Conflict Between the Human Sensory System and Cockpit Design Standards

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1990 - 1996 Navy & Marine Corps
Spatial Disorientation Mishap Statistics

Total incidents = 64
Total fatalities = 88
Total cost = $956 million

Average annual rates

? 10 mishaps per year
? 15 deaths per year
? $ 159 million per year

Mishaps study results

"…transitions from inside to outside the cockpit (or the reciprocal) under different conditions were associated with the occurrence of SD episodes"; Collins, et. al. 1995.

"Over half of the FY90-FY91 SD accidents occurred in VMC, often during low-level navigation"; Lyons, et. al. 1994.

"Finally, the narratives revealed that the onset of many of the inflight SD incidents occurred during the transition from VFR to IFR conditions."; Bellenkes, et. al. 1992.

"In 83% of the F16 incidents and 63% of the F5 incidents visual reference played an important role." Kuipers, et. al. 1990.

"39% of F5 pilots and 47% of F16 pilots mentioned, that the fact they were looking outside for something was a major cause for the disorientation incident." Kuipers, et. al. 1990.

"The most critical situation for developing spatial disorientation is night or weather formation flights." NATOPS instrument manual 1986.

Consensus for Induced Spatial disorientation

- Sudden transition to instrument.
- Going lost wingman during IMC.
- Formation flight going from VMC to IMC.
- Tanking in intermittent VMC-IMC conditions.
- Flying solo during intermittent VMC-IMC.

Research Based Assumptions related to SD

"One thing about the leans is apparent: there is no single explanation for this illusion". Kent Gillingham, Spatial Orientation in Flight, 1993.

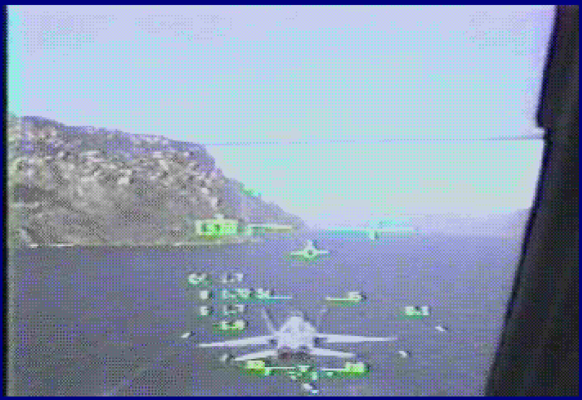
"...one must not think that the leans, or any other illusion for that matter, occurs as a totally predictable response to a physical stimulus...", Kent Gillingham, Spatial Orientation in Flight, 1993.

"...sustained angular velocities associated with instrument flying are insufficient to create Coriolis illusions...". Kent Gillingham, Spatial Orientation in Flight, 1993.

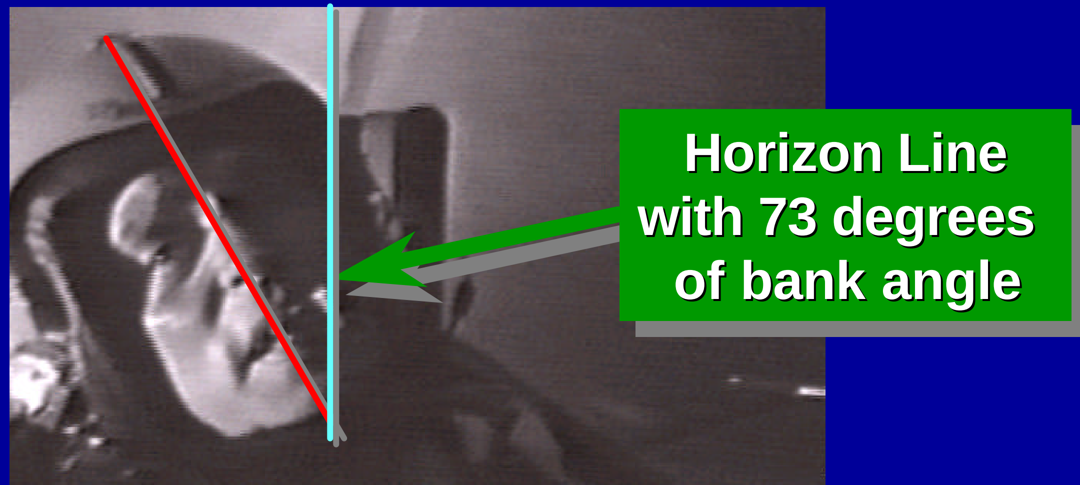
"...most disorientation mishaps do not typically involve "text book" causes of spatial disorientation". Durnford, Spatial Disorientation: A survey of U.S. Army helicopter accidents 1987-1992. US Army Aeromedical Research Laboratory, tech. report: USAARL 95-25 1995; 29.

Pilot Spatial Awareness Models

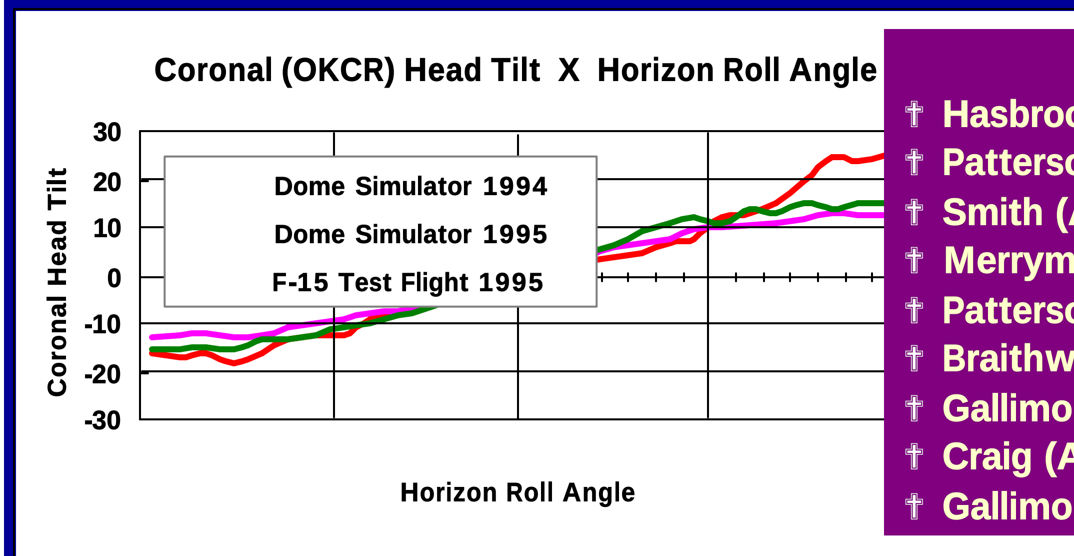
Conventional Paradigm



In-flight Opto-Kinetic Cervical Reflex (OKCR)



F/A-18 aircraft (Blue Angel) 73 degrees of bank (VMC, +Gz Turn).
OKCR Head tilt = 31degrees away from the Gz axis.

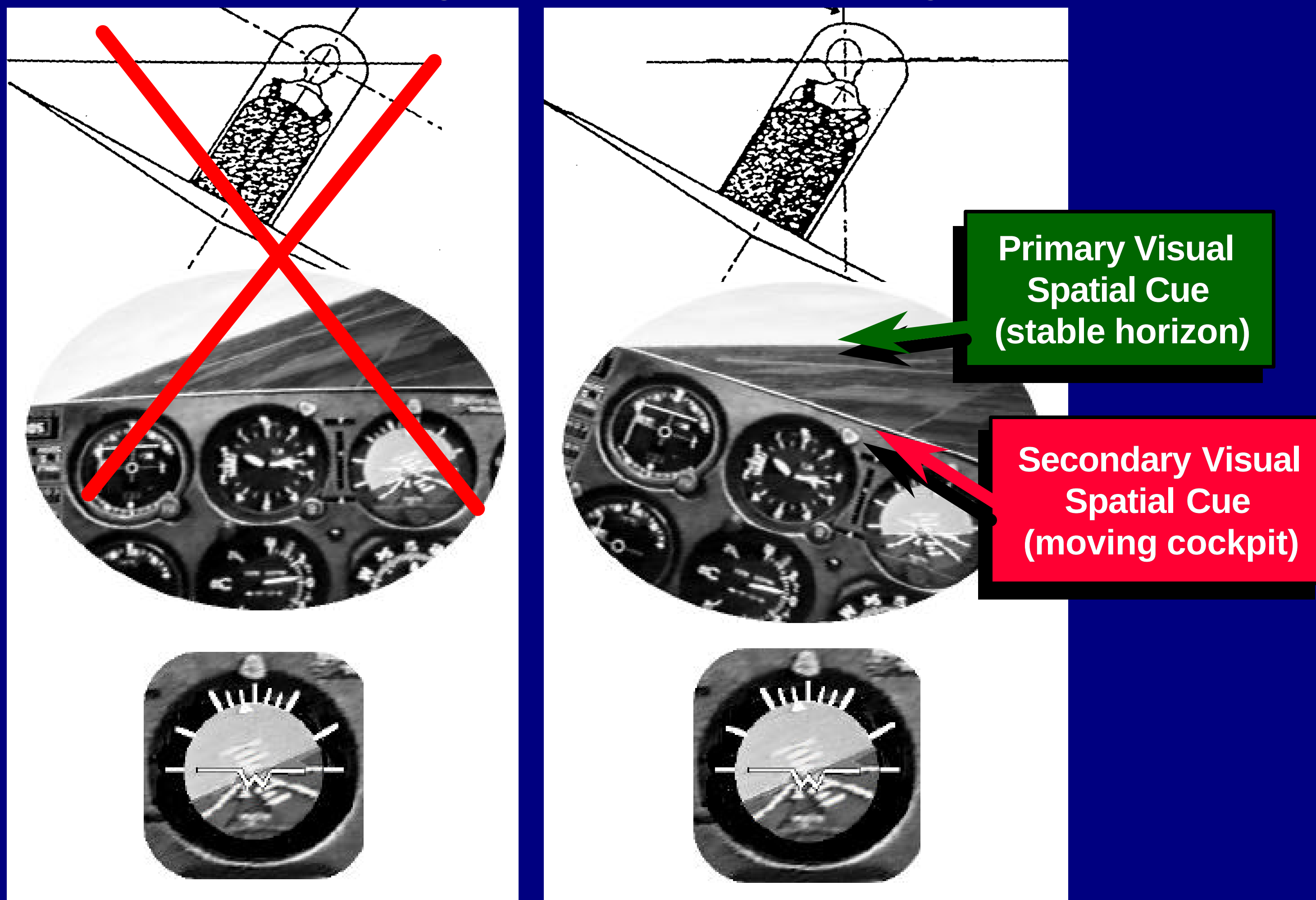


Completed Studies:

- Hasbrook (FAA 1973 / T-34 flight test; n = 32)
- Patterson (ASMA 1997 / dome simulation; n = 14)
- Smith (ASMA 1997 / dome simulation; n = 16)
- Merryman (ASMA 1997 / F-15 flight test; n = 9)
- Patterson (ASMA [ABSTRACT] 1998 HMD sim; n = 6)
- Braithwaite (ASMA 1998/ H-60 motion sim; n = 20)
- Gallimore (ASMA 1999 / FOV dome study; n = 12)
- Craig (ASMA 2000 / Canadian helo flight test; n = 3)
- Gallimore (ASMA 2000 / form flight sim study; n = 26)

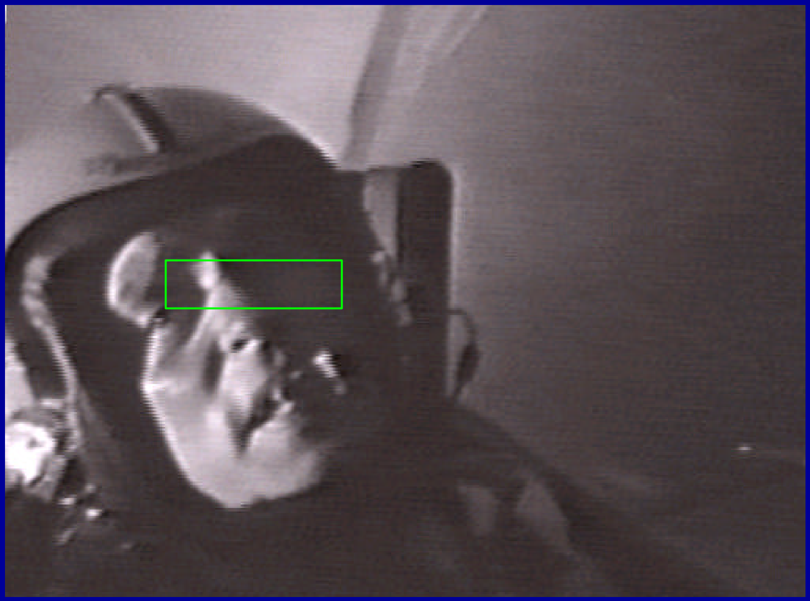
Pilot Spatial Awareness Models

Conventional Paradigm | **Revised Paradigm**



OKCR - Head Up Display (HUD) Compatibility

Collimated light from HUD is only visible if the pilots eyes are within a design eye-box: 3” high and 7.5” wide



OKCR changes perspective of geometric symbols projected on the HUD.

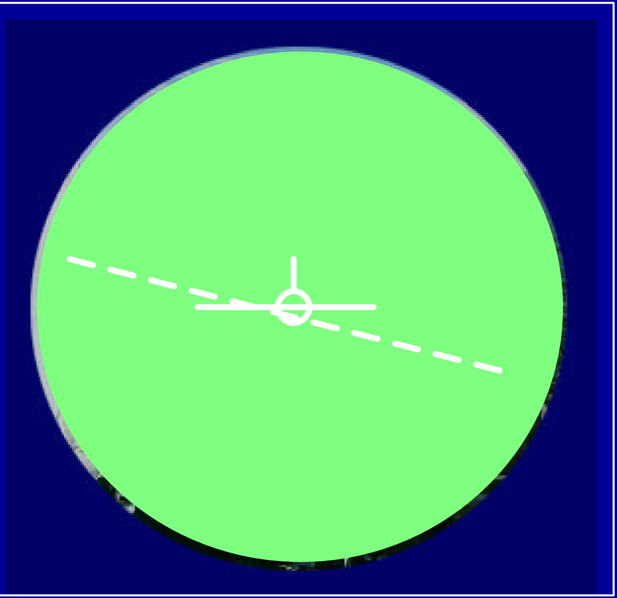
F/A-18 aircraft (Blue Angel)
73 degrees of bank (VMC, +Gz Turn).
OKCR Head tilt = 31degrees away from the Gz axis.

OKCR - Head Mounted Display (HMD) Compatibility

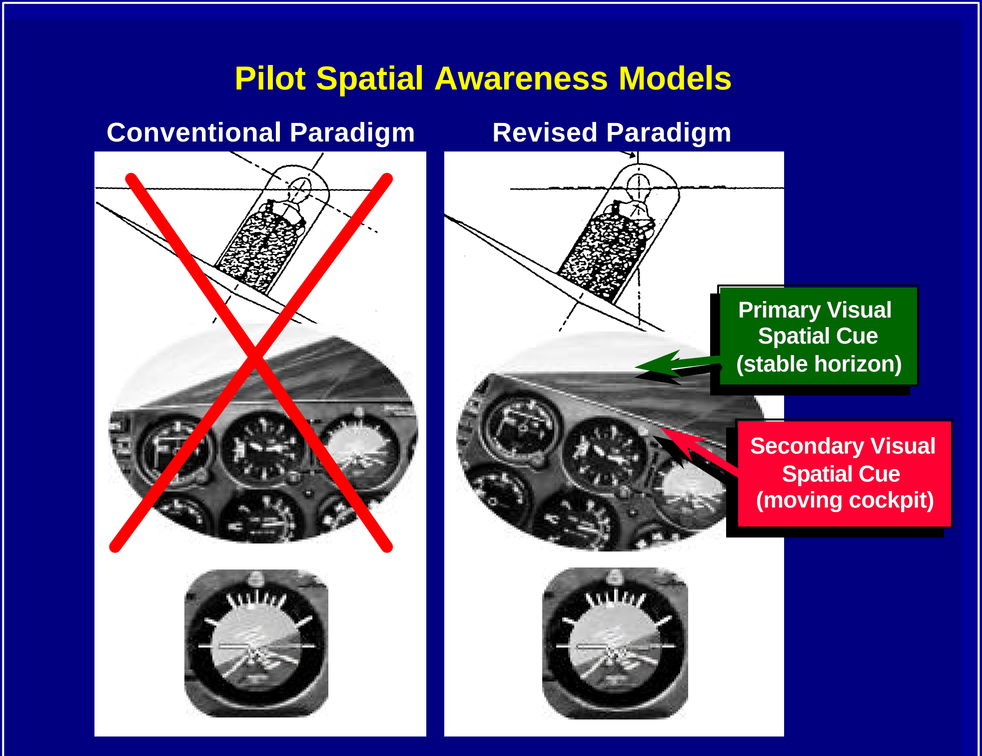
HMD used with night vision goggles (NVGs) is the product of a rapid prototype based on fixed HUD symology.

Unlike HUD symbology, NVG-HMD Horizon and aircraft symbols are often visually unsynchronized with the real horizon and aircraft.

NVG with, and without HUD symbology, significantly reduce secondary (aircraft) spatial cues.



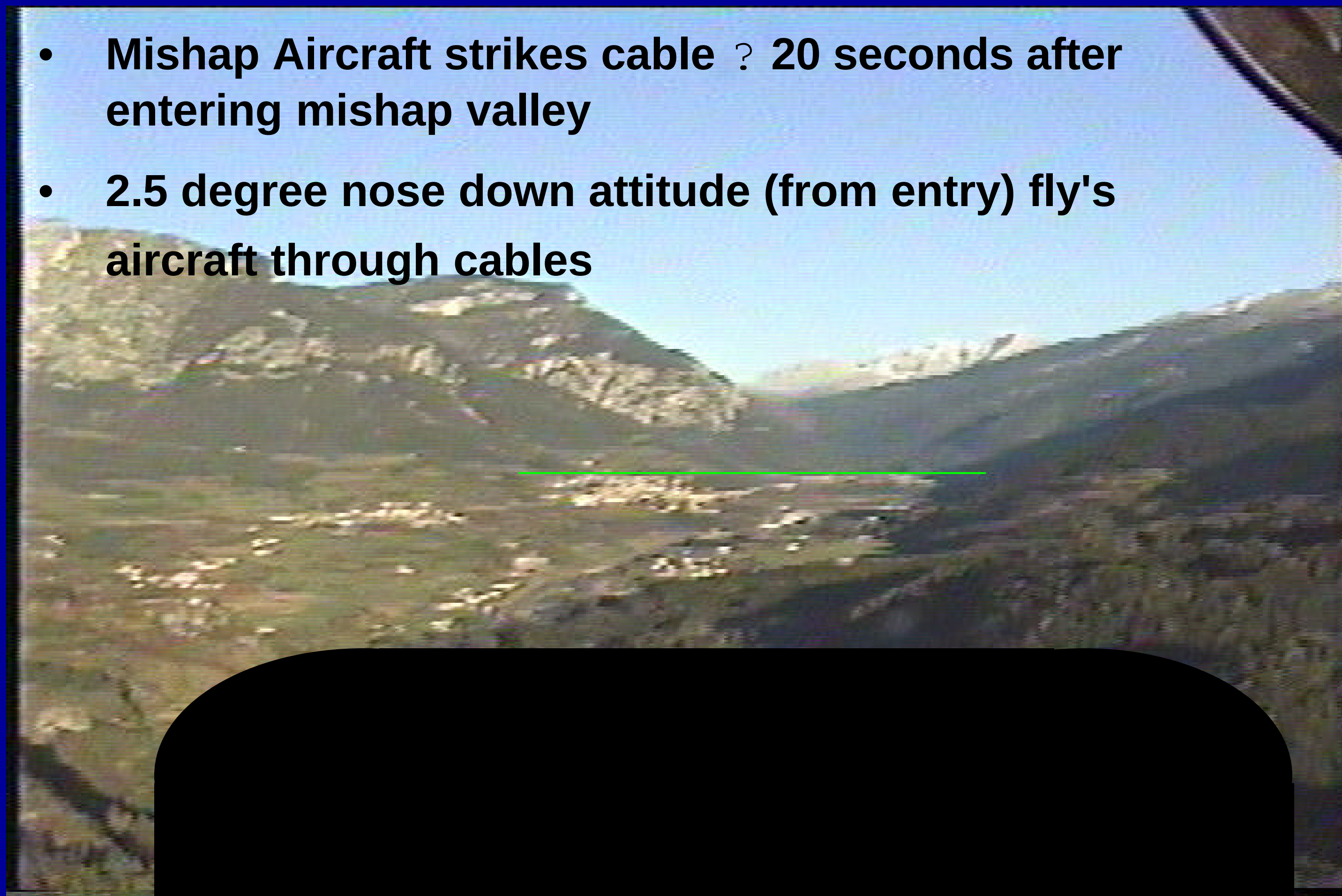
Sensory-Spatial Conflict and Control Reversal Error



Control reversal error during IMC “out” to “in” visual transition.

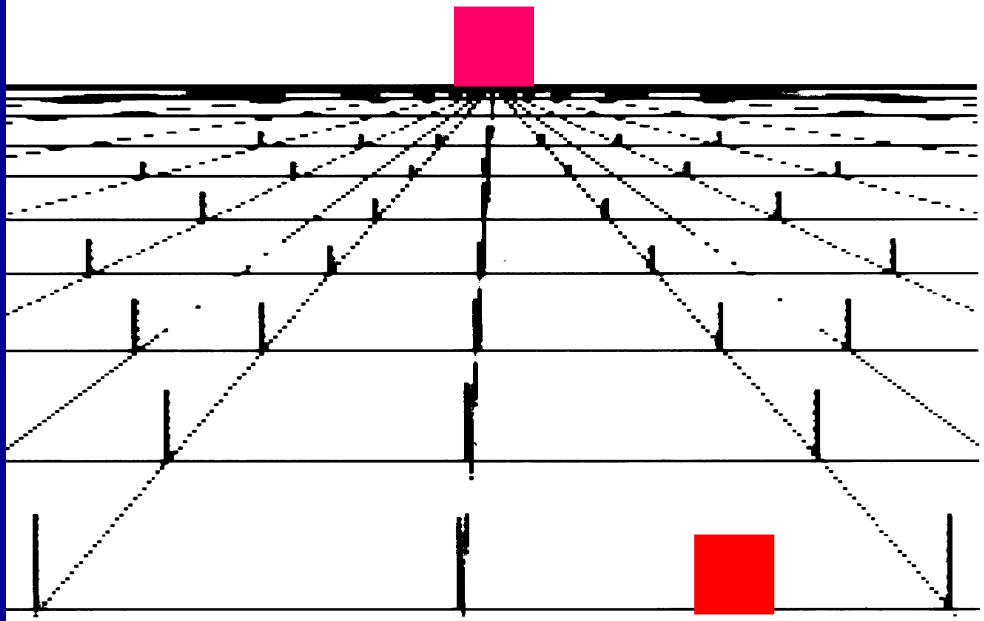
Visual-Cognitive Problems and SD

- **Mishap Aircraft strikes cable ? 20 seconds after entering mishap valley**
- **2.5 degree nose down attitude (from entry) fly's aircraft through cables**



Visually Induced
Spatial disorientation

n)



NAMRL Human Factors Test Facility

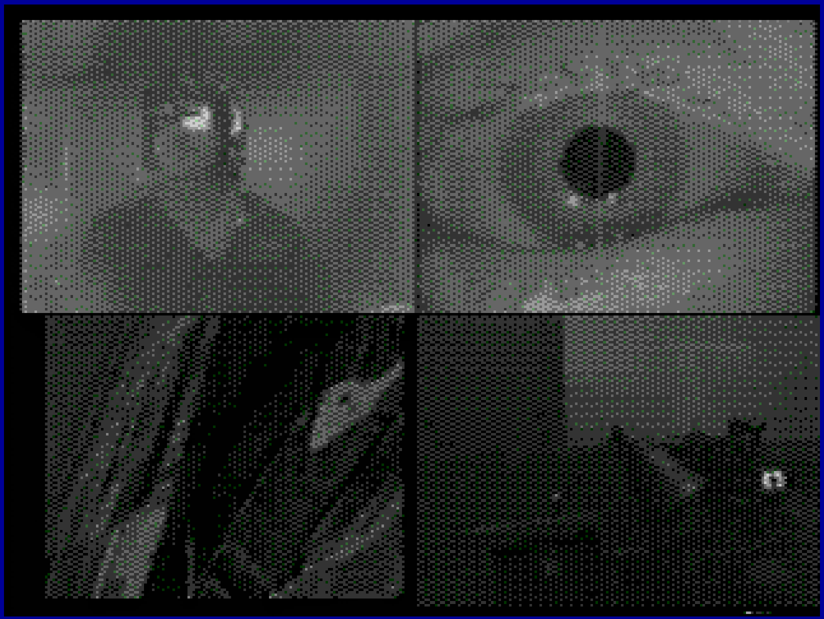
- PC Based Mission Preview
- Head Tracking
- Eye Tracking
- Biolog Linked System
- Full Color VGA HMD
- Three Channel Monitor linked systems with head down displays

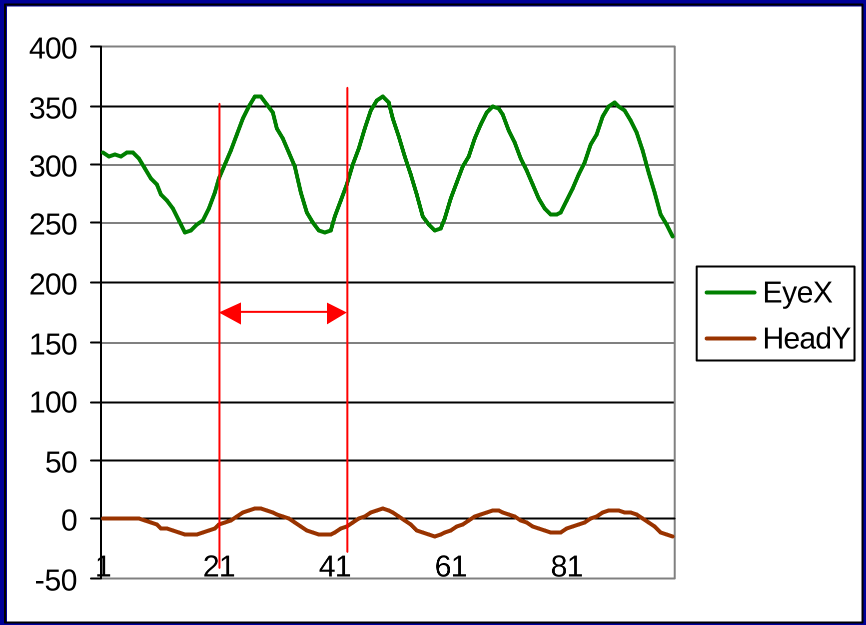
NAMRL Aviation Bioengineering Research

Effectiveness of cockpit displays are affected by sensory-spatial reflexes such as: vestibular ocular reflex (VOR)

opto-kinetic nystagmus (OKN)

opto-kinetic cervical reflex (OKCR)





Conclusions

- “Inside” spatial representations (presented with current cockpit displays) are sensory incompatible and conflict with a pilot’s intuitive “outside” spatial strategy.

- With poor outside visual conditions, the necessity to transition between two different spatial strategies (“inside” and “outside”) during final approach and take-off, increases both pilot workload and the possibility of disorientation (control reversal error).

Recommendations

- Develop sensory compatible display systems (HMD, HUD, & HDD) that present an intuitive “outside” spatial perspective. Also require that predictive or command symbology be incorporated into future display designs.

- Develop sensory-compatible cockpit structures that enhance pilot awareness of both primary and secondary spatial cues.