HUDs versus HDDs:

A comparison of formats for presentation of highway-in-the-sky primary flight displays

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Problem: Scanning outside the aircraft

- Concern that HITS-format display was too compelling and would trap scan in head-down presentation
- Initial belief that HUD would ameliorate effect to some degree
- Need to evaluate cognitive capture effects of HITS in HUD presentation

Previous Findings & Limitations

- Some data suggest that cognitive capture is a significant factor in HUDs (Wickens, et. al)
- Limitation on Wickens data was that HUD image was projected on the same screen as the out-the-window scene; it was not a HUD device per se
- Observations of extensive head-down time with HITS display (CAMI studies) were "subjective"

Primary questions:

- How “compelling” is the HITS-format display?
  - Will task requirements produce inordinate dwell times?
  - Will surveillance of surrounding airspace and monitoring of other cockpit displays suffer?
- Can relocation to a Head-up display reduce the effects on surveillance of surrounding airspace?

Secondary questions:

- Given HUD use, what are the relative benefits of conformal and nonconformal presentations?
  - Conformal matches the external scene but can produce restricted field of view on HUD. Does this affect performance?
  - Nonconformal presents sufficient pitch data for climb with horizon visible on display, but doesn't match external scene.
- Can one format be used throughout a flight for all tasks?
  - How do pilot performances and preferences align with formats?
- *Definitions...*

Illustrations: Head-down display

Head-up display...

Head-REALLY-up display...

Experimental Design

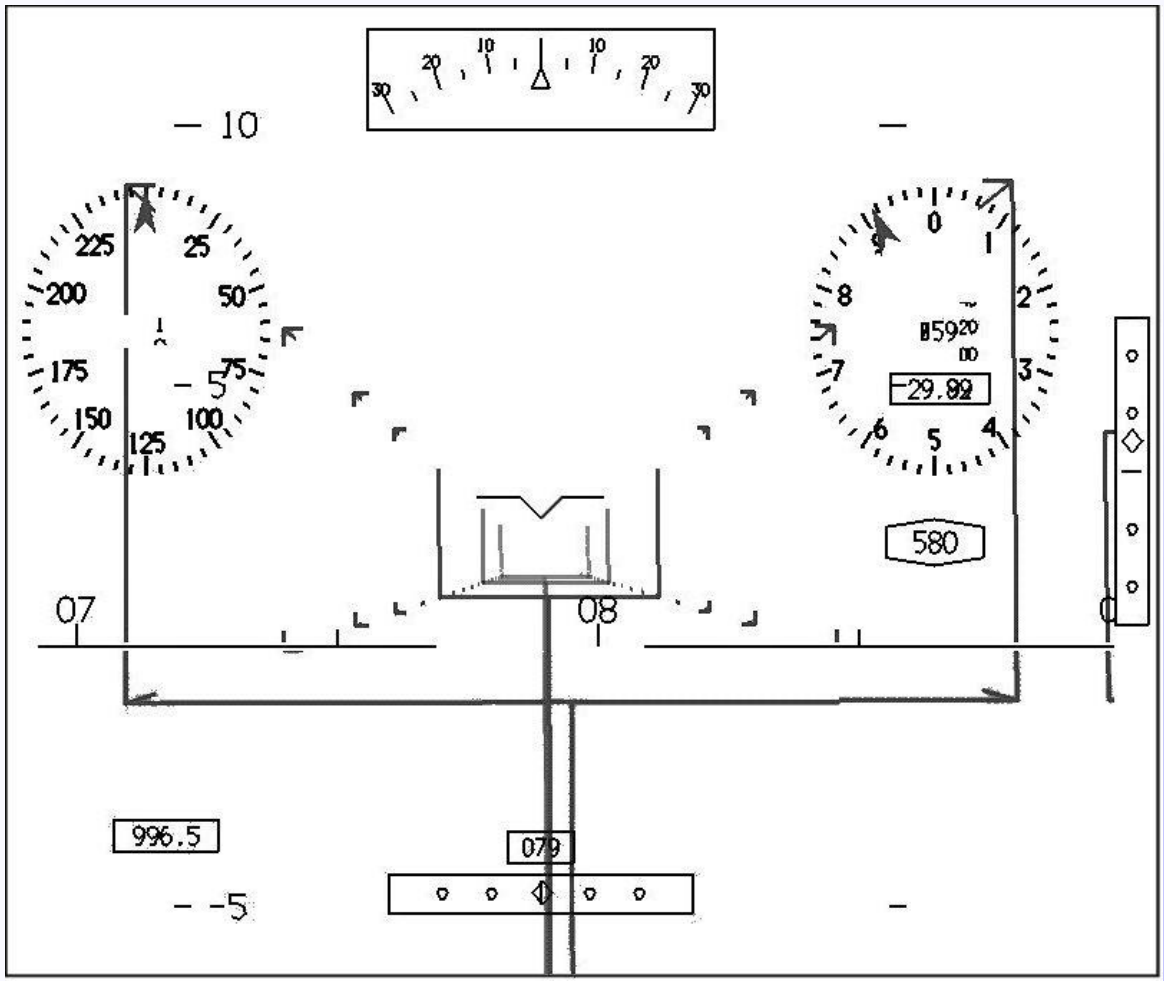
- Three HITS display configurations
  - Nonconformal *(40 degrees of HITS represented)*
    - Head-down display
    - Head-up display
  - Conformal *(22 degrees of HITS represented)*
    - Head-up display
- Within-subject design
  - Counter-balanced presentations

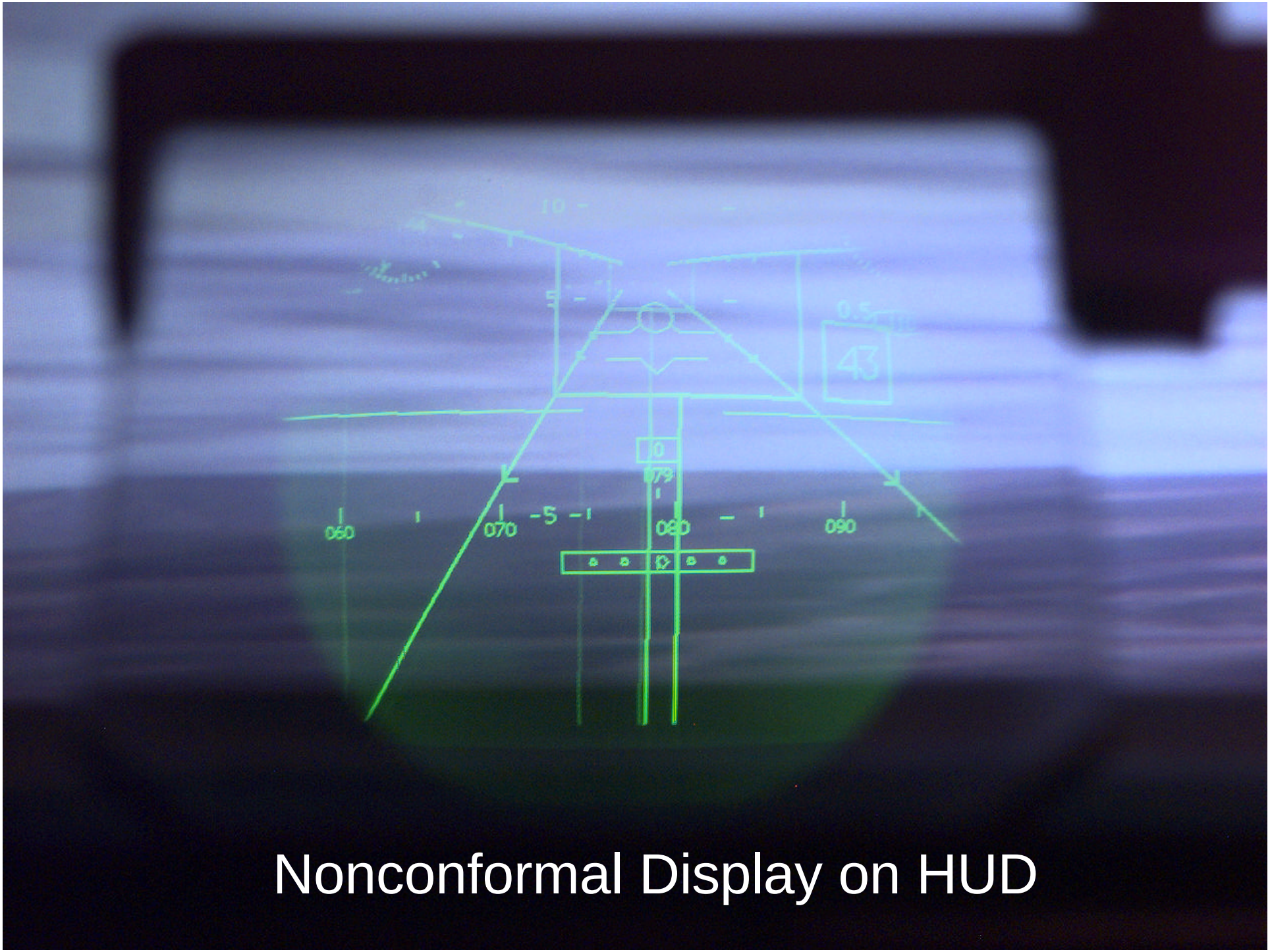
Procedure

- Warm-up flight, conventional instruments
  - Familiarization with aircraft performance
  - Familiarization with geographic location (Albuquerque)
- Pre-flight briefing
  - Description of tasks and displays
- Data-collection flights
  - Eye tracker mounted and calibrated
  - Two data flights conducted; then a short out-of-cockpit break before third data flight

Advanced General Aviation Research Simulator

HITS Display (conformal)

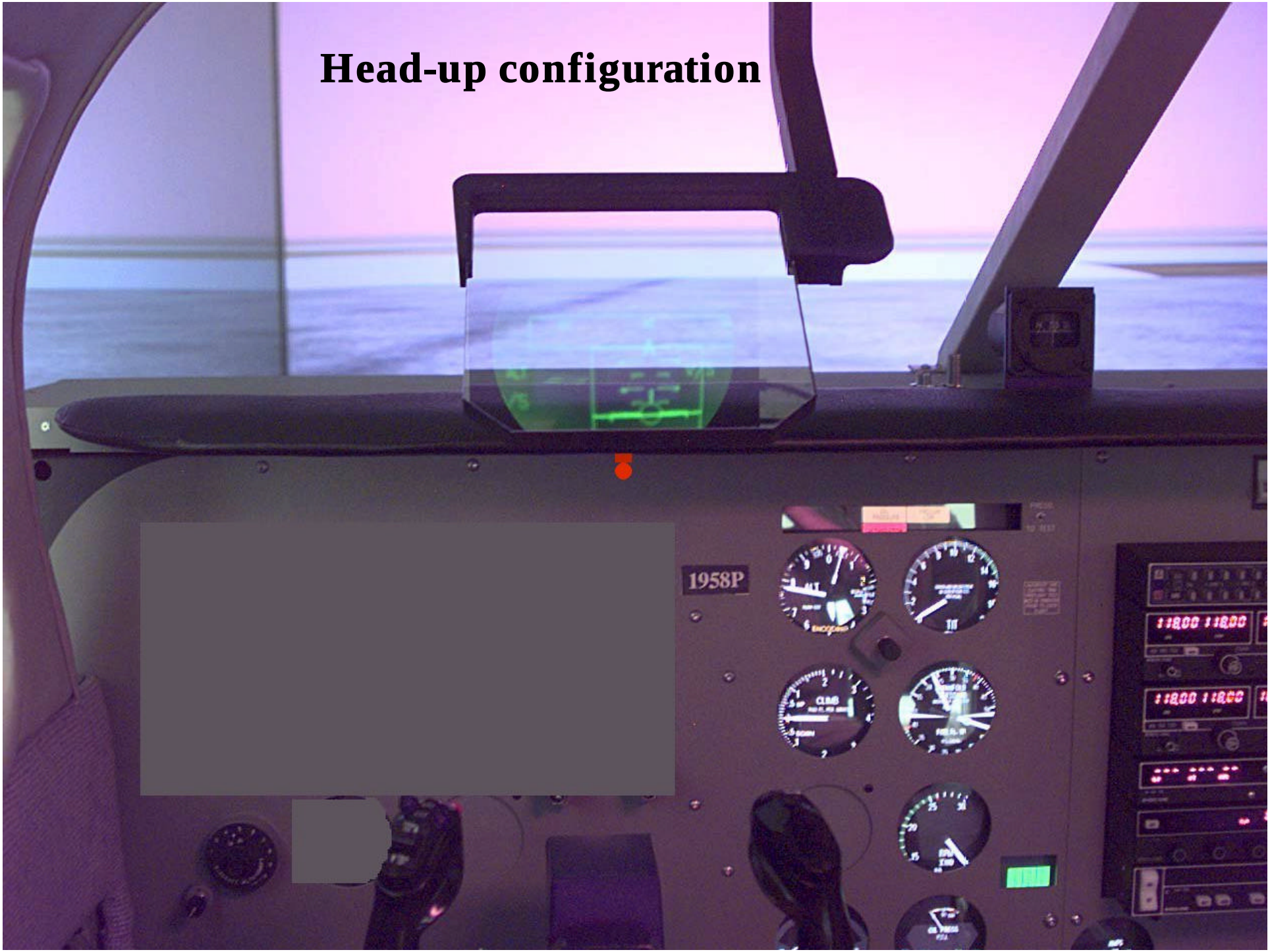




Nonconformal Display on HUD

Head-down configuration

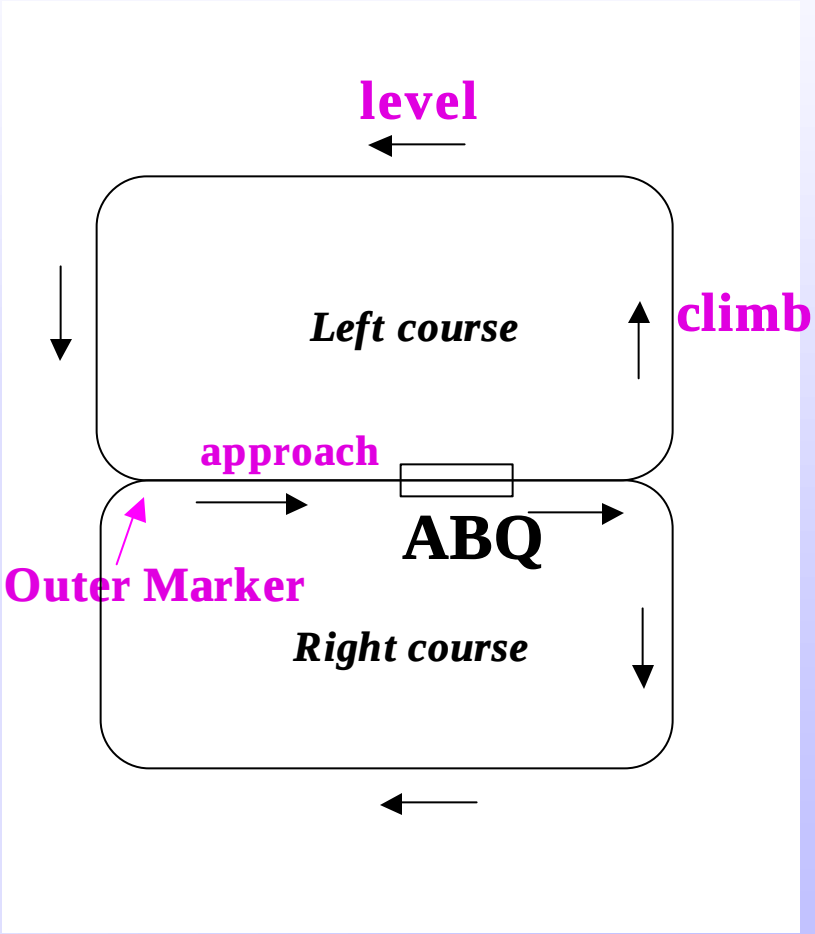
Head-up configuration



Eye-tracking apparatus

Flight Task (in AGARS)

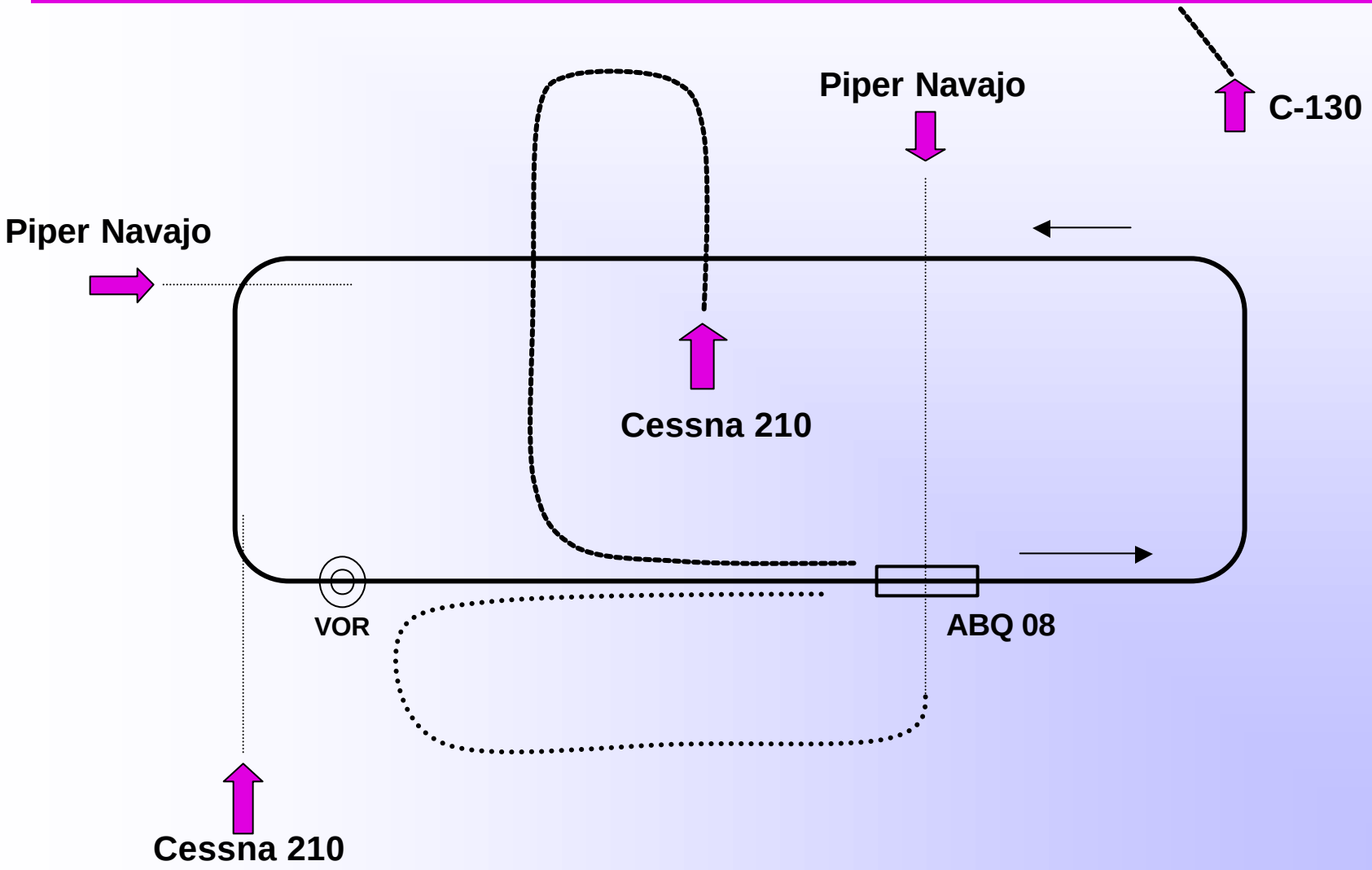
- Take-off Runway 08
- Climb - intercept path (IMC)
- Level downwind (140-150kts) (VMC)
- Approach / Landing (IMC - VMC)
- 20 minutes per circuit



Pilot Tasks

- Pilot aircraft, using guidance provided by HITS symbology
- Maintain communications with ATC
- Detect and report airborne targets
- Respond to probe-RT light using yoke-mounted keypad *(also used to check alignment of eye tracker)*

Detail of airborne target paths



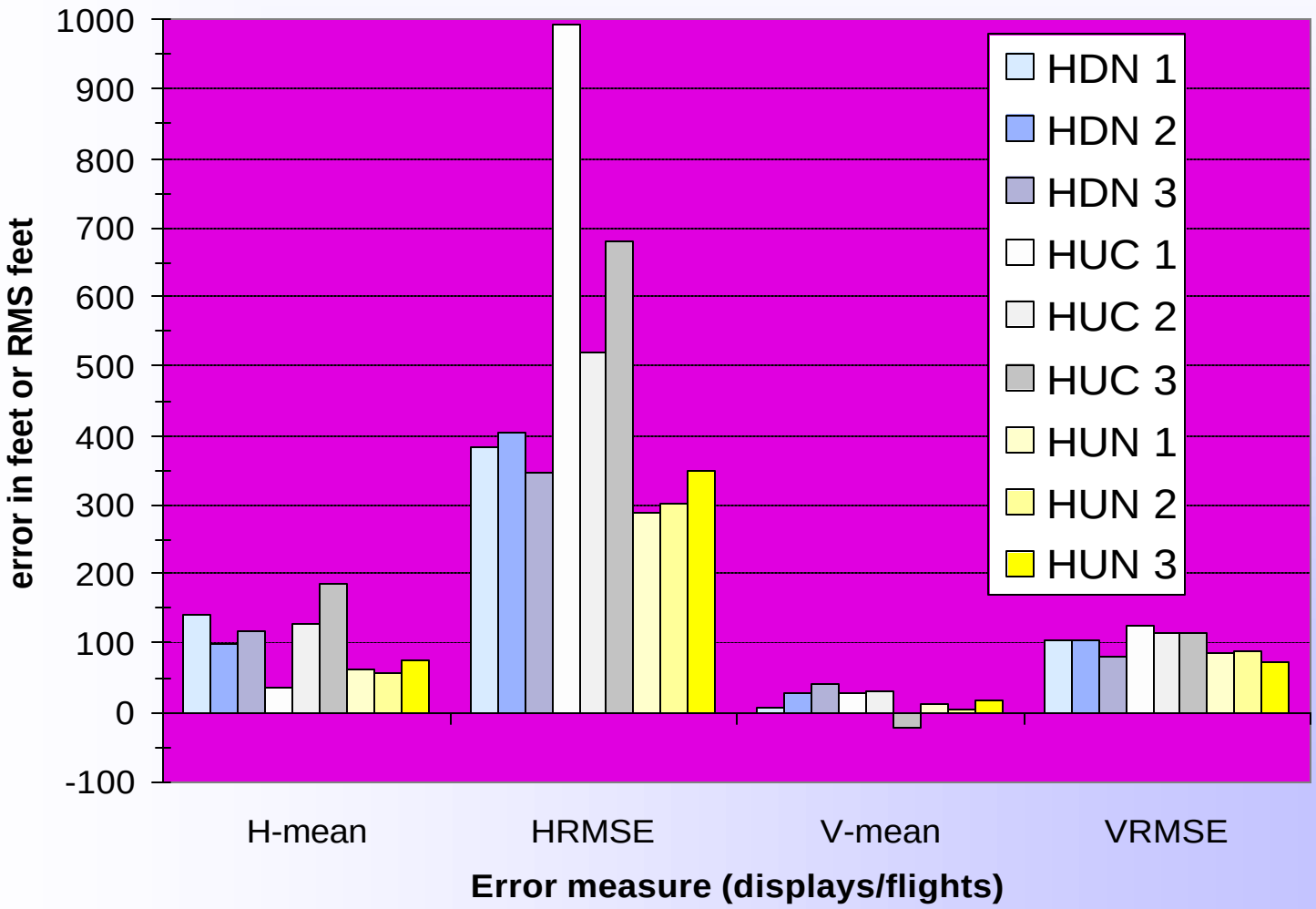
Performance measures

- Flight technical error (horizontal, vertical)
- Visual performance
  - Dwell time
  - Transition frequency
  - Target detection rate / distance
- Workload (Probe RT)

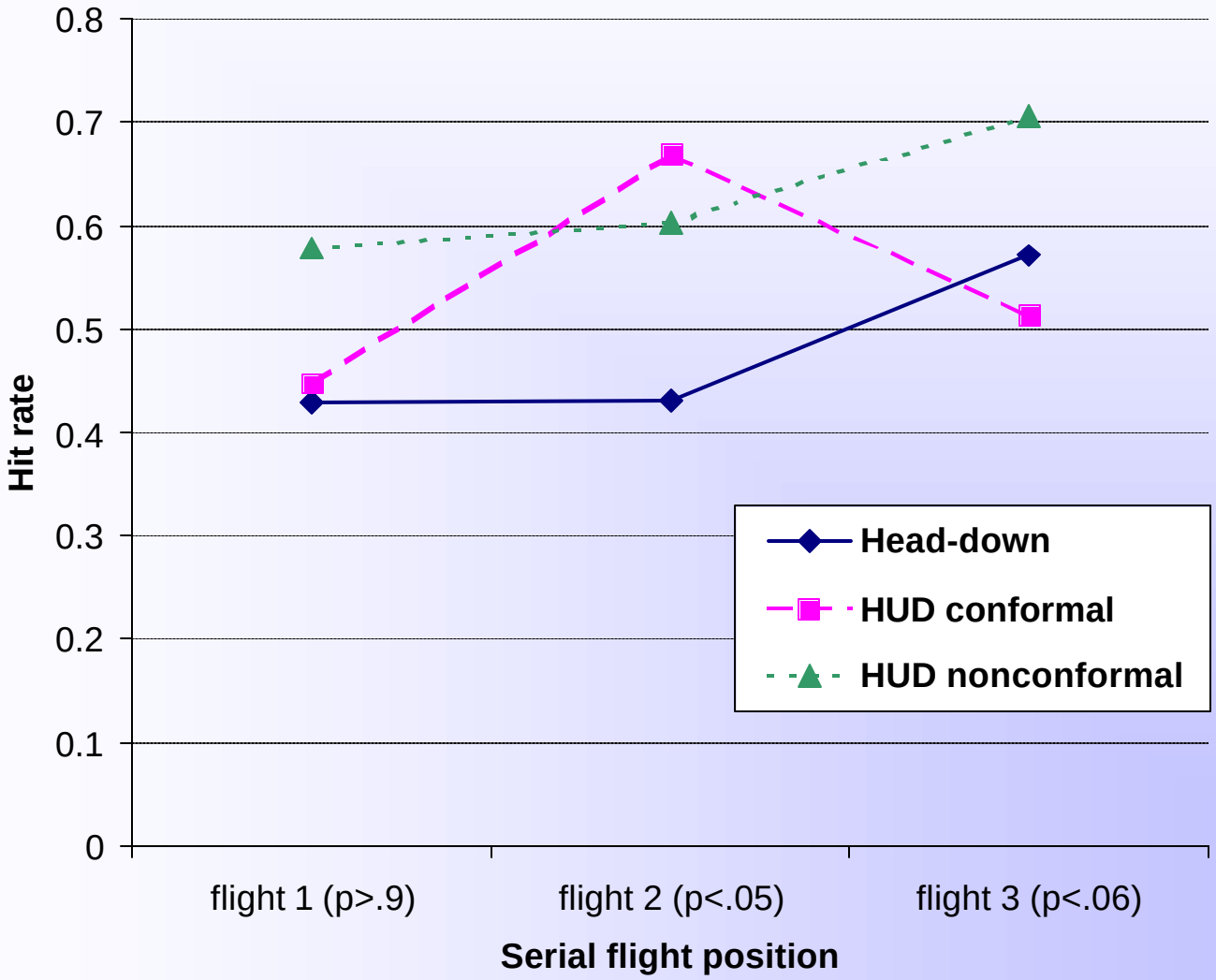
Preliminary Results

- Course-tracking error -
  - Horizontal error in turns less for nonconformal displays
  - Greatest error when conformal HUD flown first or last
- Vertical error -
  - Greatest with conformal HUD, but magnitude of difference small

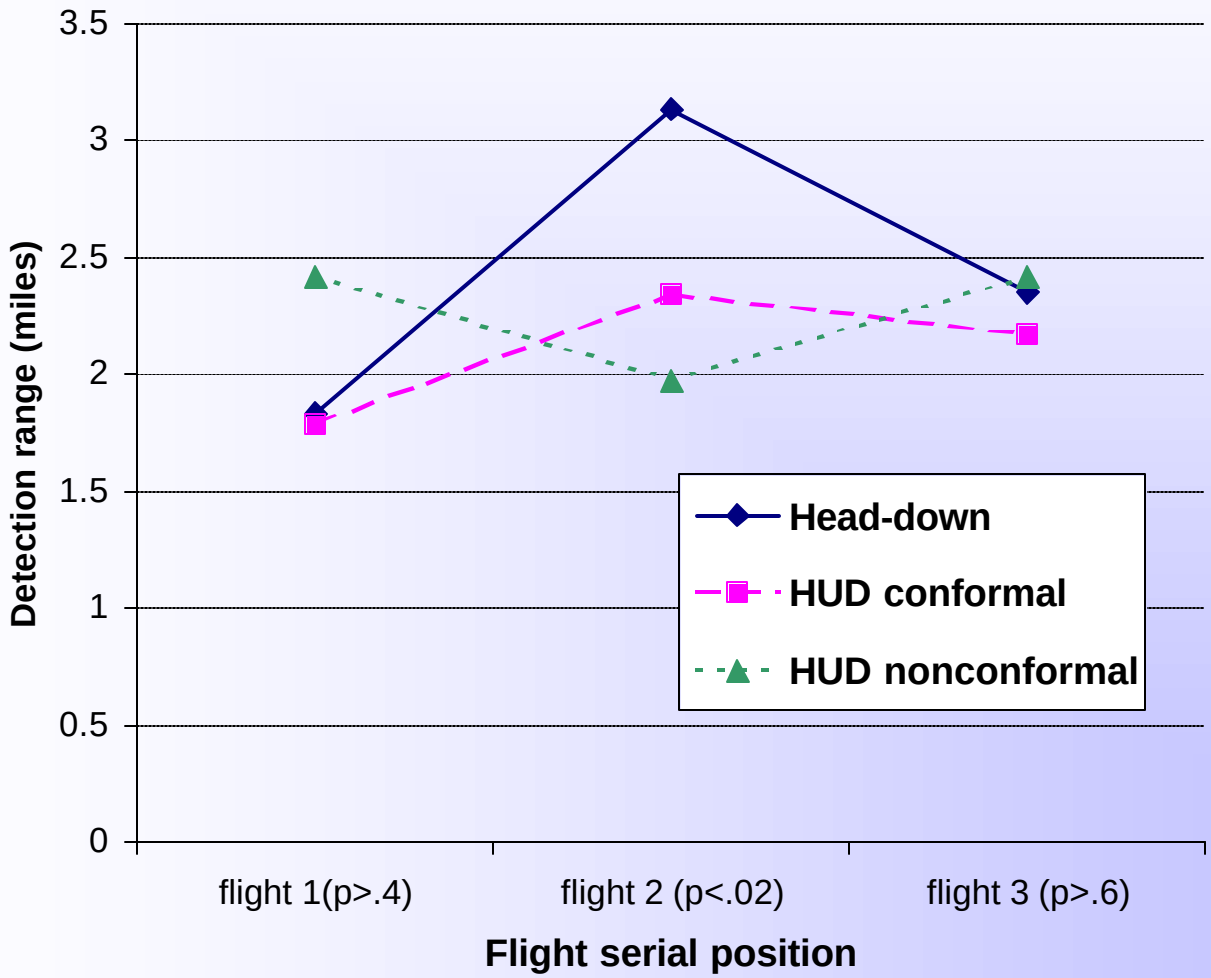
Flight technical error



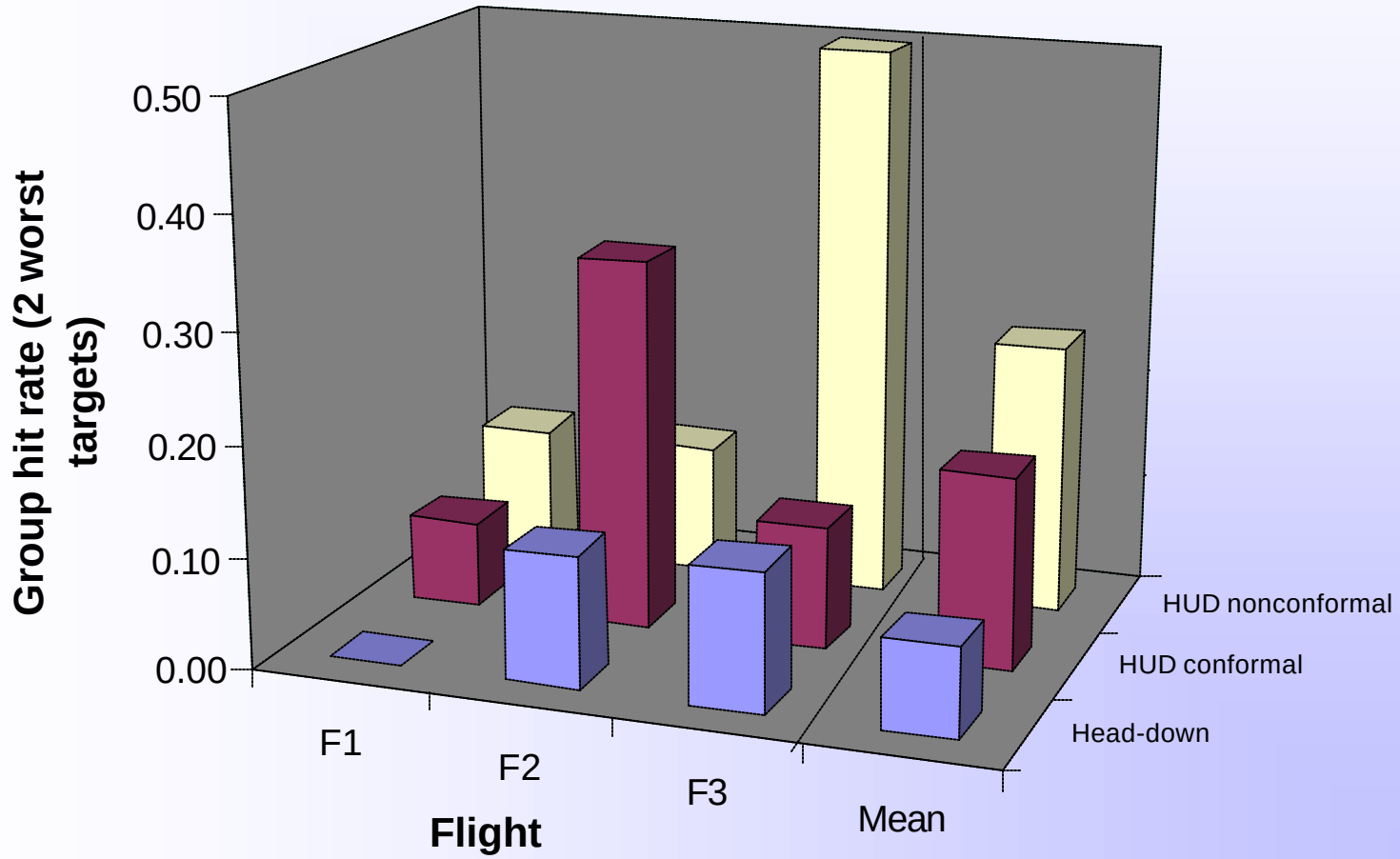
Airborne Targets: Hit rate by flight and display



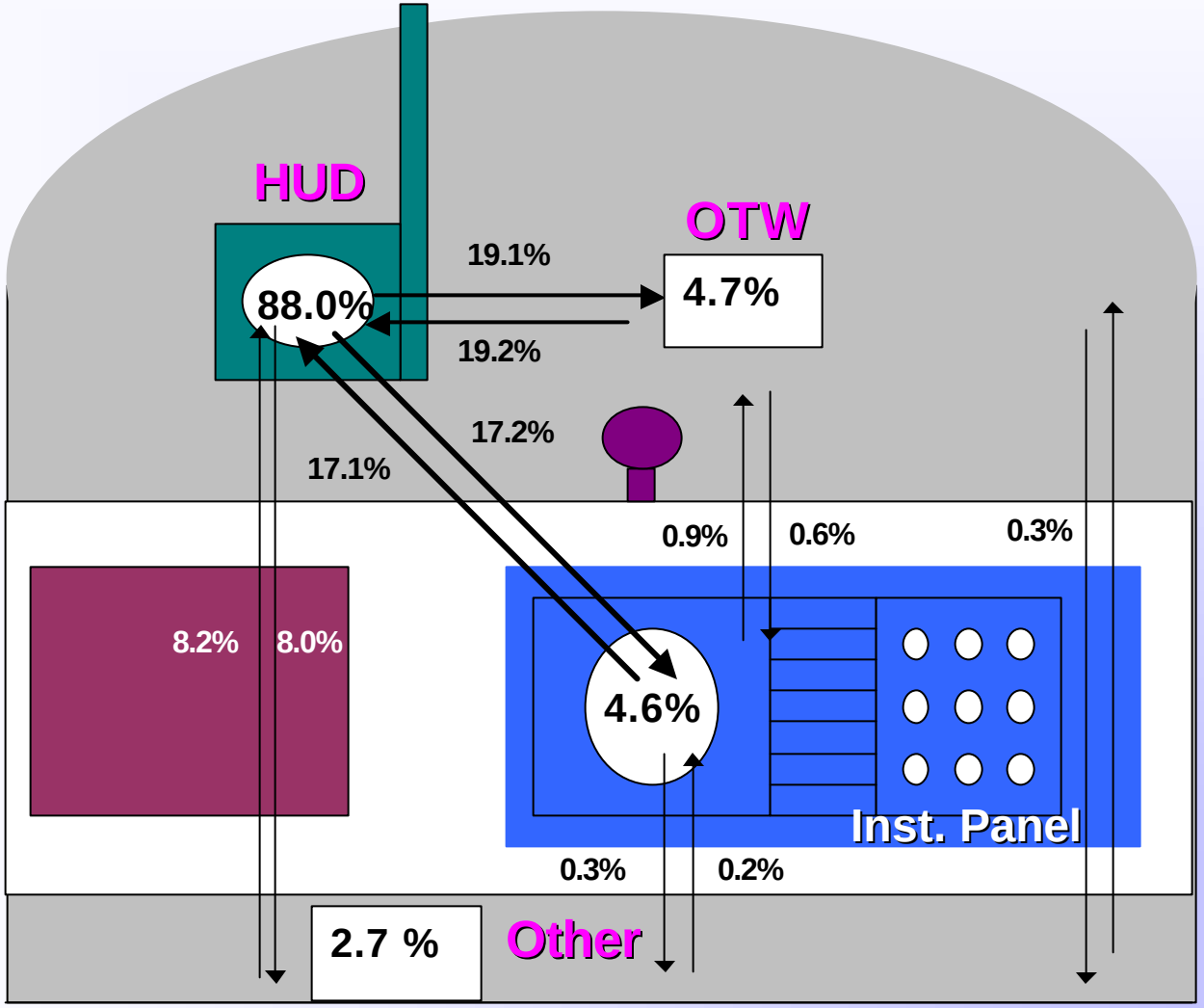
Airborne targets: Detection distance by flight and display



Hit Rates; two most difficult targets

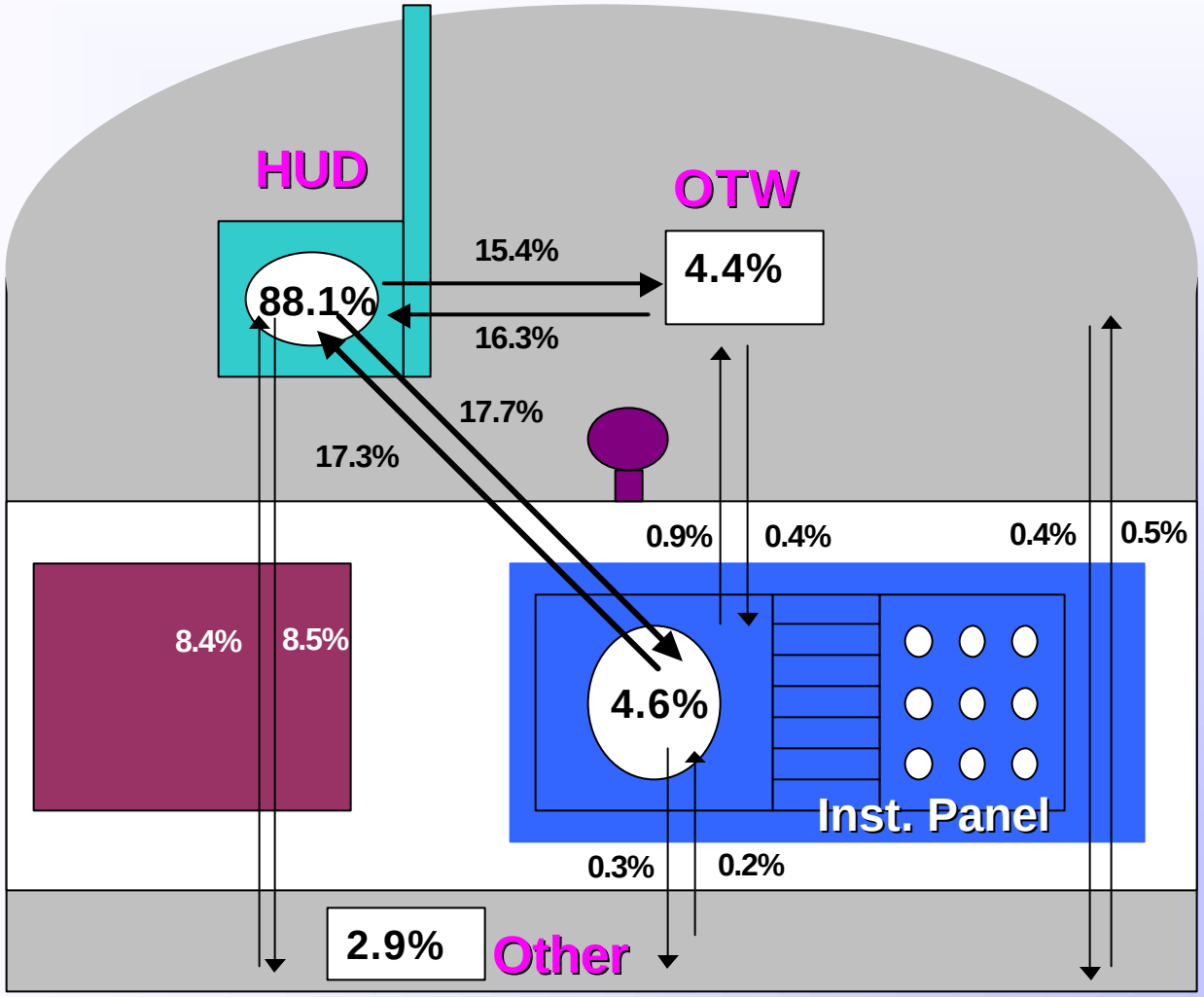


Eye-movement data: nonconformal HUD



(without segment 0)

Eye-movement data: conformal HUD



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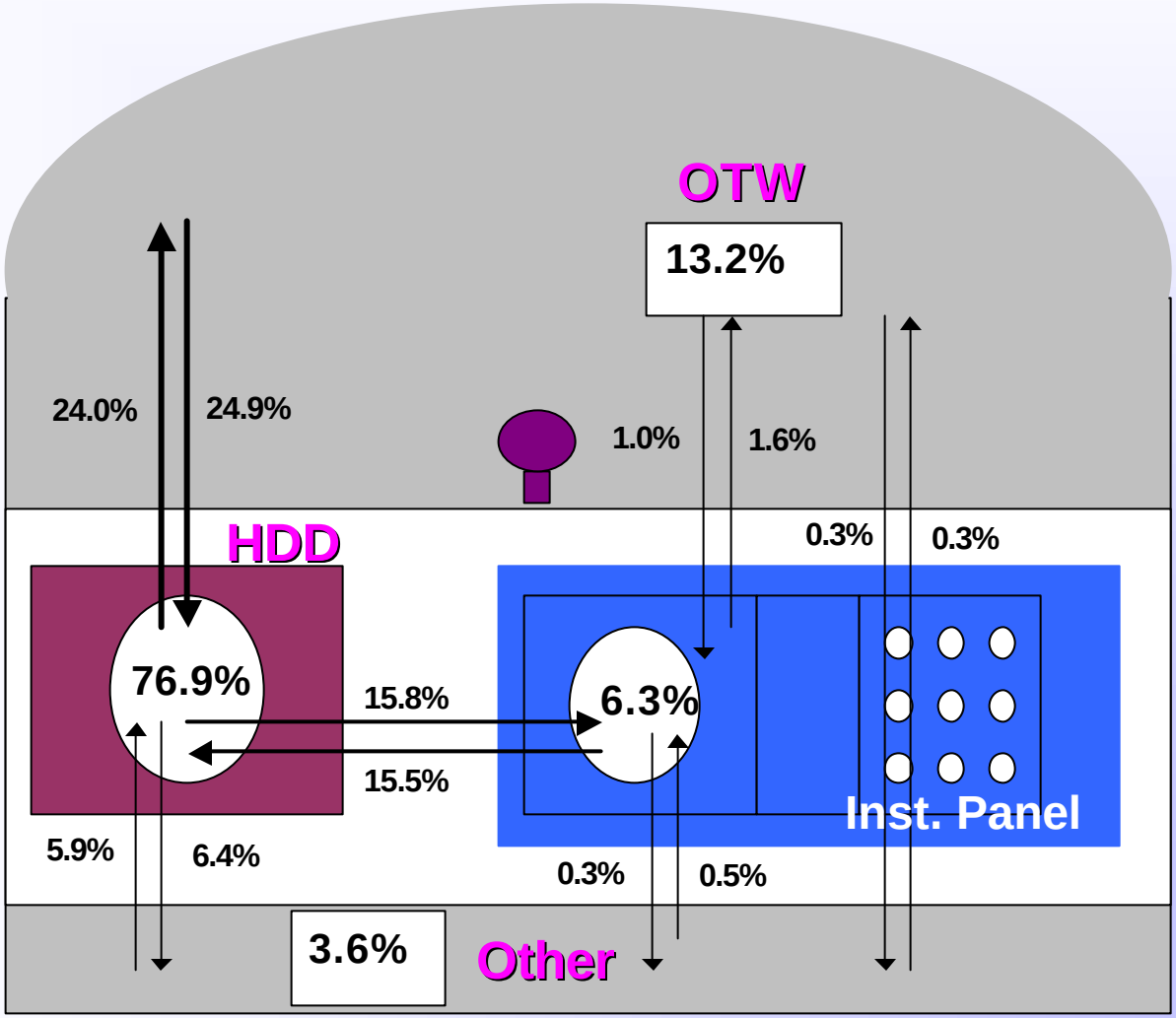
Eye-movement data: nonconformal HDD



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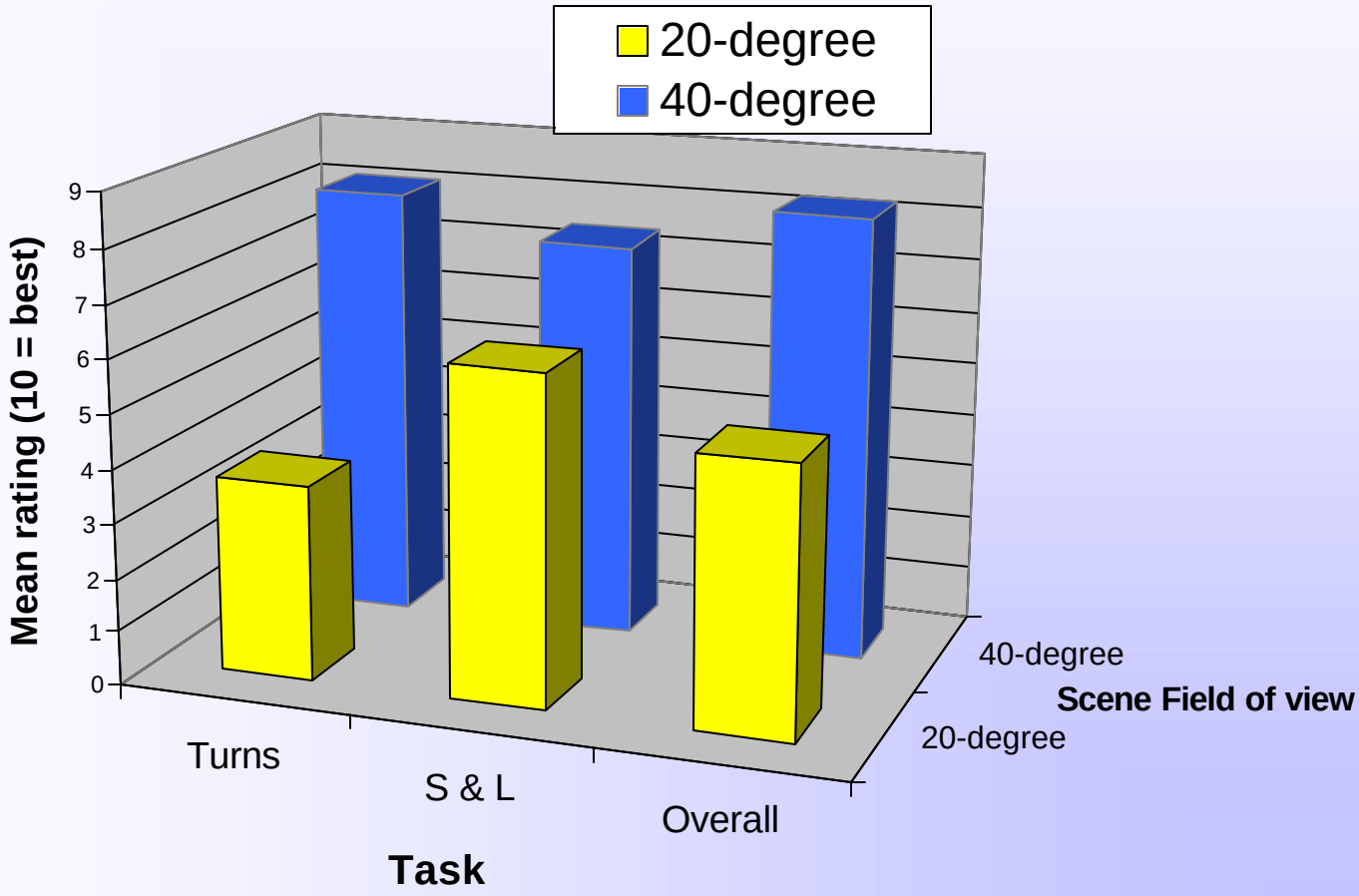
Rating Results

- Participants rated displays by tasks
  - Preferred nonconformal for turns
  - Preferred conformal for straight-and-level flight over conformal for turns
  - Preferred nonconformal over conformal in general
  - Preferred HUD over HDD
    - HUD(17); HDD(5); NP(1); ND(3)

Preference ratings by display and task



Summary

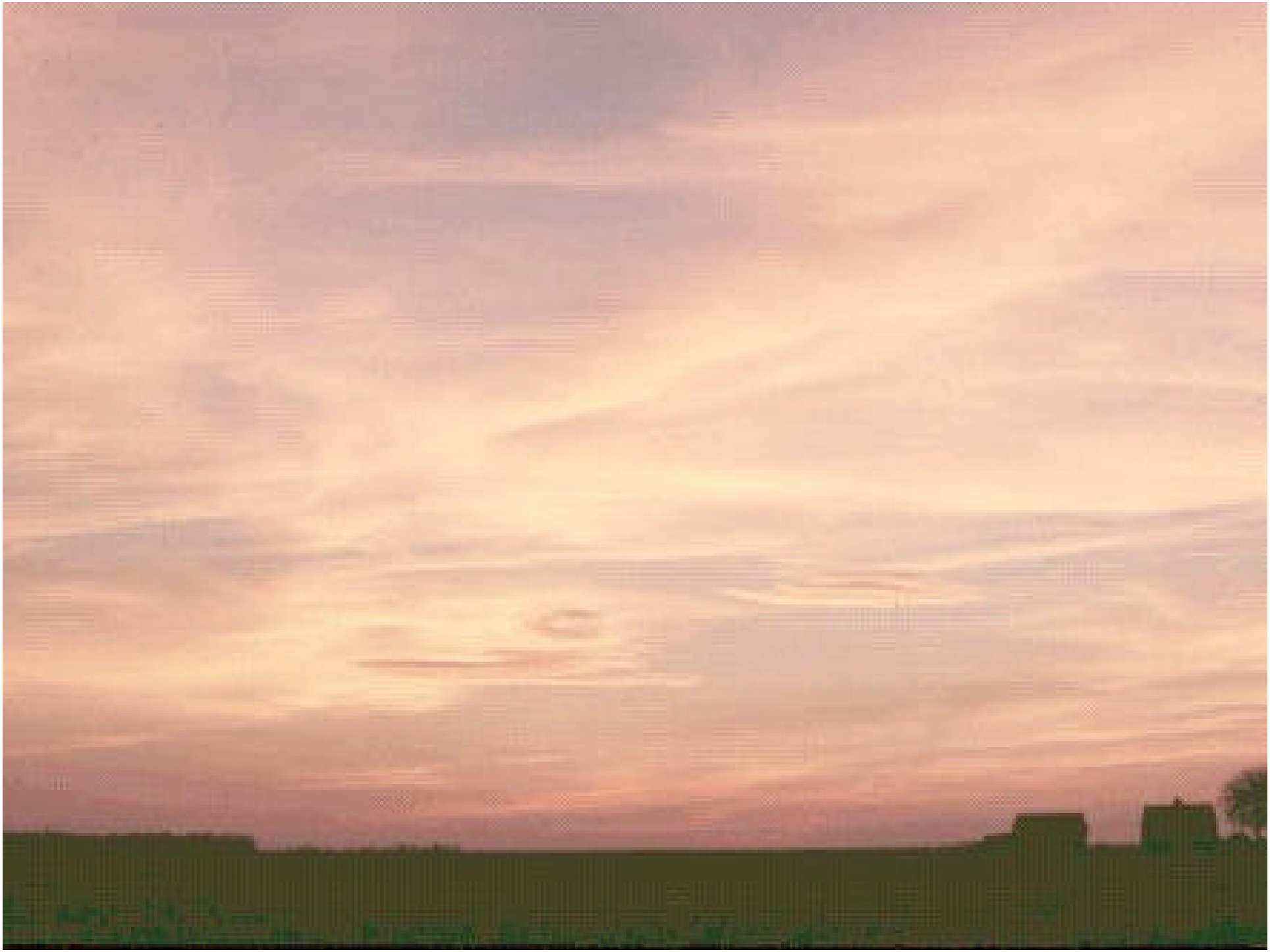
- Is the HITS display “compelling”?
  - Dwell times suggest that it is.
- Can the HUD ameliorate impacts to target detection?
  - Nonconformal HUD appears to do so.
- Is there evidence of cognitive capture with the HUD?
  - Detection latencies are consistent with this.

Summary (continued)

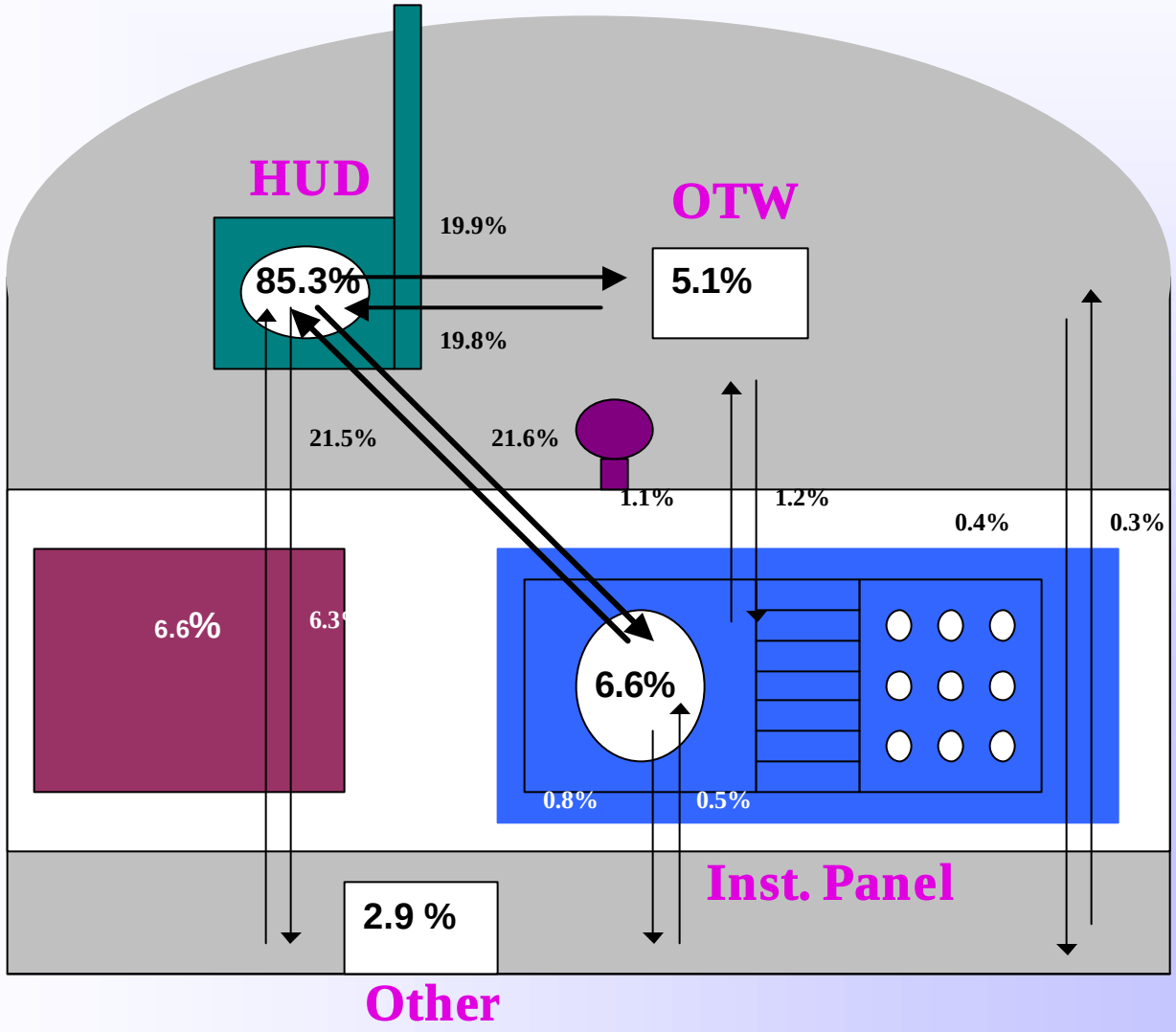
- Learning effects ameliorate differences to some extent, but conformal HUD is consistently inferior for turns
- Pilots expressed preference for a wide-angle view in turns but narrower field of view for straight-and-level cruise (less cluttered)
- Majority of pilots preferred the HUD

Conclusions

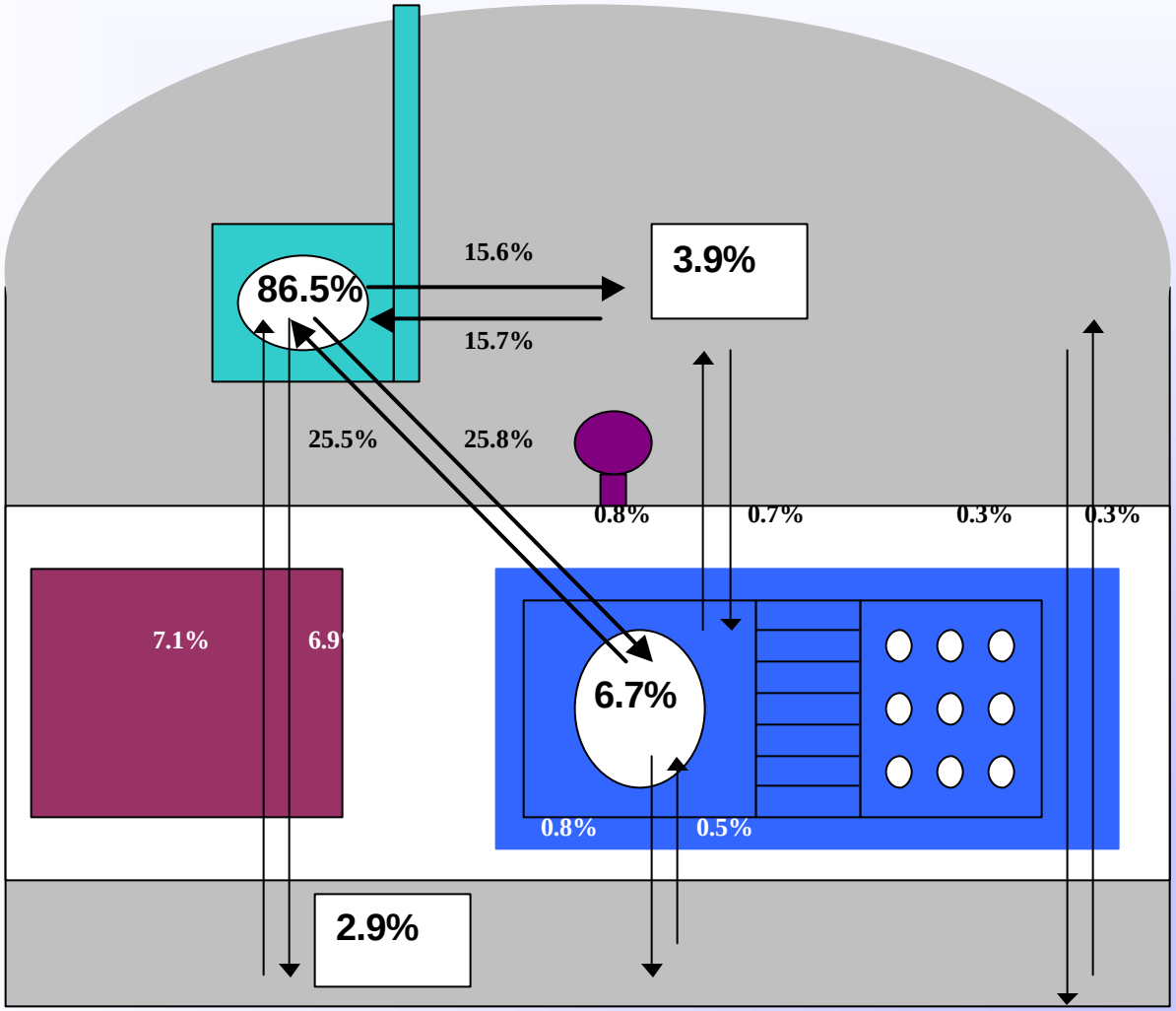
- Results support practice of offering selectable conformal vs. nonconformal modes for different flight tasks (cruise, approach, etc.)
- 40 degrees appears to be a reasonable compromise between a direct mapping and a sufficiently wide field of view.



Eye-movement data: Nonconformal HUD



Eye-movement data: conformal HUD



Eye-movement data: nonconformal HDD