# 16.886
# 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):
  - Military: C-17: 171', C-141: 160', C-5: 223'
  - 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

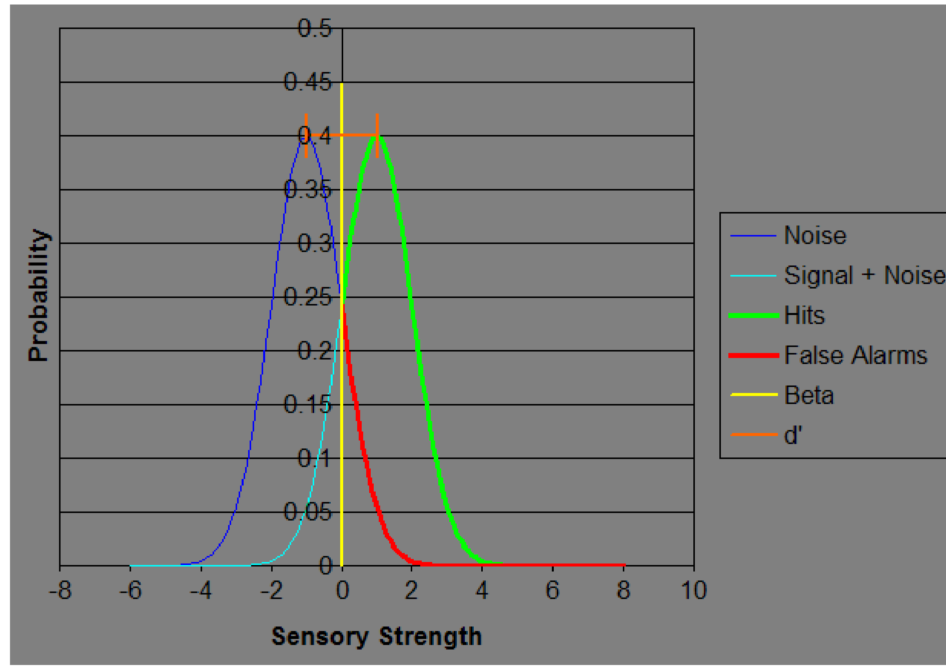
- Air Force Flight Test Center, 2 & 3 T-38s
  - October 2001
- Pilot workload assessments
- They found that maintaining the minimum drag formation was a comparable workload to maintaining other types of formations. (not a good thing)
- The longest duration the pilots could maintain the position operationally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

| | True in the World | |
|---|---|---|
| Pilot Response | Signal Occurred | Signal Did Not Occur |
| Signal Occurred | Hit | False Alarm |
| Signal Did Not Occur | Miss | Correct Rejection |

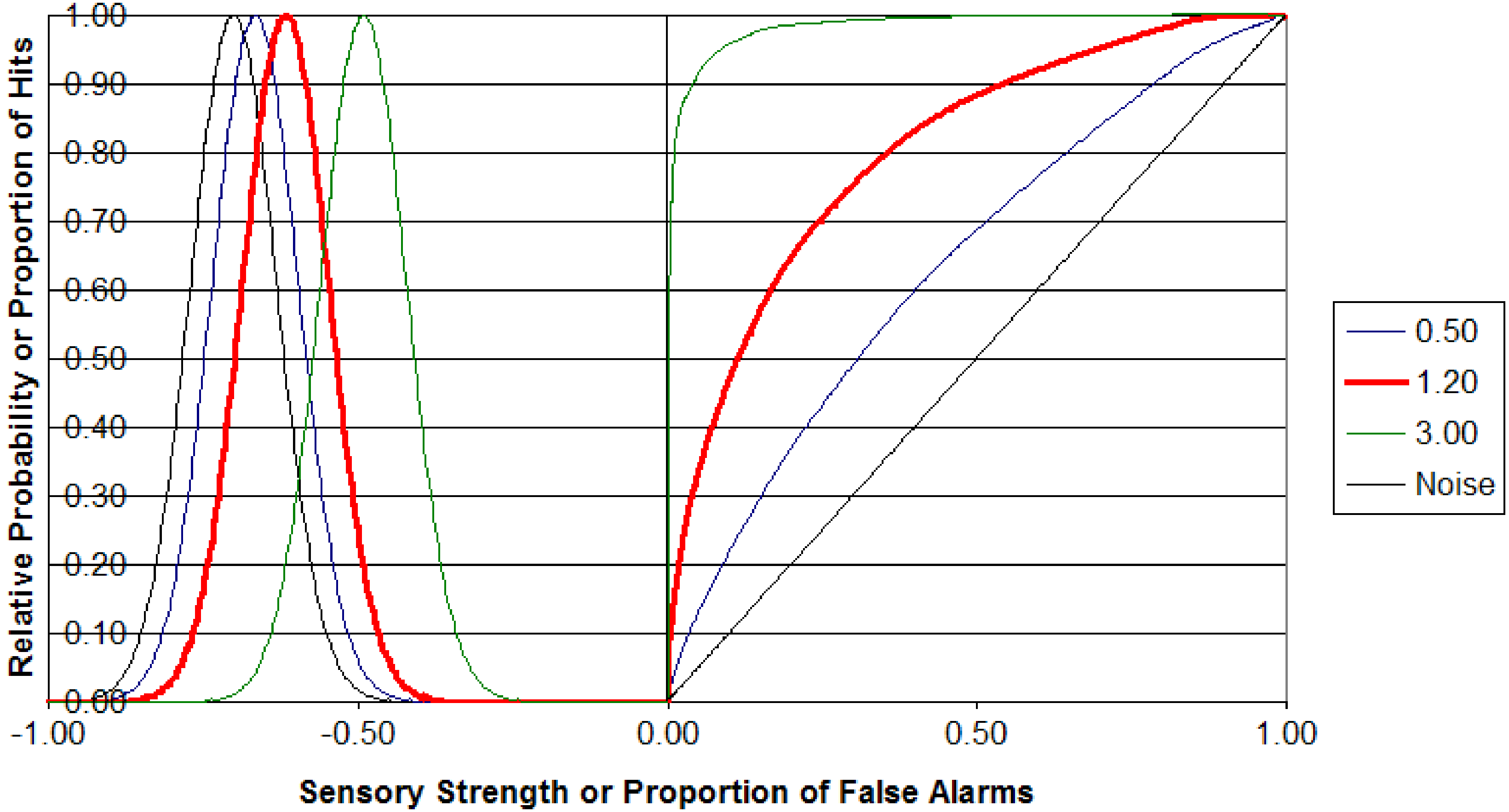


Graph generated at http://psych.hanover.edu/Krantz/STD/

d’ = sensitivity to signal

B = criterion

# 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