UAV ➔ Toggle UAVs ➔ Arm missile ➔ Fire

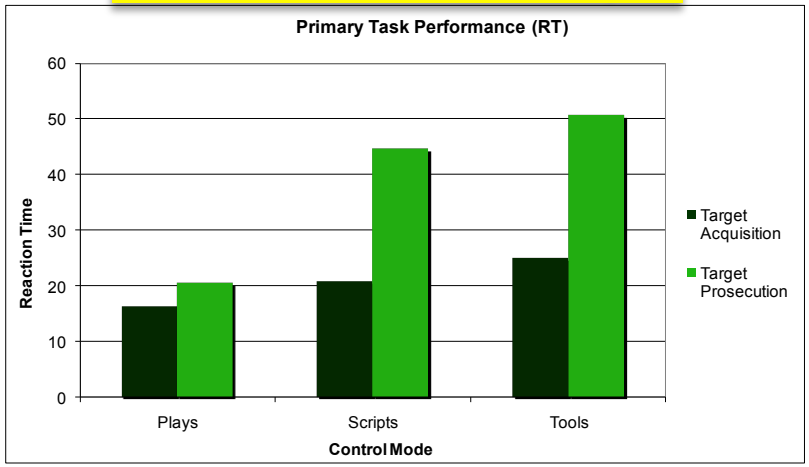
**Scripts**:

Select 'Lase' script ➔Toggle UAVs ➔ Arm weapons ➔ Fire

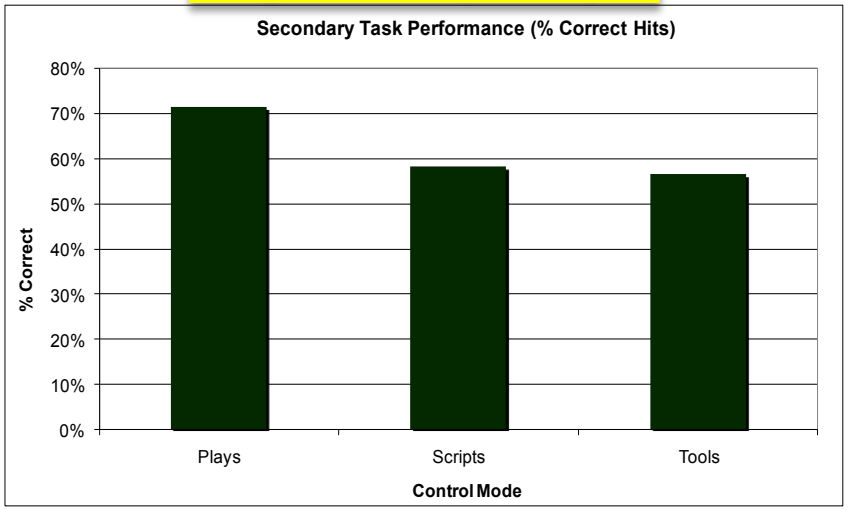
**Plays**:

Select 'Prosecute Target' play ➔ Fire

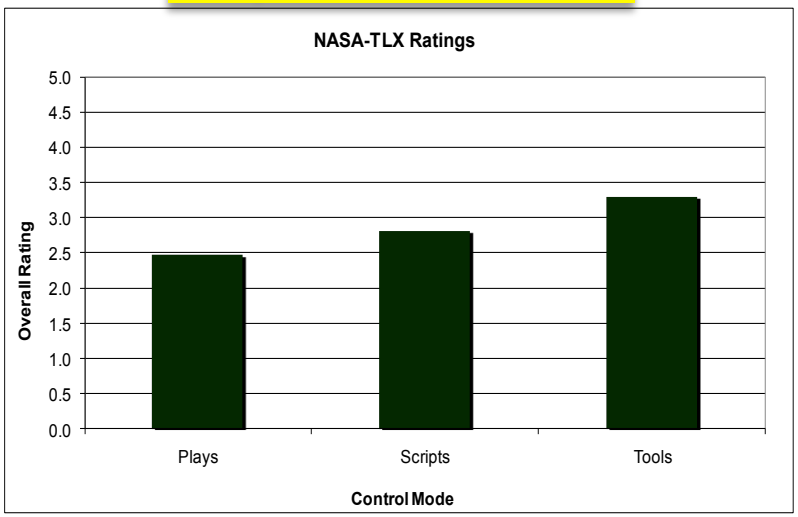
Shorter Reaction Time for Plays




Higher Accuracy for Plays




Plays had lower workload



# Manned-Unmanned Teaming: MUM

**Level IV Control:**
**Control of Payload and Vehicle**
**Excluding Take-off and Landing**

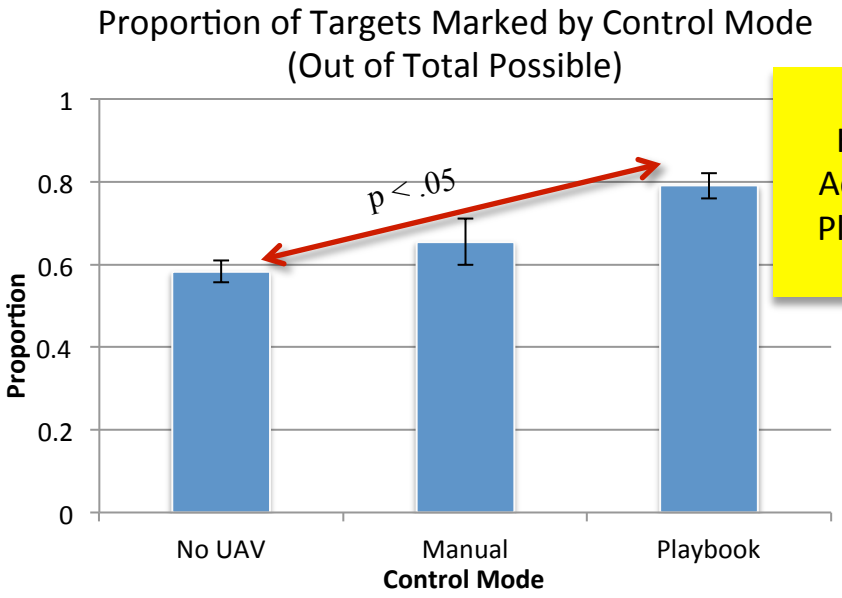
**Extend to simultaneous control of multiple heterogeneous UAS**

# Manned-Unmanned Teaming: MUM

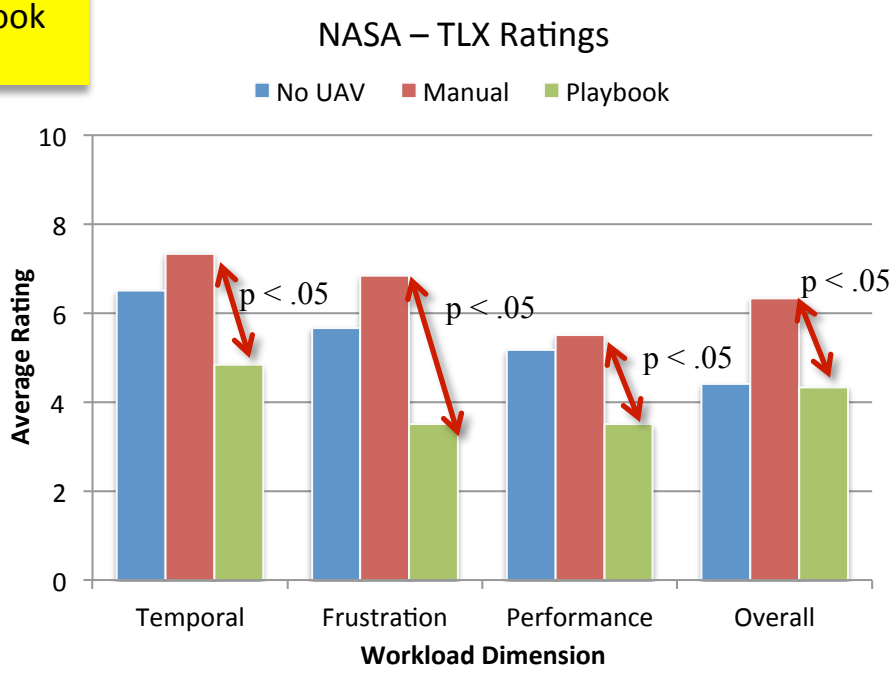
Goals:

- Apply Playbook® methodology and DelCon lessons learned to helicopter cockpit; Test in simulation
- Increase capability and efficiency of UAS control by helicopter pilots
- Supervisory control of multiple, heterogeneous UAS
- Develop infrastructure and lay foundation for later efforts

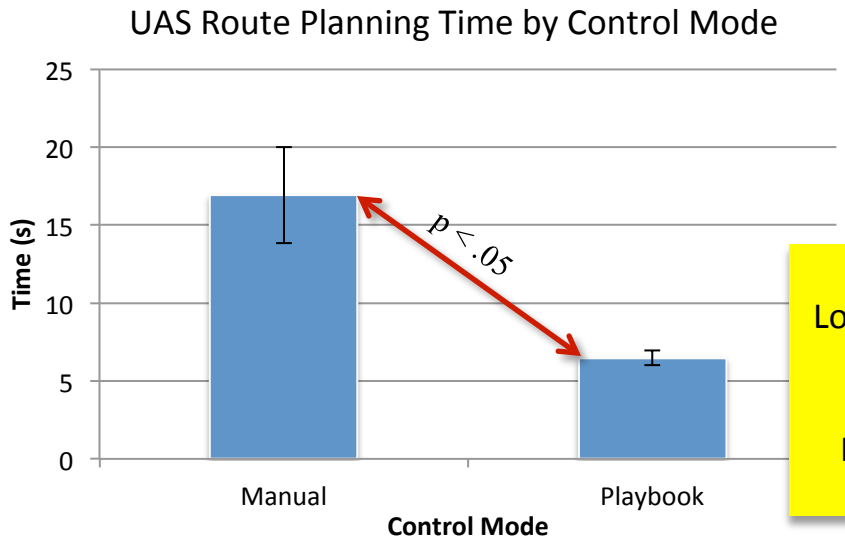
# Results




Higher Accuracy Playbook




Lower workload for Playbook on several dimensions




Lower Route Planning Time for Playbook

# Flight Demonstration 2009

*Ft. Ord CA, 23 APR 2009*

Goal:

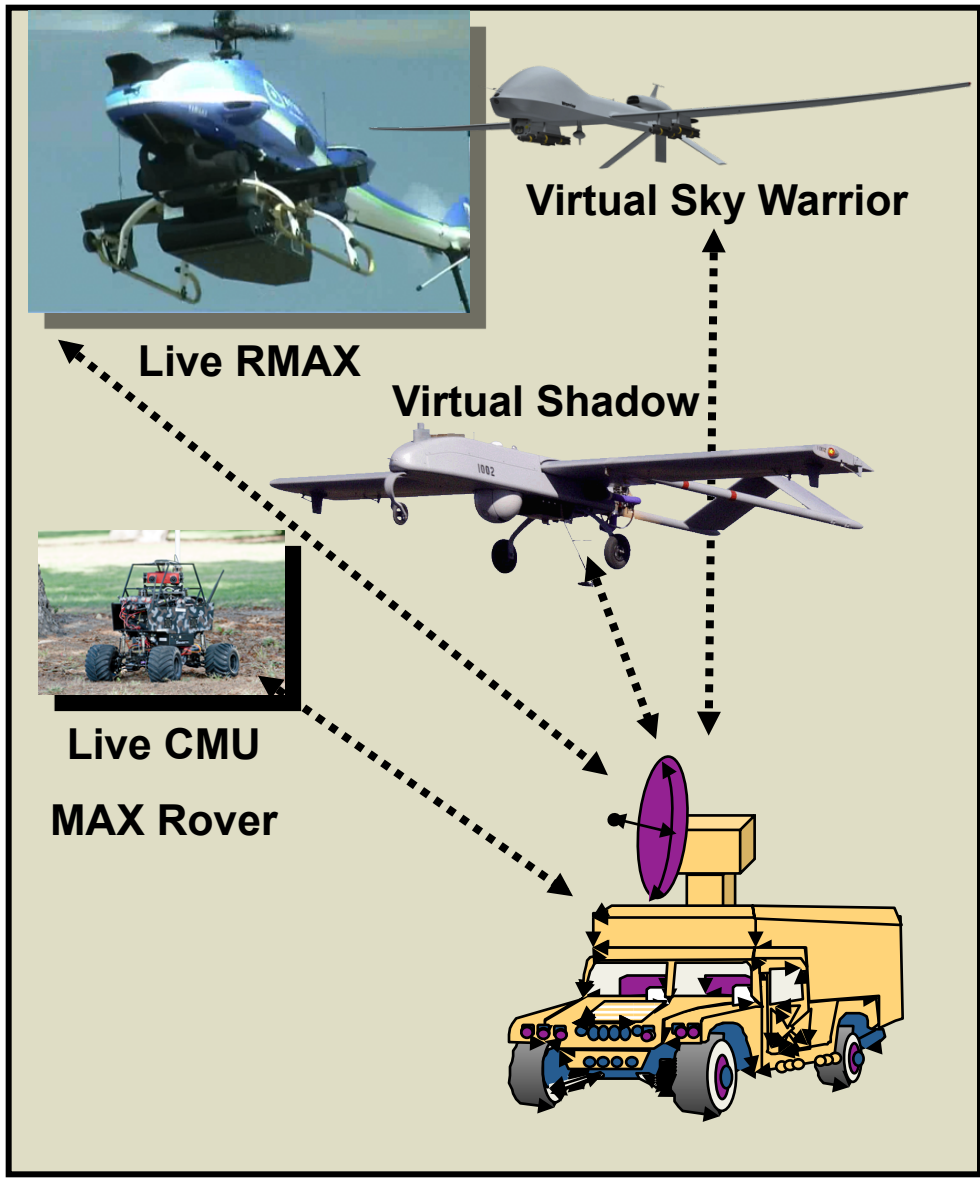
- Demonstrates initial proof of concept of Delegation Control (Playbook) in flight – supervisory control of multiple air/ground assets in MOUT Scenario

Method:

- Live/Virtual Demo – Controlling RMAX, CMU MAX Rover and 2 virtual UAS with Delegation Control
- Voice RGN Control (USAF)

Features:

- Delegation control human-machine interface supports control and monitoring 4 payloads
- Automation Transparency
- Live UGV-UAV coordination for slung load drop
- Reduced operator workload/high situation awareness



# Top Plays

- Troops in contact
- Route Recon
- Area Recon
- Convoy support
- Quick Meds

# Flight Demonstration 2011

*Ft. Hunter-Liggett CA, 19 May 2011*

Purpose:

- Build on previous simulations and flight test examining single operator control of multiple heterogeneous ground/air unmanned systems through delegation control employment
  - Operator performance data collection/workload assessments
  - Heterogeneous flight assets: Boeing Scan Eagle and Yamaha RMAX; two virtual UAS
  - Testing in operationally relevant mission scenarios
  - Multi-sensor cross-cue in support of both targeting and convoy support
- Army AFDD/Boeing CRADA

Key Objective:

- Develop and test DelCon Top Priority Plays; route recon, convoy support, troops in contact

# Supervisory Control Summary

Demonstrated in numerous simulations and flight tests (even NOPE simulations)

- AFRL – Base security, UAS ground station
- RCO – Dispatch, cockpit
- Human Automation Teaming (HAT)

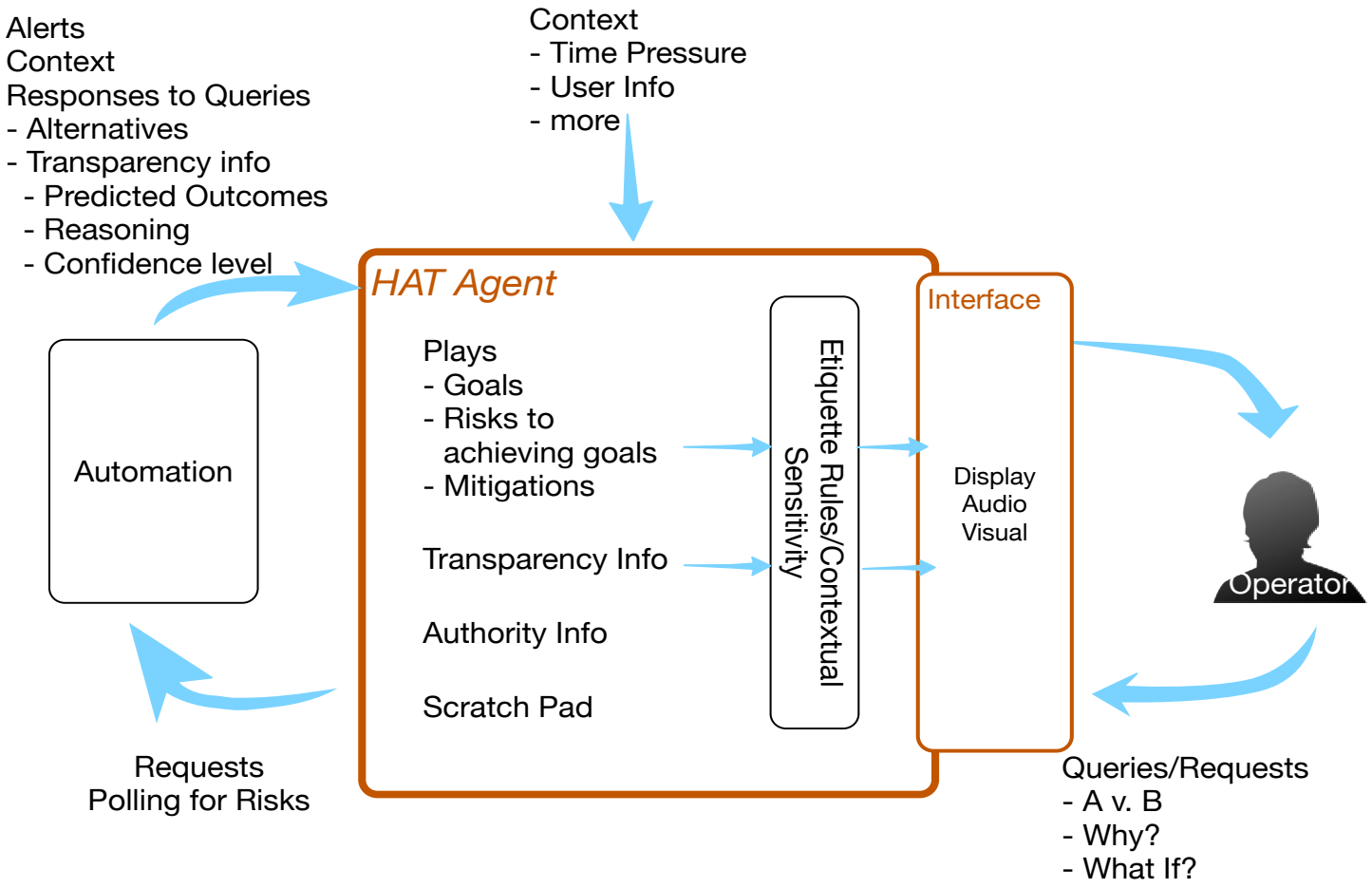
# Civil UAS Plays

- Monitor Border
  - Fly designated border
  - Alert any “signs of life”
    - UAS1 – fly waypoint a to b
    - UAS2 – fly WP b to C
    - UAS3 – follow-up with any alerts
- Evaluate powerlines
- Transit airspace

# Civil Plays

- Search and Rescue
  - Fly designated areas of search zone – lawn mower pattern, alert shapes, colors, etc.
  - Survival drop – as soon as WP is designated
    - Meds
    - Radio
    - Food/water
    - Shelter

# HAT Agent


Alerts
Context
Responses to Queries
- Alternatives
- Transparency info
- Predicted Outcomes
- Reasoning
- Confidence level
Context
- Time Pressure
- User Info
- more
HAT Agent
Plays
- Goals
- Risks to achieving goals
- Mitigations
Transparency Info
Authority Info
Scratch Pad
Etiquette Rules/Contextual Sensitivity
Interface
Display
Audio
Visual
Operator
Automation
Requests
Polling for Risks
Queries/Requests
- A v. B
- Why?
- What If?

# HAT Attributes

- Pilot directed interface
  - No intent inferencing
  - Directed by pilot actions
  - No set roles and responsiblities
  - Playbook
- Bi-directional Communication
  - Why ?
  - How confident ?
  - What if ?
  - Add information
- Transparency
  - Calibrated trust
  - Granularity
  - Time pressure

# Problems with Automation

- Brittle
  - Automation often operates well for a range of situations but requires human intervention to handle boundary conditions (Woods & Cook, 2006)
- Opaque
  - Automation interfaces often do not facilitate understanding or tracking of the system (Lyons, 2013)
- Miscalibrated Trust
  - Disuse and misuse of automation have lead to real-world mishaps and tragedies (Lee & See, 2004; Lyons & Stokes, 2012)
- Out−of-the-Loop Loss of Situation Awareness
  - Trade-off: automation helps manual performance and workload but recovering from automation failure is often worse (Endsley, 2016; Onnasch, Wickens, Li, Manzey, 2014)

# HAT Solutions to Problems with Automation

- Brittle
  - **Negotiated decisions** puts a layer of human flexibility into system behavior
- Opaque
  - Requires that systems be designed to be **transparent**, present **rationale** and **confidence**
  - Communication should be in terms the operator can easily understand (**shared language**)
- Miscalibrated Trust
  - Automation **display of rationale** helps human operator know when to trust it
- Out−of-the-Loop Loss of Situation Awareness
  - **User directed interface**; adaptable, not adaptive automation
  - Greater interaction (e.g., **negotiation**) with automation reduces likelihood of being out of the loop

# Working Agreements

- Pre-determined authority sharing agreements with automation
  - If the water cooling level drops below a certain value, open valves to emergency cooling

# Summary

- Autonomy
  - Not much in today's "approved" UAS
  - Words Matter
    - ICAO
- Business case for single operator supervisory control of multiple UAS
  - Playbook delegation is one successful method
- HAT
  - Cooperative agent with knowledge of work domain
  - Shared world knowledge
  - Can be extended to network supervision