Spatial Disorientation, Army Helicopter Crash Case Reports, and Potential Countermeasures

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UH-60 Mishap #1

- Multi-ship training flight
- Light rain, mist
- Moon below horizon
- Night vision goggles
- Flight of two aircraft entered orbit while waiting to enter gunnery position at range
UH-60 Mishap #1 (con’t)

- On the second turn in holding, #2 rolled right and impacted the ground nearly inverted
- All 5 crew perished
UH-60 - Mishap #2

- Two-ship training flight
- Thick sea fog offshore
- Weather worse than briefed
- Night vision goggles
UH-60 - Mishap #2 (con’t)

• One aircraft turned back
• Flight became erratic
• Crashed into water
• All crew and pax killed

www.washingtonpost.com
UH-60 - Mishap #2 (con’t)

Approximate Route of Flight

Shoreline
“Formation flying in adverse weather under NVG is the most likely of all situations to produce disorientation”

-Ercoline, et al., 2000
Why is formation flight w NVGs disorienting?

- Pilots must rely on lead acft for orientation
- Tend to rely on vestibular cues
- Poor instrument cross-check
Common Elements in These Accidents
Two Points for Discussion

• Reliance on pilot to sense orientation and fix

• Emphasis on vision channel for orientation cues
  – Visual inputs come from entire 3D space
    • Sound comes from localized points
  – Central vision provides high resolution
    • Order of magnitude better than auditory
  – Visual inputs do not habituate
    • Unlike vestibular

But the vision channel can be saturated…
Complementary Cueing
“Multisensory”

Approach to Landing
Longitudinal Speed at Touchdown

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<th>Visual</th>
<th>TSAS</th>
<th>Aural</th>
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Error Bars +/- 1 S.E.

Approach to Landing
Lateral Speed at Touchdown

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Error Bars +/- 1 S.E.
A recent accident illustrates that no aviation community is safe from spatial disorientation (SD) accidents. Unfortunately, many top-flight pilots have fallen victim to this loss of reference, and statistics suggest more mishaps will occur in the future.

In today’s Army aviation community, there is an added emphasis on night flying, all-weather capability, and low-altitude missions, which are all circumstances that increase SD. Aviation SD mishaps increase dramatically in times of conflict. The sharp spike in SD mishaps during Operation Desert Storm occurred with the onset of wars in Iraq and Afghanistan. These theaters of engagement are associated with conditions of degraded visual environments (DVE), primarily overcast. However, SD is also a leading cause of noncombat aircrew fatalities. The costs of SD mishaps include mission failure, the impairment of mission effectiveness, the monetary value of aircraft/equipment lost and fatalities and disabilities.

This work is a factor closely associated with SD under conditions of DVE. In contrast with the older training and legacy aircraft, new helicopters, and updated legacy aircraft, possess many more sensors to provide pilots with the necessary information to land under DVE conditions. The problem is that all this information is shown on multifunction displays to an already overloaded pilot. As many pilots have noted, there is often simply too much information to assimilate under the highly dynamic conditions of DVE. Many aircraft manufacturers and research groups are actively developing visual displays to present that information in a format that can be used by pilots. Unless the pilot is provided sufficient flight parameter information intuitively, the only solution viable to remove the pilot from the cockpit and use automated procedures to land under brownout or other DVE conditions.

The U.S. Army Aeromedical Research Laboratory (USAARL) is developing the Tactical Situational Awareness System (TSAS) to use the sense of touch to provide spatial orientation and situational awareness information to the pilot. The system consists of a matrix of tactile stimulator facets embedded into a lightweight cooling garment that maintains the factors in close proximity to the torso.

Using data from existing aircraft sensors or a custom self-contained sensor package for non-aircraft, TSAS obtains the aircraft position, velocity, attitude, altitude and threat information. In lieu of pages of a multifunction display, TSAS has the following modes for displaying critical information during various phases of flight:

- In the hover mode, TSAS provides horizontal drift velocity and vertical altitude information.
- In the forward flight mode, TSAS provides overall heading and altitude cueing. It can also provide navigational cueing in conjunction with existing navigation displays.
- In the approach mode, TSAS provides glide-slope and course information, as well as arrival and departure information.
- In the taxi mode, TSAS provides the threat direction and general distance to the pilot without the pilot actively having to use vision information. As the pilot turns and maneuvers the aircraft, the factors continuously provide threat orientation position and distance information. This mode of operation permits the pilot to fly with eyes outside the aircraft in a wide environment.

The TSAS has been flight tested in the UH-60A, MH-53M, and Canadair BD-105 aircraft as well as CV-22, MH-47, MH-53M, and MH-66K simulators. Pilots participating in the simulator and in-flight testing agree that TSAS reduces pilot workload and increases flight safety by decreasing instrument scanning requirements during degraded visual conditions. Both qualitative and subjective data demonstrate that hover performance is improved with the use of TSAS.

The TSAS is intuitive and quick for pilots to learn. Within 10 minutes, pilots could hover without the aid of visual instruments. A USAARL scientist recently conducted a study demonstrating that degraded pilots performed considerably better when TSAS was available to provide orientation cues. Since fatigue is a contributing factor in many SD-related mishaps, TSAS may provide a countermeasure to reduce mishaps.

With the widespread use of night vision goggles, army aviation can justify claim to “own the night.” New technologies such as TSAS, in conjunction with recently developed sensors, will help provide Army pilots with the ability to fly safely under conditions of DVE.
Should we rely on pilots to sense and fix themselves?

- We do...

We train our pilots to avoid and cope with disorientation...
Should we rely on pilots to sense and fix themselves?

• Unrecognized SD accounts for most accidents and fatalities (although “recognized” is more frequent)

• 54.9% of fighter ejections are “delayed” (Miles, 2015)
Should we rely on pilots to sense and fix themselves?

- Automatic Ground Collision Avoidance System (Auto-GCAS)
  - Aimed at reducing CFIT accidents by 90%
  - 4 confirmed saves (Oct 2016)

https://youtu.be/WkZGL7RQBVw
Should we rely on pilots to sense and fix themselves?

- In one of the accidents presented, autopilot was engaged but too late

- Helicopters lack true auto-recovery systems
  - Autohover
  - Autopilot

- When to give up control?
  - To copilot
  - To automation

TRUST?
Adaptive Automation
3 main approaches

• Critical event strategy
  – Assumes workload goes high when critical events occur

• Performance measurement strategy
  – Examines operator performance and infers workload

• Neurophysiological measurement strategy
  – Preferred but most difficult
  – EEG, fNIR, fMRI, ECG, GSR
Conclusions

• Disorientation remains a killer
• Augmenting the visual sense can preserve orientation
• Pilots won’t fix a problem they don’t notice
• Assisting the pilot with technology can save lives
• Research needed to mature the technologies
Questions?