U.S. Army Research, Development and Engineering Command

Designing Flight Symbology for the Air Soldier System Common Helmet Mounted Display

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Outline

- Degraded Visual Environment Problem
- Degraded Visual Environment Solutions
- Air Soldier System
  - Common Helmet Mounted Display (CHMD)
- Questions & Hypotheses
- Methodology
- Results
- Conclusion
- Path Forward

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Degraded Visual Environment (DVE) is a major problem for US Army Aviation

- Losses during OEF/OIF (OCT 01 – SEP 09) from non-hostile & non-combat:
  - 305 aircraft (81% of total aircraft losses)
  - 351 fatalities (71% of total fatalities)
  - Greatest causal factor of these non-hostile & non-combat losses due to lack of situational awareness and other human factors (78% of aircraft losses, 84% of fatalities)

(Couch & Lindell, 2010. Study on Rotorcraft Survivability, *Aircraft Survivability*)

NATO Task Group HFM-162 (2008 – 2011)

- Rotary-Wing Brownout Mitigation: Technologies and Training (NATO RTO Technical Report TR-HFM-162, 2012)
  - Helmet Mounted Displays (HMD)
    - 2D Symbology, e.g. Brownout Symbology System (BOSS)
    - **3D Head-tracked Conformal Symbology**
    - Synthetic Vision
  - Alternative Displays
    - 3D Audio
    - Tactile
  - Sensor-based Solutions
    - Radar
    - LADAR
    - Passive Electro-Optical Imaging
  - Flight Controls
  - Training, Techniques, and Procedures

Air Soldier System

- **Integrated Helmet and Display System:**
  - HGU-56/P as common helmet platform
  - Helmet Mounted Display and head tracker with flight and 3D Degraded Visual Environment symbology
  - Enhanced Laser Eye Protection (limited implementation)

- **Suite of Integrated Personal Electronics:**
  - Integrated Soldier Power and Data System
  - Personal Display Module
  - Mission Display Module (aircraft-mounted)
  - Soldier Computer Module
  - Lightweight Environmental Control System (limited implementation)
  - Radio Interface Control Module

- **Integrated Layered Clothing:**
  - Improved cooling vest
  - Active heating garment
  - Single layer lightweight CB protection
  - Multi-purpose CB and immersion protective garment

- **Integrated Protective Equipment:**
  - Lightweight soft body armor
  - 72 hour survival items
  - Integrated gear carriage and body armor system
  - Fully integrated flotation system
  - Lightweight composite emergency breathing device and oxygen bottles

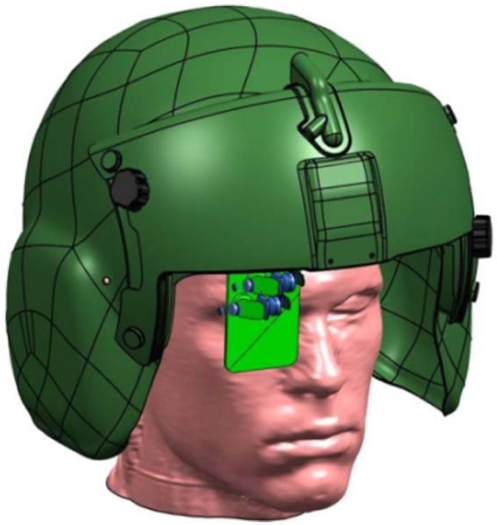
Product Manager Air Warrior

CHMD with Head Tracker & 3D Conformal Symbology

Description: Common digital display with integrated head tracker for all aircraft (except AH-64)

Operational Function:

- Provides pilots with visual cues during day and night flight (compatible with NVGs)
- Improves pilot SA (promotes “heads up”) by displaying conventional aircraft generated symbology (cautions/advisories, altitude, attitude, torque, mission routing info)
- Displays 3D conformal symbology used for safer takeoff, flight, and landing in degraded visual environments (i.e., brownout)
- Allows pilots greater focus outside the aircraft instead of increased focus on aircraft instruments during degraded visual environment flight



Question & Hypotheses

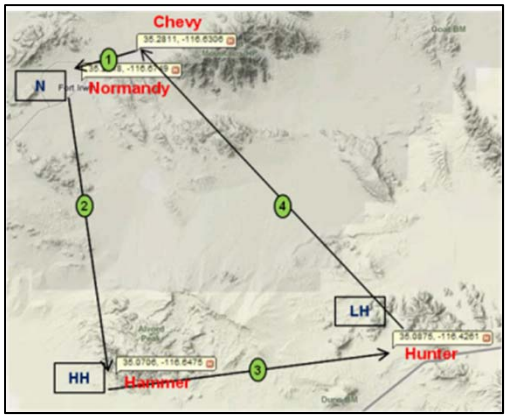
Real-world human factors problem with customer constraints

- **Question:** Program Manager wants to know effects of proposed (3D) versus legacy (2D) Helmet Mounted Display (HMD) symbology

- **Hypotheses:** The proposed symbology will:
  1. Improve situation awareness
  2. Reduce mental workload
  3. Improve safety
  4. Improve performance

Design Methodology

- February 2011 – AMRDEC/SSDD APEX II Lab, UH-60L fixed base simulator
- Pilots
  - Six Kentucky Army National Guard Pilots, range of flight hours
  - Each served as pilot and co-pilot
- Mission Vignettes
  - Three unique map routes
  - Four flight legs in each mission



Independent Variables & Levels

- HMD Symbology
  - Legacy 2D Symbology
  - Proposed 3D Head Tracked Conformal Symbology
- Critical Flight Tasks
  - Takeoff
    - Takeoff in Visual Conditions
    - Takeoff in DVE
  - Landing
    - Normal approach in Visual Conditions
    - Normal approach in DVE
    - Low hover approach in DVE
    - High hover approach in DVE

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Dependent Variables & Measures

- Situation Awareness
  - Modified Situation Awareness Rating Technique (SART) (Taylor, 1989)
  - China Lake Situation Awareness (Adams, 1998)
- Workload
  - Modified NASA Task Load Index (NASA-TLX) (Hart & Staveland,1988)
  - Bedford Workload Rating Scale (Roscoe & Ellis, 1990)
- Safety
  - Crash Landings
- Performance
  - Takeoff heading and roll change 10 seconds after lift-off
  - Landing heading and roll change 2 seconds prior to touch-down
  - Landing vertical and lateral speed at touch-down
  - Landing zone (LZ) distance error

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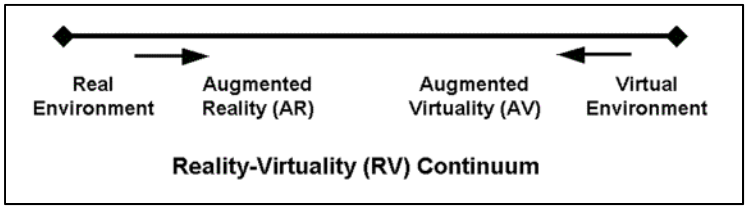
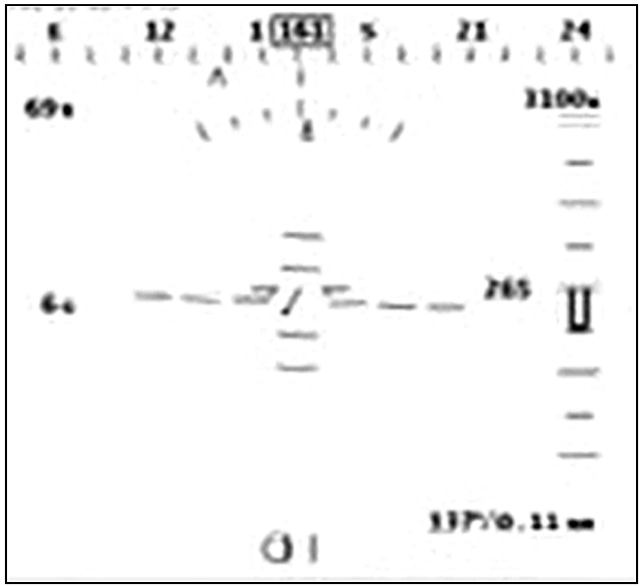
Helmet Mounted Display Symbology

- Elbit Systems, Ltd. Helmet Display Tracking System (HDTS) with DVE capabilities
- Augmented Reality Concept (Milgram, et al.,1994)



Helmet Mounted Display Symbology

- Legacy 2D Symbology (Currently fielded AN/AVS-7)
  - Attitude (Vertical Situation Indicator), Heading, Waypoint Bearing & Distance, Altitude, Aircraft Performance, Velocity Vector



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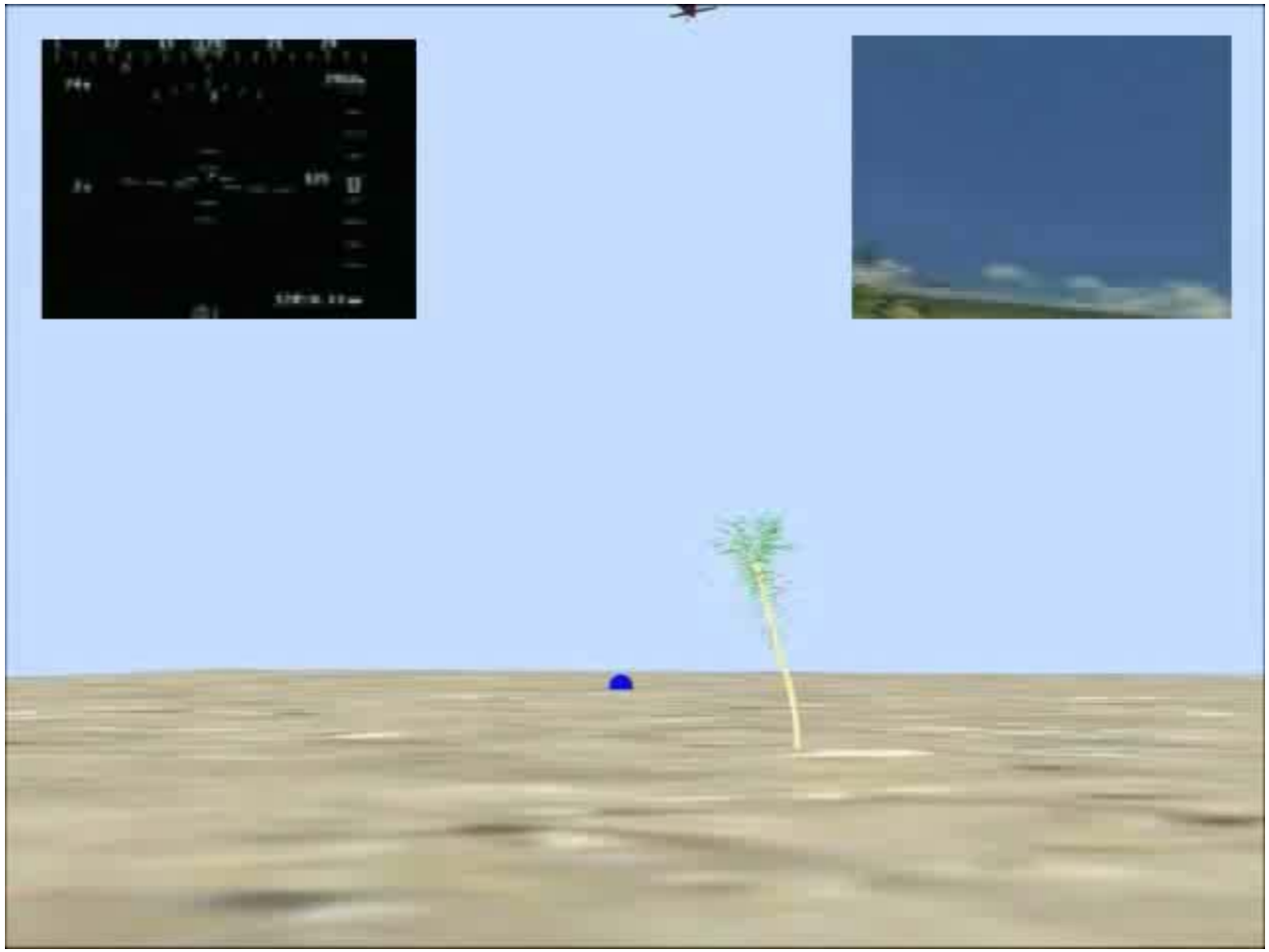
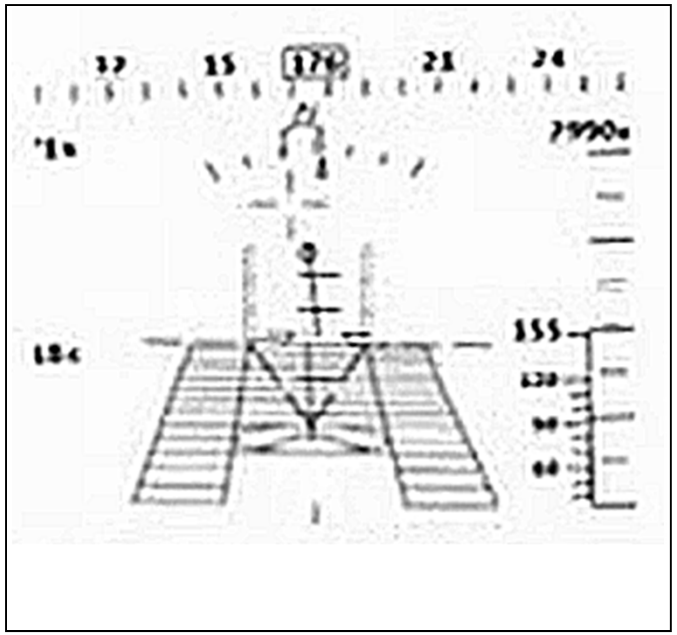
2D Symbology Video

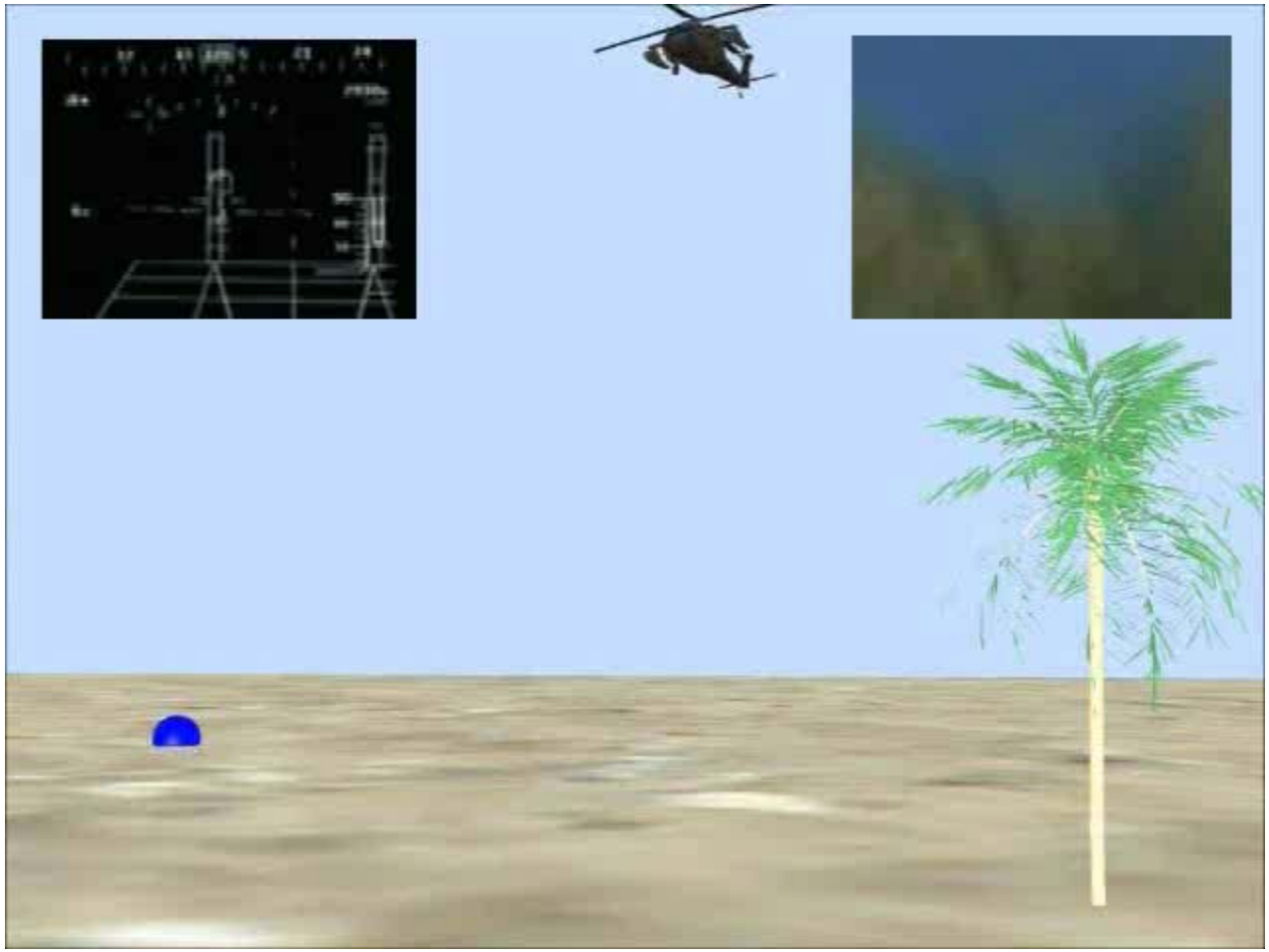


Helmet Mounted Display Symbology

- Proposed 3D Head Tracked Conformal Symbology
  - Legacy 2D plus Improved 2D Symbology: Acceleration Cue, Landing Zone Marker, Flight Path Marker & Touch Down Box, Radar Altitude Ladder with Rising Deck
  - Head Tracked 3D Symbology: Other Pilot's Line of Sight, 3D Wingmen, and 3D Landing Grid

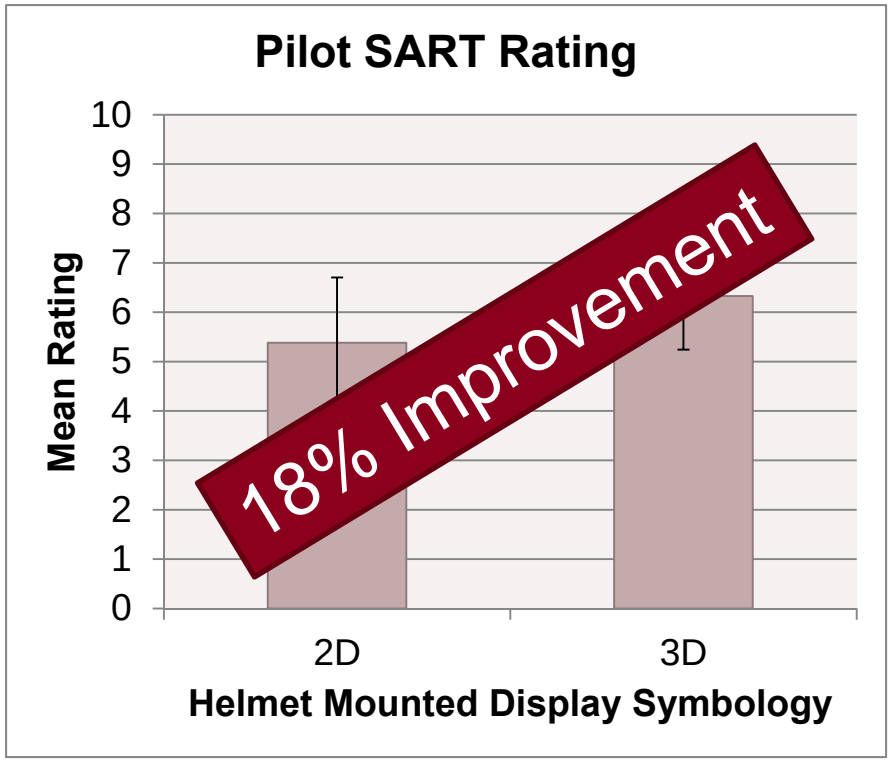


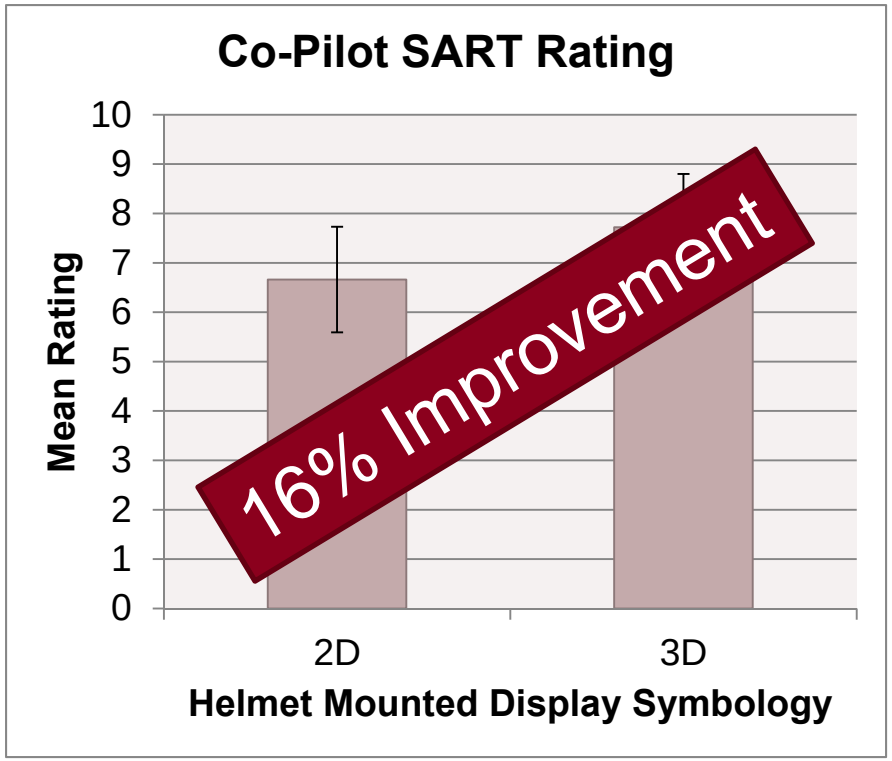
3D Symbology Video



Detailed Results

H_1: The proposed symbology will improve situation awareness





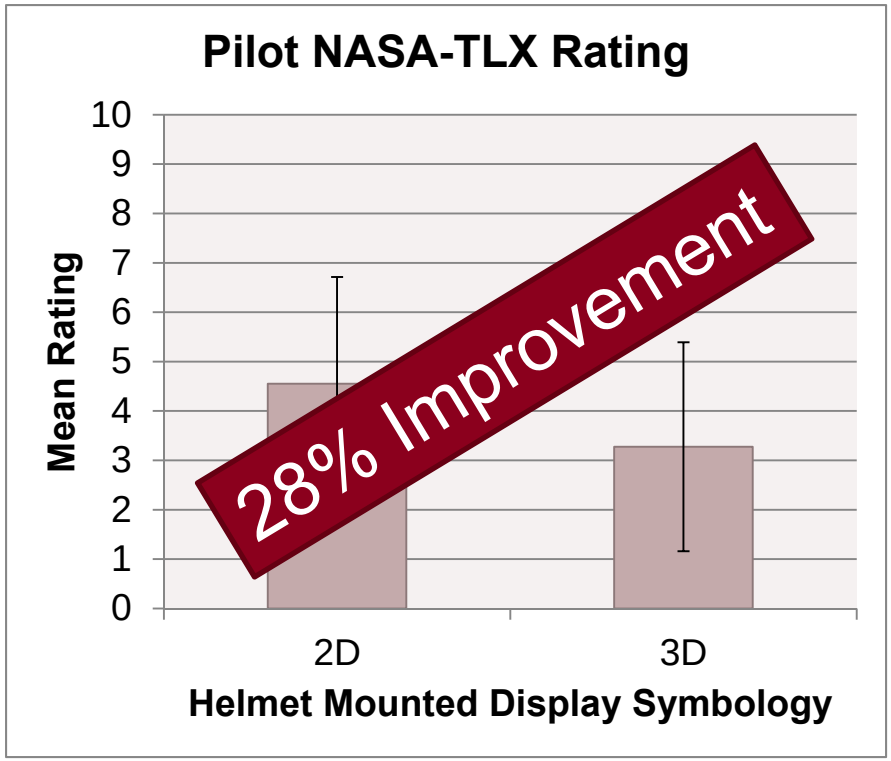
Error Bars show 95% Confidence Intervals

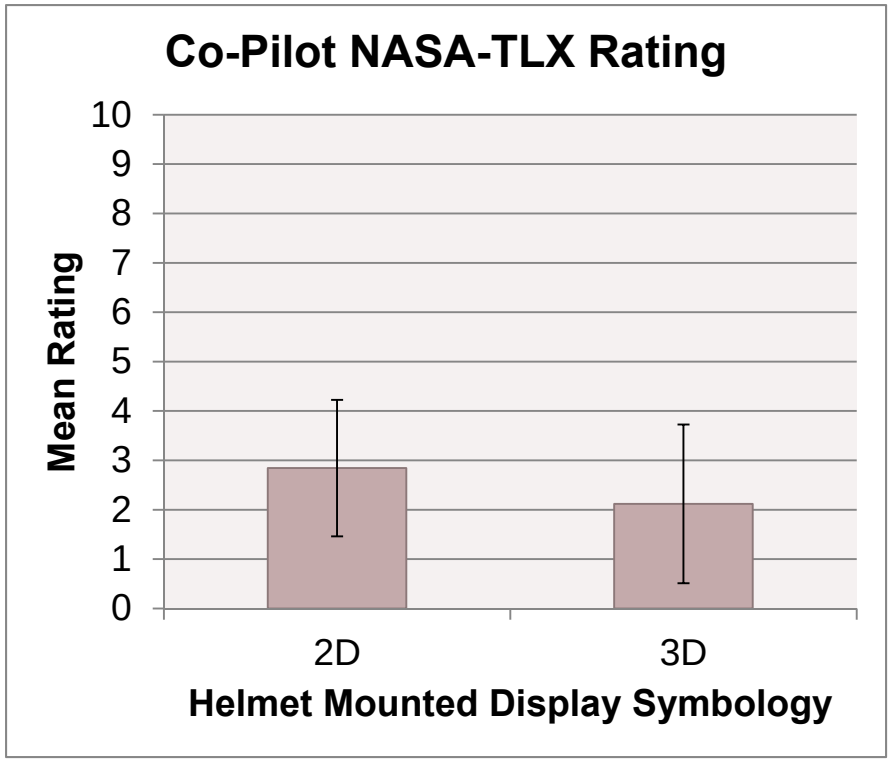
Significant Main Effect:
F (1,5) = 18.026, p = .008

Significant Main Effect:
F (1,5) = 25.544, p = .004

Detailed Results

H_2: The proposed symbology will reduce mental workload





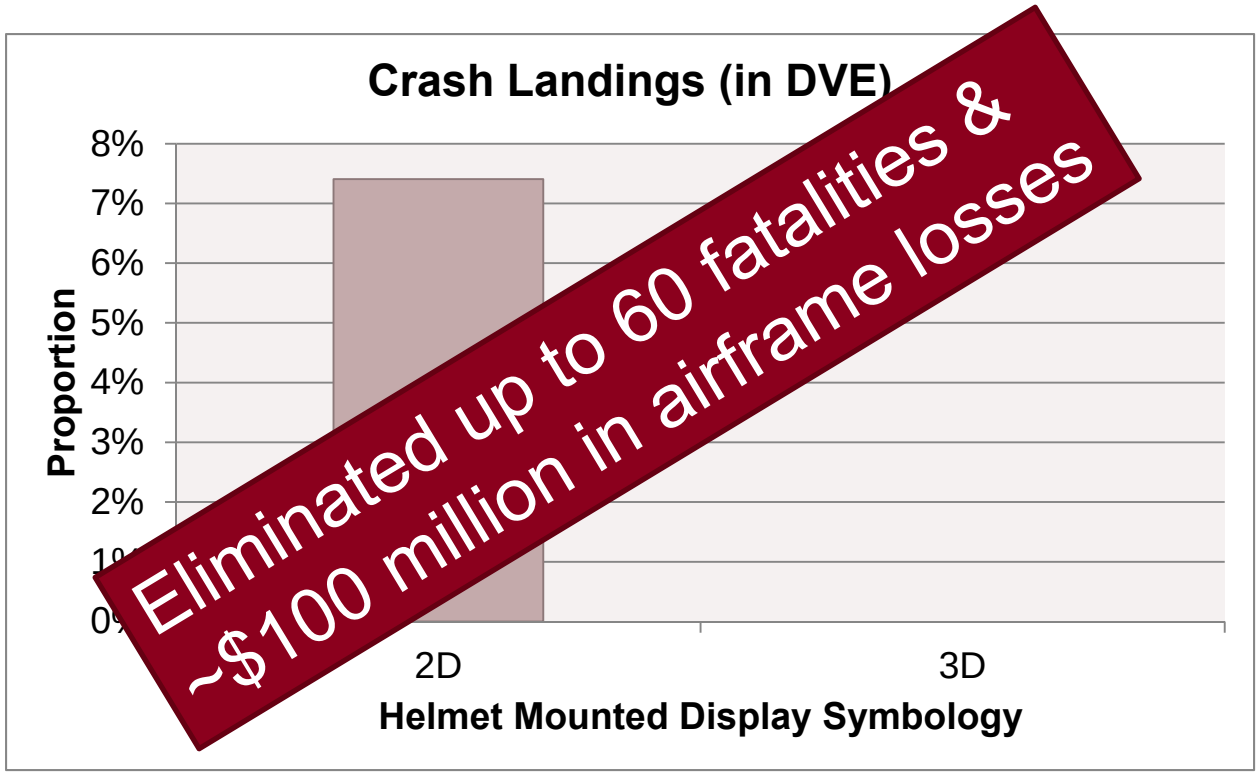
Error Bars show 95% Confidence Intervals

Significant Main Effect:
F (1,5) = 23.308, p = .005

NO Significant Main Effect:
F (1,5) = 4.567, p = .086

Detailed Results

H_3: The proposed symbology will improve safety

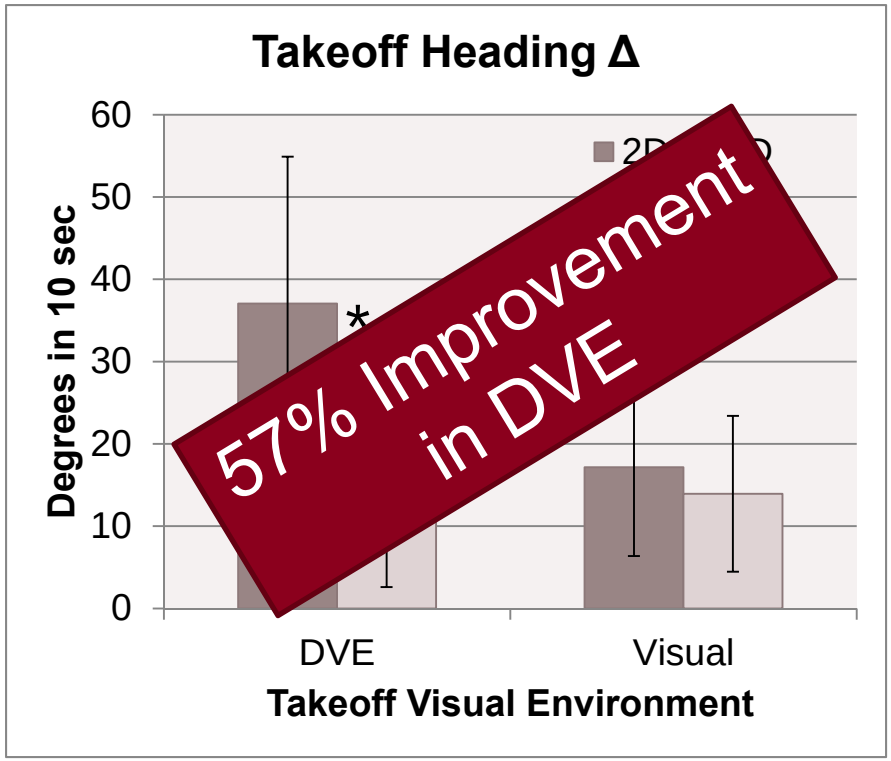


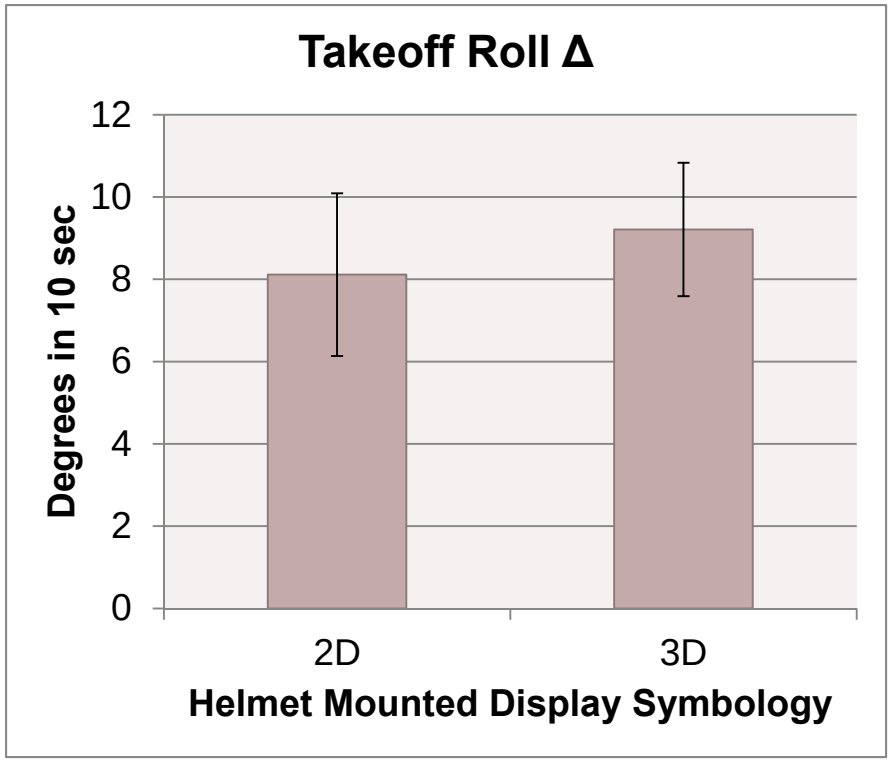
Significant Difference:

$z = -2.353$, $p = .009$

Detailed Results

H_4: The proposed symbology will improve performance





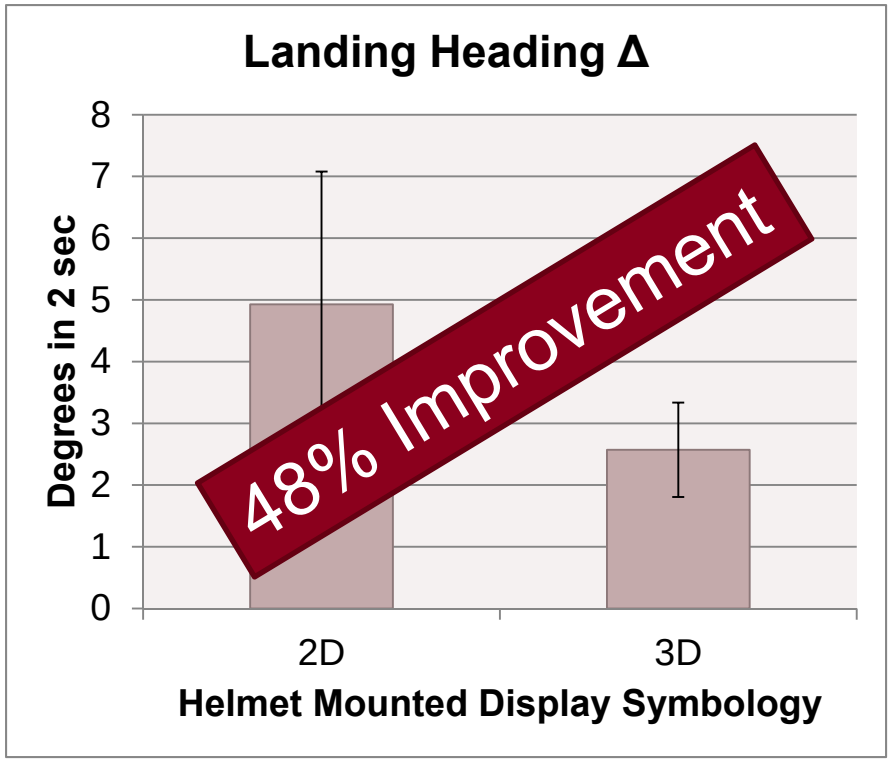
Error Bars show 95% Confidence Intervals

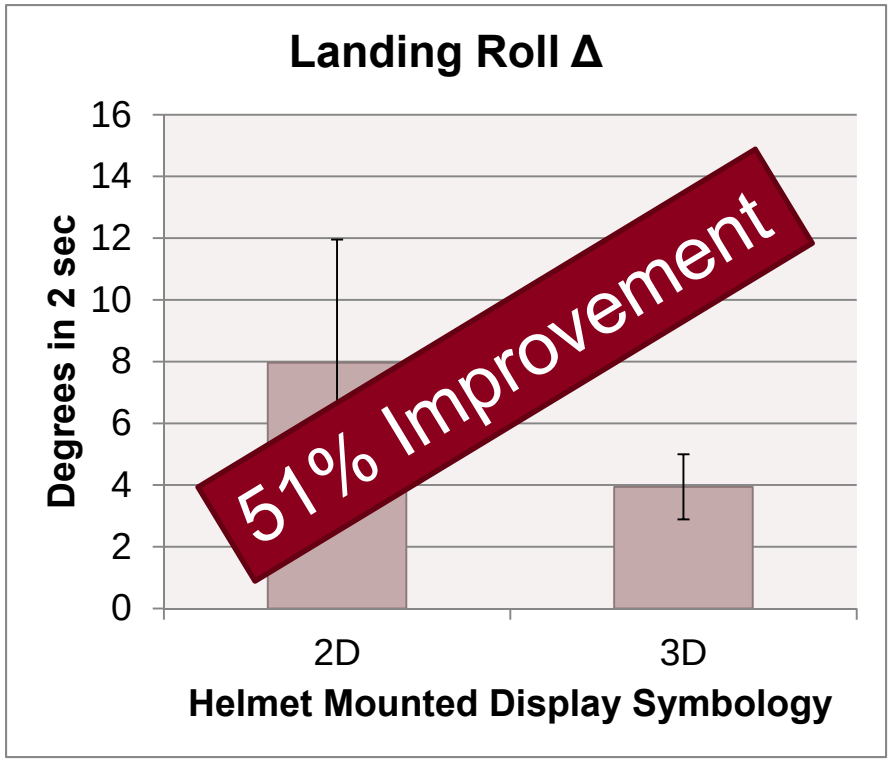
*** Significant Interaction Effect**
HMD x Visual Environment:
F (1,5) = 84.434, p < .001

NO Significant Main Effect:
F (1,5) = 0,772, p = .420

Detailed Results

H_4: The proposed symbology will improve performance





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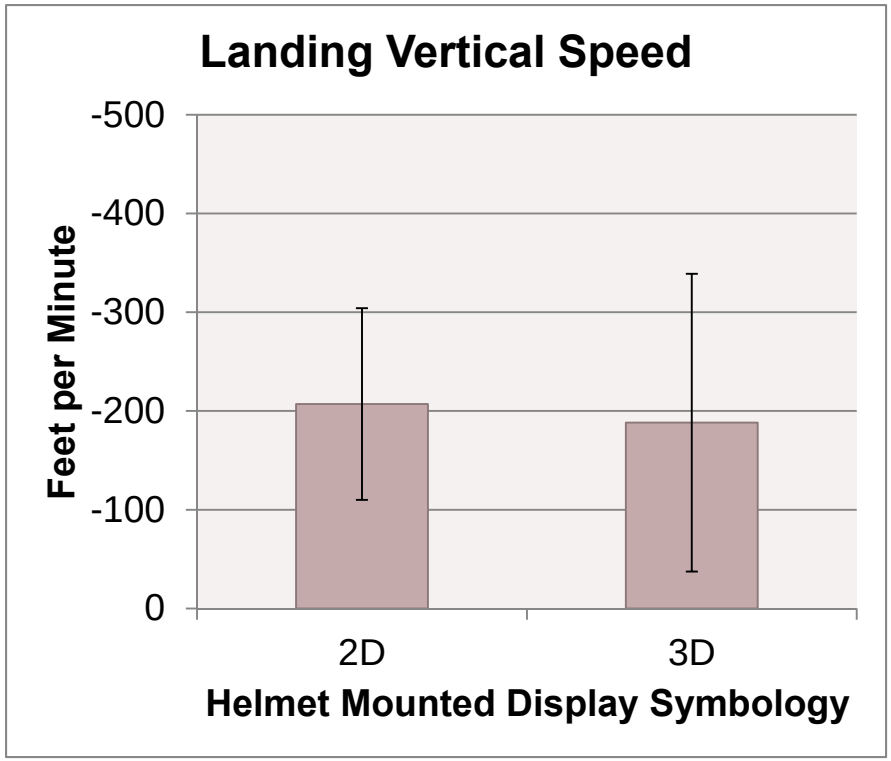
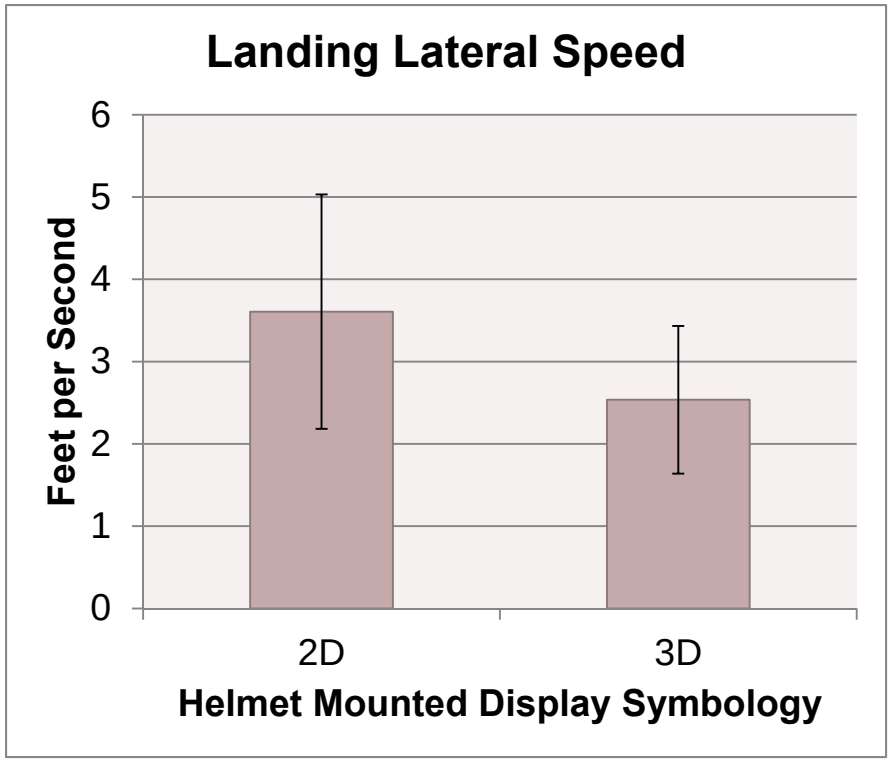
Significant Main Effect:
F (1,5) = 8.172, p = .035

Significant Main Effect:
F (1,5) = 8.084, p = .036

Detailed Results

H_4: The proposed symbology will improve performance





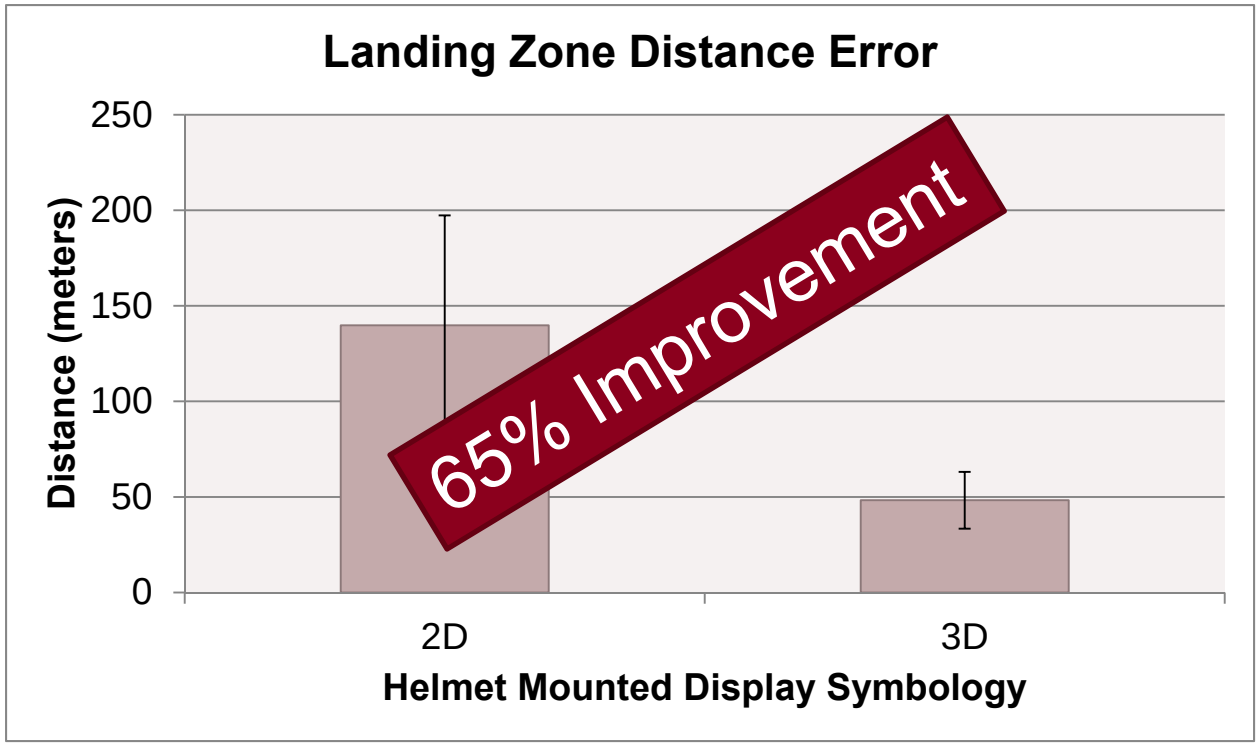
Error Bars show 95% Confidence Intervals

NO Significant Main Effect:
F (1,5) = 0.220, p = .659

NO Significant Main Effect:
F (1,5) = 2.029, p = .214

Detailed Results

H_4: The proposed symbology will improve performance



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Significant Main Effect:
F (1,5) = 15.439, p = .011

Conclusion

- **These data show that the proposed symbology:**
  - Significantly Improved Pilot and Co-Pilot Situation Awareness
  - Significantly Reduced Pilot Workload
  - Significantly Improved Safety, Eliminating Crash Landings in DVE
  - Significantly Improved Performance:
    - Takeoff Heading Stability
      - 2D HMD / DVE takeoffs violated standards
      - 3D HMD / DVE takeoffs were better than standards
    - Landing Heading & Roll Stability
    - Landing Zone Distance Error

Path Forward

Goal:

- Continue to improve on 3D HMD symbology for US Army Aviation through the Air Soldier System Program

Method:

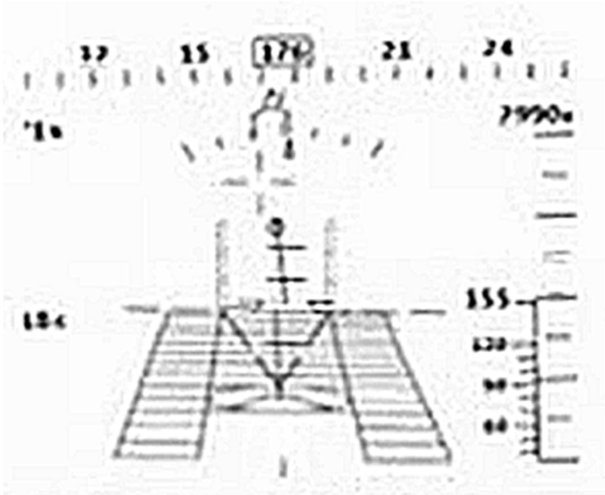
- Understand the needs of the user community, materiel developers, and other Army Aviation stakeholders
- Iterative design process to prototype and evaluate HMD symbology

Schedule:

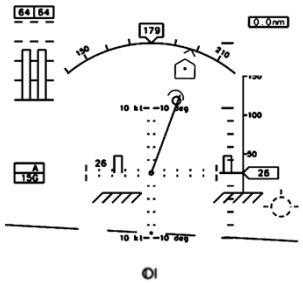
- Findings Reported – January 2013
- First Unit Equipped – FY 2015

CHMD Symbology Design Influences

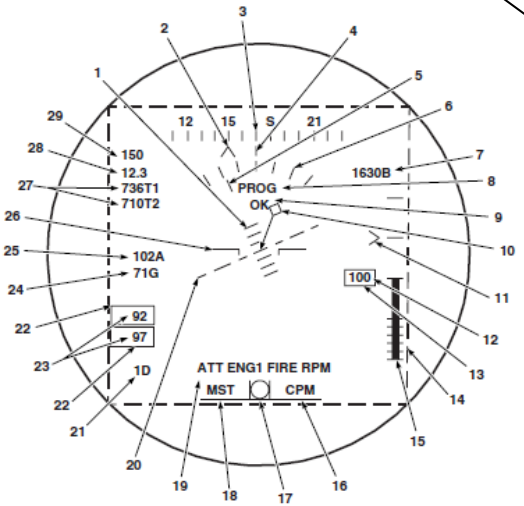
Human Factors
Scientific Research



COTS 3D Conformal

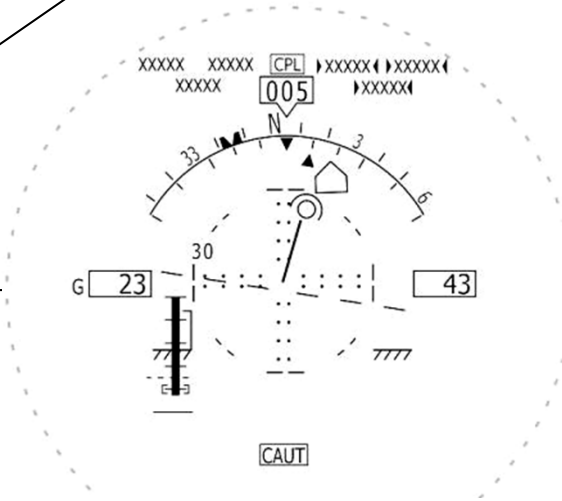


Other Advanced Displays



Legacy HUD

CHMD



Platform Displays

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