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Human Factors for Autonomous Formation Flying

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Formation Flight Basics

• Section v. division differences
• The tighter the formation, the higher the workload
  – Implications for system management
• Wingman uses significantly more fuel
• Formation flights account for 14 percent of all midairs

U.S. Navy photo
Autonomous Formation Flying in Action

Keeping Position

• http://www.dfrc.nasa.gov/Gallery/Movie/AFF/HTML/EM-0081-01.html

Refueling

• http://www.dfrc.nasa.gov/Gallery/Movie/AAR/HTML/EM-0053-01.html
Position Issues

• Wing must stay within 10% of lead’s wingspan for 30% fuel savings (Proud et al., 1999):
  – Commercial: 747: 196’, A300: 147’

• Previous flights
  – 2001: 55’ (two F/A-18s) (12% savings)
  – 2003: 200’ (DC-8/F/A-18) (29% savings)

• Pilots most sensitive to changes in roll
  – The most significant vortex disturbance when positioned for maximum drag reduction is a strong rolling moment effect (Hansen et al., 2002)

• Vortex turbulence generally avoided
  – Step up and down
Spatial Disorientation

- A false perception of one’s position and motion with respect to the earth
  - Sensory illusions
- Primarily due to transition between inside/outside scans
- Especially prominent in transition between VMC/IMC in formation flying
  - False horizons
  - “The leans are most commonly felt when flying formation on the wing in the weather or at night (Wright Patt).”
Vigilance Issues

• Sustained attention
  – Not a human strength
• Vigilance can deteriorate significantly after 30 mins
• What is the threshold for pilot intervention?
  – False alarms
  – Cost of premature pilot intervention
    • Reaction times could be affected
• Alerting systems can help
  – Advisories versus warnings
Previous Flight Test Results

- Air Force Flight Test Center, 2 & 3 T-38s
  - October 2001
- Pilot workload assessments
- They found that maintaining the minimum drag formation was a comparable workload to maintaining other types of formations. (not a good thing)
- The longest duration the pilots could maintain the position operationally was approximately 20-30 minutes.
  - Recall vigilance discussion
General Research Areas

• Alerting systems
  – Prediction
  – Probabilistic representations
  – Signal detection theory

• 2D versus 3D displays
  – Is one remarkably better or more confusing than the other?
  – Which one produces more false alarms?

• Situation awareness
  – How do these design issues impact pilot’s SA for both AFF alerting system as well as other systems?
Signal Detection Theory

<table>
<thead>
<tr>
<th>Pilot Response</th>
<th>True in the World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal Occurred</td>
<td>Hit</td>
</tr>
<tr>
<td>Signal Did Not Occur</td>
<td>False Alarm</td>
</tr>
<tr>
<td>Signal Did Not Occur</td>
<td>Miss</td>
</tr>
<tr>
<td></td>
<td>Correct Rejection</td>
</tr>
</tbody>
</table>

d’ = sensitivity to signal
B = criterion

Graph generated at http://psych.hanover.edu/Krantz/STD/
Receiver Operating Curves

Graph generated at http://psych.hanover.edu/Krantz/STD/
2D Versus 3D Displays

• Human is supervising, not actively flying
• Need to know where the system is now and where it is predicted to be at some point in the future.
• Is one type a better alerting system?
• Does one promote SA more than the other?
Situation Awareness

• Knowing what is going on around you both now and in the near-term future
  – Geospatial
  – Temporal
  – System
  – Environmental

• Mental model
  – Categorization mapping

• Not the same as workload

• Automation impact
Other Research Areas

- Relationship of distance/size of aircraft to pilot workload/vigilance
  - Ability to respond to problems/failures
- Trust issues
  - Stress at close ranges
- Long range missions
  - Both physical and cognitive fatigue
- Division issues
- Take the human out of the loop?
  - Ground controller