A Shift in Automation Philosophy: From Manned to Unmanned

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Talk Outline

• Emerging Importance of UAVs
• Levels of Automation
• Automation Lessons Learned
• Manned Philosophy
• Unmanned Philosophy
• Research Areas and Issues
• Trade-off Tool
• Conclusions
Emerging Importance of UAVs

- Dull, dangerous and dirty
- Safe, effective (and lethal) recon
- Extension of conventional systems
- Battlefield (just in time) delivery of blood, ammo, etc.
- Savings from procurement costs, logistics, personnel, training, operating costs
- UAVs in the National Air Space (NAS)
Automation Enablers

- One operator controlling multiple UAVs
- Swarming UAVs that autonomously work together to achieve mission goals
- Collaborative UAVs that modify mission goals in response to circumstances
- UAVs that locate terrorists, estimate collateral damage and eliminate the terrorists (Bright, 2002)
- Semi-autonomous systems in which the operator only intervenes for contingency management/ off-nominal conditions
- Autonomous collision avoidance
<table>
<thead>
<tr>
<th>Level</th>
<th>Definition</th>
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<tr>
<td>10</td>
<td>Fully Autonomous Swarm</td>
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<td>9</td>
<td>Group Strategic Goals</td>
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<td>8</td>
<td>Distributed Control</td>
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<td>6</td>
<td>Group Tactical Re-plan</td>
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<td>5</td>
<td>Group Coordination</td>
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<td>Onboard Route Re-plan</td>
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<td>3</td>
<td>Adapt to Failure and Flight Conditions</td>
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<td>2</td>
<td>Real Time Health/Diagnosis</td>
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<td>Remotely Guided</td>
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Autonomous Control Level Trend

Scale:

- Fully Autonomous Swarms: 10
- Group Strategic Goals: 9
- Distributed Control: 8
- Group Tactical Goals: 7
- Group Tactical Replan: 6
- Group Coordination: 5
- Onboard Route Replan: 4
- Adapt to Failures & Flight Conditions: 3
- Real Time Health/Diagnosis: 2
- Remotely Guided: 1

Timeline:

- 1955
- 1965
- 1975
- 1985
- 1995
- 2005
- 2015
- 2025

Key:
- UCAR
- AF UCAV
- UCAN
- Global Hawk
- Predator
- Pioneer
Levels of Autonomous Behavior

1. Simple Automation
2. Automated Functions
3. Scripted Mission
4. Semi-Automated Missions w/Simple Decision Making
5. Complex Missions Specific Reasoning
6. Dynamically Mission Adaptable
7. Synergistic Multi-Mission Reasoning
8. Human-like Autonomy in a Mixed Team
9. Autonomous Teams with Unmanned Leader/Mission Manager
10. Autonomous - Conglomerate

Today
- 1 Simple Automation
- 2 Automated Functions
- 3 Scripted Mission
- 4 Semi-Automated Missions w/Simple Decision Making
- 5 Complex Missions Specific Reasoning
- 6 Dynamically Mission Adaptable
- 7 Synergistic Multi-Mission Reasoning

Future
- 8 Human-like Autonomy in a Mixed Team
- 9 Autonomous Teams with Unmanned Leader/Mission Manager
- 10 Autonomous - Conglomerate
What’s the Problem?
Effective Human-Automation Interaction is Difficult!

• Everyday Examples
  – VCR
    • Auto record programs
  – Computer helper
    • Paperclip
    • Auto-format
    • Spelling (hsi = his)
  – Automated voice menu
Examples from Manned Aviation: Mode Awareness (Degani, 2003)

- **KAL 007**
  - Pilots were in heading hold
  - Moved Mode Control Panel selector to Inertial Navigation System (INS)
  - Did NOT meet entry conditions
    - Within 7.5 miles of route
    - In general direction of route (~30 degrees)
  - INS never engaged, heading hold is less accurate and over time they drifted hundreds of miles off course
Complacency (Azar, 1998)

- 1995 Panamanian cruise ship Royal Majesty off the coast of Nantucket
- Satellite-based navigation failed
- Other sources of info were correct and available, but unmonitored
- The ship ran aground
More Examples

• Automation Bias - Tendency to utilize automated cues as a heuristic replacement for vigilant information seeking and processing (Mosier, Keyes, Bernhard, 2002)
• Accountability - Who is responsible?
• Loss of situational awareness - out of the loop unfamiliarity (OOTLUF), Lee & Moray, 1994
• Scope of error - …while reducing small errors, computer-based systems may invite large blunders (Wiener, 1985a, 1988)
• Wiener (1989) - We find the present generation of automation essentially sound, but lacking in proper user interface design
Manned Philosophy

- Billings (1991)
  - The Human must be in command.
  - To command effectively, the human operator must be involved and informed.
  - The automated system must be predictable.
- Rotorcraft Pilots Associate (1999)
  - “Although RPA can initiate actions on contact, it always keeps the pilot in charge of the aircraft. The pilot's authority allows for acceptance or rejection of any RPA suggested action.”
- “Boeing flight decks are designed to provide automation to assist, but not replace, the flight crew member responsible for safe operation of the airplane.”

Unmanned Philosophy Shift

• Removing the pilot from the vehicle eliminates man-rating requirements, pilot systems, and interfaces.

• For UAV systems to reach their full potential, they have to be highly automated.
  • “Execute mission automatically, Intelligent wingman, Auto mission adjust”
  The Army’s Future UAV Force, Cerny, 2001

• Shift from Human in command to human gives the UAV its “proxy” for full autonomy.
  Clough, 2002
Why the Perception of Shift?

- Numerous briefs that stress autonomy and don’t mention human interaction
- To fly in commercial airspace, we must automate as much as possible
  - Aircraft manufacturer
- We can reduce the fatal accident rate of general aviation, if we can automate enough
  - Former regulatory official
Philosophy is Not Necessarily Explicit

- Association for Unmanned Vehicle Systems International (AUVSI) Title Frequency Search
- 2003
  - 12 Instances of Autonomy/Autonomous
  - 0 Instances of Human/Operator
    - 1 Humanoid, 1 Humanitarian
- 2002
  - 13 Instances of Autonomy/Autonomous
  - 3 Instances of Human/Operator
Not all automation is bad or badly implemented

- Examples of Successful Automation
  - VCR - TiVo
  - Commercial Airline Crew Reduction
  - Anti-lock brakes
  - F-16 Flight Controls

- Successes tend to be skill-based and sometimes rule-based behaviors
  - Knowledge-based behaviors are more difficult to automate and more difficult to interface to the human
  - Knowledge-based behaviors are defined as those controlled by the highest level of cognitive processing hierarchy and rely on a mental model of the system (Rasmussen, 1983)

- Not all UAV designs or functions are following this trend:
  - Weapons release
Philosophical Shift Concerns

• But, automation comes with risk:
  – Poor human-system interaction, leading to poor performance
  – High operator workload, low situational awareness

• Risk is elevated with automation of knowledge-based behaviors:
  – Group Tactical Goals
  – Distributed Control
  – Group Strategic Goals
  – Fully Autonomous Swarm
  – “Human-like” Autonomy
Research Areas & Issues

- Guidelines specific to Human-Automation Interaction for UAVs
- Requirements driven function allocation. Don’t automate just because you can. HF has to push back. (The designers/ program managers aren’t going to.)
- UAV Human-Automation lessons learned database
- Optimal automation levels for mission context, workload and automation transitions
- Adaptive automation levels based on workload, physiological indices
- Measures of “goodness” of human-automation interfaces
Cost/ Benefit Trade-off Analysis Tool for UAV Automation

• Analysis of trade-offs among:
  – Probability of mission success
  – Level of UAV automation
  – Context/Mission/Platform
  – Operator workload/ situational awareness
Notional Tool Example

• Inputs
  – Context/Mission Platform
    • Recon of large area
    • Apache teamed with three UAVs (Shadows)
  – Level of automation
    • Vary from 5 (complex mission specific reasoning) to 9 (Autonomous team w/ unmanned leader)
    • Contingency Management
      – Lost link (to one or more)
      – Equipment failures (of one or more)

• Outputs
  – Workload and Situational Awareness
    • Co-pilot gunner
    • Ground station operator
  – Probability of mission success
Conclusions

• There is a philosophy shift from manned to unmanned aircraft
• UAV industry must take advantage of lessons learned
• Perception that high levels of automation are necessary for UAV systems to reach full potential
• Automation comes with risk, especially for knowledge based behaviors
• Need guidelines for UAV Human-Automation interaction
• Need for research to populate a trade-off tool