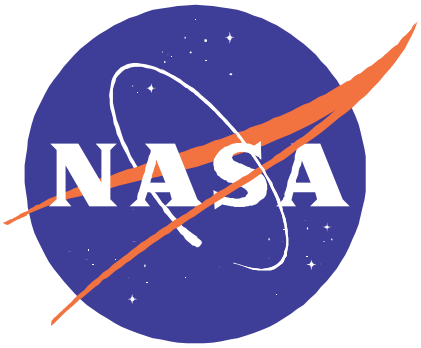
NASA's Surface Operations Human Factors Research



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http://human-factors.arc.nasa.gov/ihi/tnasa

NASA Ames Research (1995 - Present)

TASK ANALYSIS / INITIAL REQUIREMENTS
Current Taxi Operations
Jump Seat Field Study (35 crews)
Focus Group (16 pilots, 8 ATC)

RESEARCH INITIATIVES
5 HUD/Map Part-Task Studies (91 pilots)
2 T-NASA Part-Task Studies (33 pilots)
3 High Fidelity Simulations (46 crews)
1 ATL B757 Flight Test (6 pilots)

Total of 308 pilots, 9 airlines

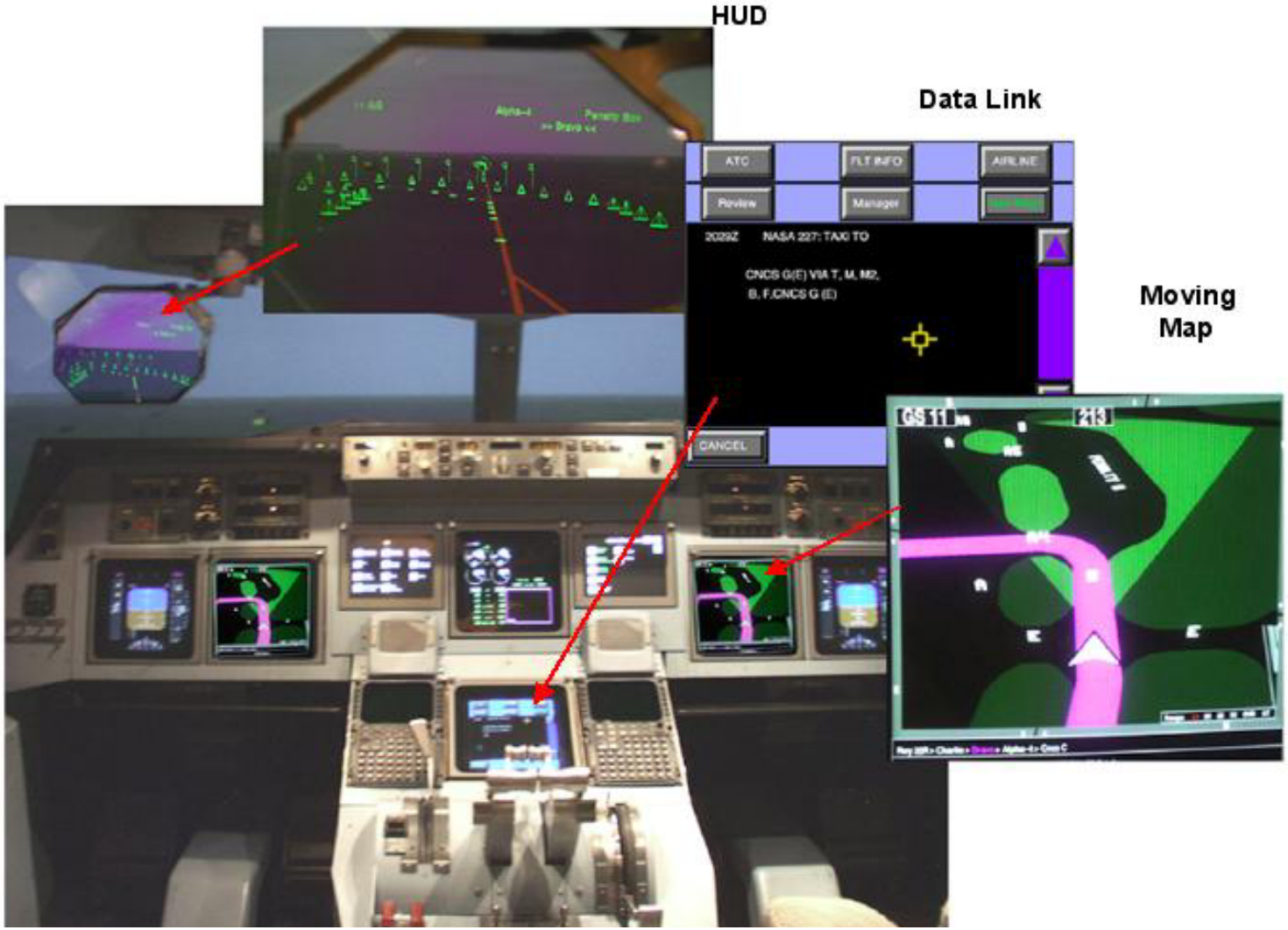
TAXI CONDITIONS
Visibility: RVR 300, 600, 700, 1000'
Night
Holds / LAHSO,
Route amendments

DEPENDENT VARIABLES
Navigation Errors (where, when, why)
Communications (quantity/nature)
Taxi Efficiency (speed, time stopped)
W□orkload
Situational Awareness

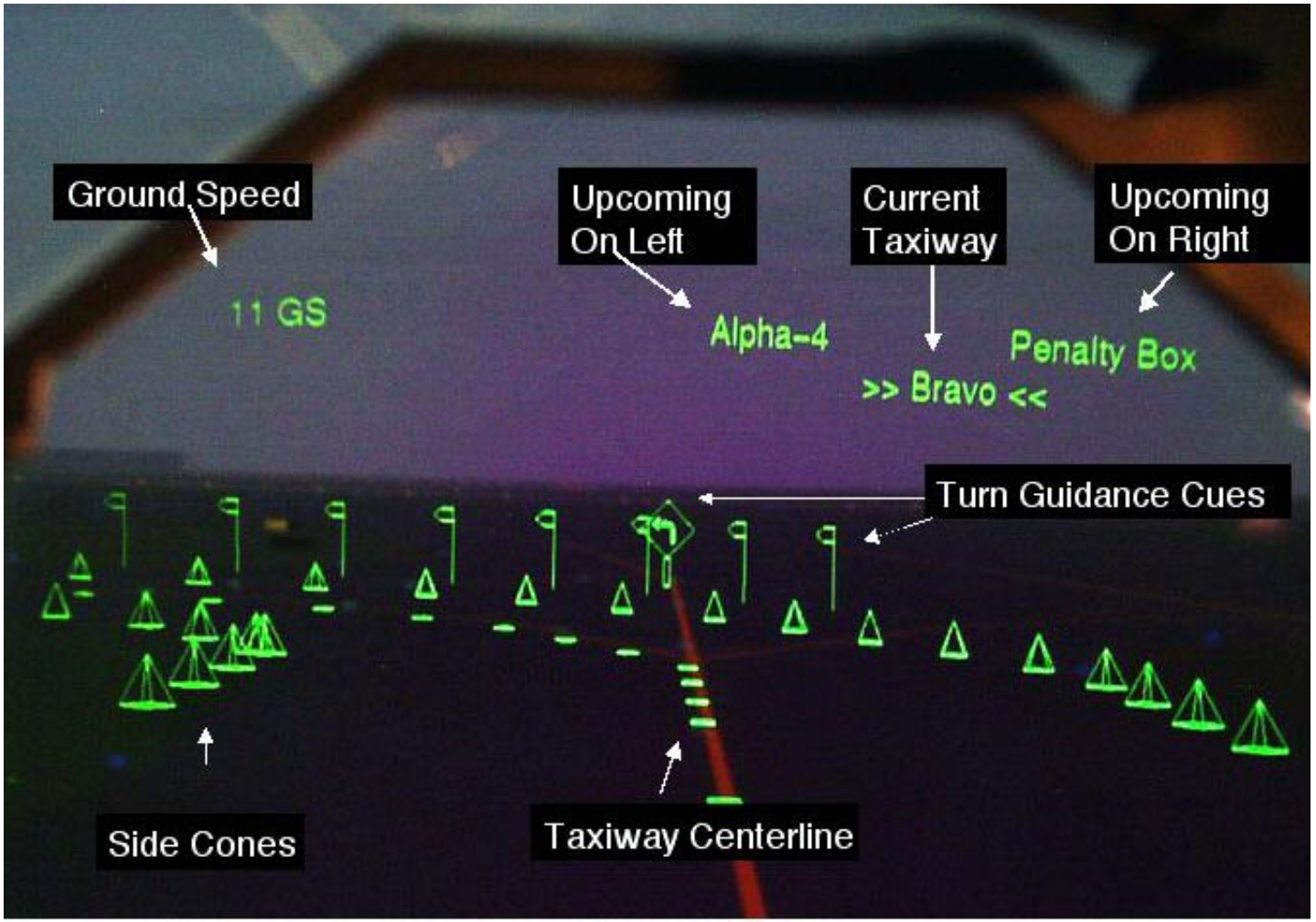
SAFETY INTERVENTIONS
Cockpit Displays (T-NASA)
Datalink
Crew Procedures & Communications
Operational Modifications

Cockpit Display Technologies

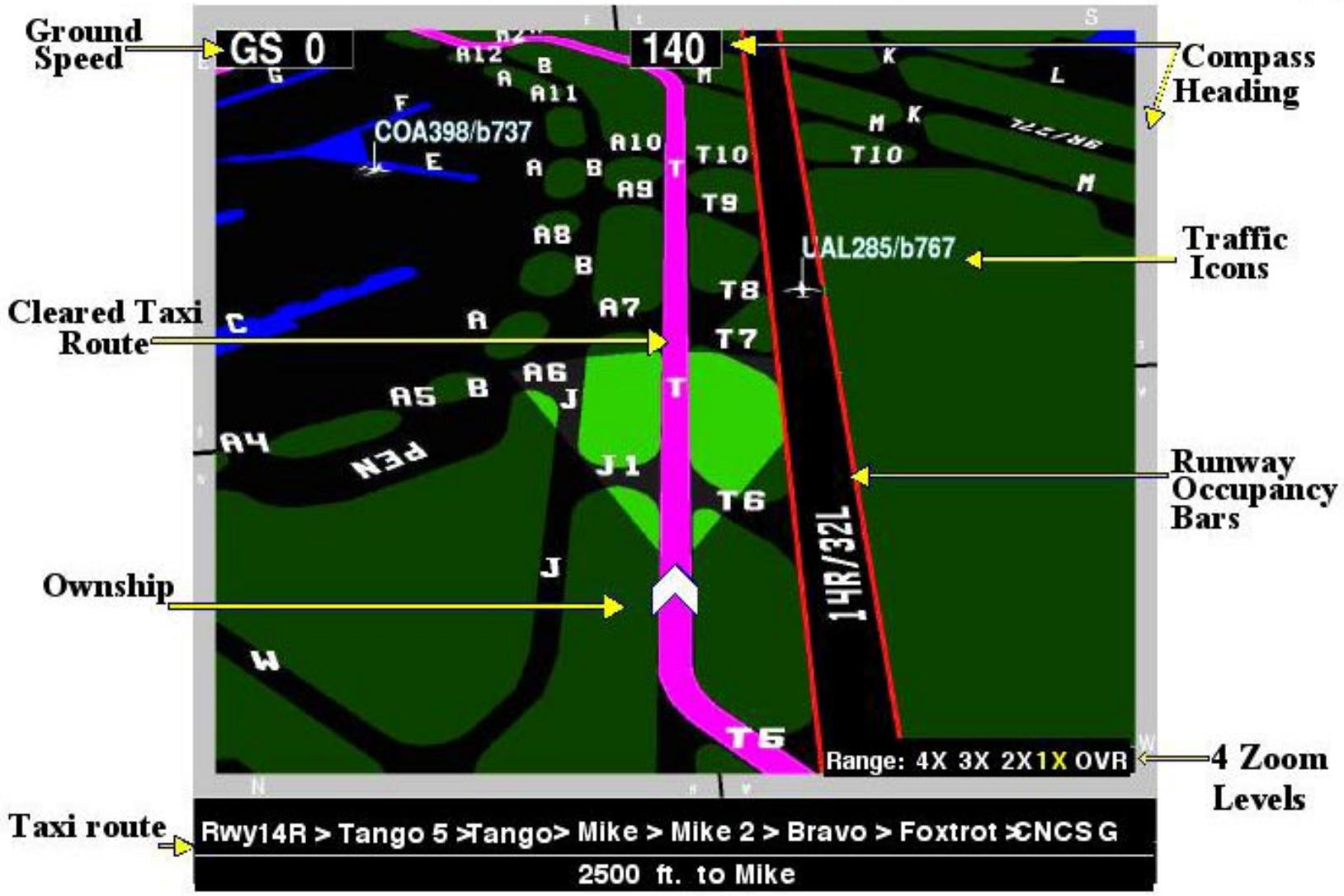
Taxiway Navigation and Situation Awareness (T-NASA)



T-NASA Head-Up Display (HUD)



T-NASA Electronic Moving Map (EMM)



Datalink for Surface Operations

Routine ATC-Pilot Communications:

- Preferred runway exit
- Taxi clearance
- Hold and proceed
- Route amendments

Example: New Taxi Clearance

Example: Review logged message

A Post-Hoc Analysis of Navigation Errors: Identifying Contributing Factors and Mitigating Strategies

Hooey, B. L. & Foyle, D. C. (2001)
11th International Symposium on Aviation Psychology

http://human-factors.arc.nasa.gov/ihi/tnasa

Surface Operations Simulation Studies

	Crews	Visibility	Trials
	16	700' RVR (8 crews) Night VFR (8 crews)	Current-Day (6/crew, 48 total) EMM Alone (6/crew, 48 total) EMM + HUD (6/crew, 48 total)
	18	1000' RVR (18 crews)	Current-Day (3/crew, 54 total) Datalink Alone (3/crew, 54 total) EMM + HUD + Datalink (3/crew, 54 total)

Combined total of 150 current-operations trials

Study #1 (McCann, Hooey, Parke, Foyle, Andre, Kanki, 1998)
Study #2 (Hooey, Foyle, Andre, Parke, 2000)

Full-Mission Simulation Facility
(Both studies)

Participants

- Captain and First Officer
  matched by airline and aircraft

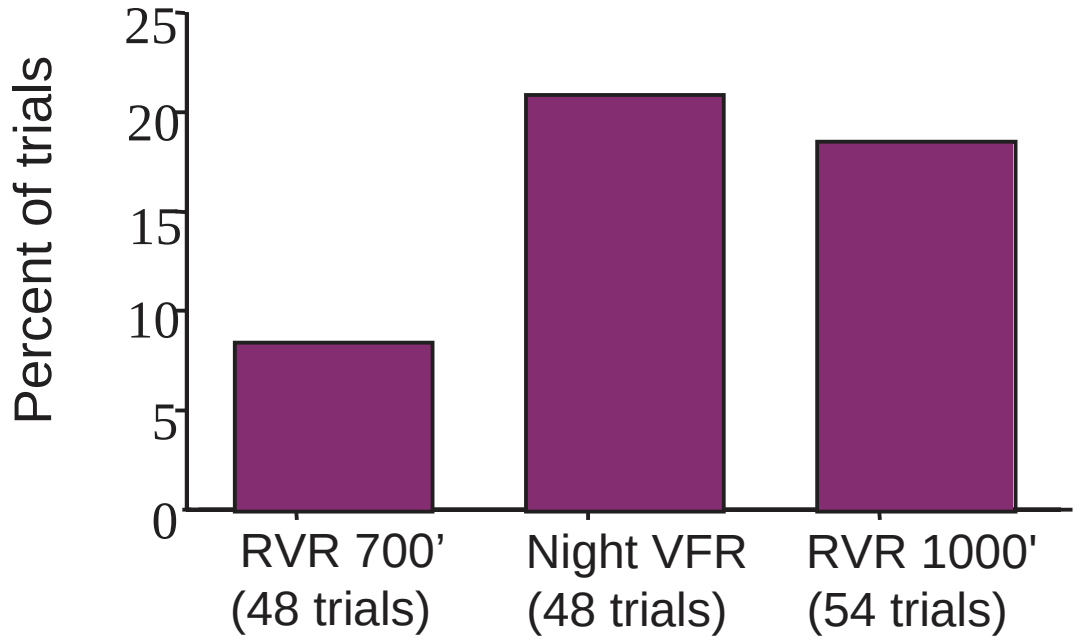
Apparatus

- NASA's ACFS Simulator
- Chicago O'Hare, RVR 1000'
- High-fidelity visuals (paint, signage)
- 180 deg. cross-cockpit viewing
- Full 6 degree-of-freedom motion
- Confederate ATC & pseudo-pilots
- Dynamic traffic
- HUD, EMM, Audio, Datalink

Advanced Concept Flight Simulator

Frequency Of Navigation Errors
(Deviations from ATC-issued clearance)

- 26 of 150 (17.3%) current-operations trials contained an off-route navigation error
- Navigation errors occur as often at night as low-visibility



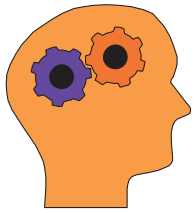
Navigation Errors as a Function of Visibility

Error Analysis Methodology

- Analyzed all off-route navigation errors
  - Video and audio tape analysis
  - Real-time coding
  - Sim software playback and review
  - Debrief & questionnaire comments
- Classified errors
- Identified contributing factors (i.e., clearance, paint, etc.)
- Investigated mitigating effect of technologies by error type

3 Classes of Error

Determined via post-hoc analysis



Formulate Taxi Plan

Perceive, understand, and communicate the taxi clearance

Planning Errors

Make Decisions

Make turn-by-turn decisions based on knowledge of current location & destination

Decision Errors

Execute Plan

Discern cues from the environment to execute required turn maneuvers

Execution Errors

Route Conformance

Navigation Error

Planning Errors

- Formulate an erroneous taxi plan or intention (but then carry out the plan correctly).
- Examples
  - Misunderstanding the taxi clearance
  - Inadvertently modifying the taxi clearance

Planning errors accounted for 23% of all errors (6 out of 26)

Factors that Contribute to Planning Errors

(Formulating an Erroneous Taxi Plan)

- Miscommunicating the initial clearance (2/6 errors)
  - Writing down clearance incorrectly
  - Readback errors
  - Confusion with another aircraft's clearance

- Inadvertently altering the clearance by substituting or omitting a taxiway (4/6 errors)
  - Alter clearance to conform to expectations

Mitigating Planning Errors

(Formulating an Erroneous Taxi Plan)

DATALINK and the T-NASA EMM may facilitate pilot-ATC and pilot-pilot communication of taxi clearances.

Providing a written record in cockpit

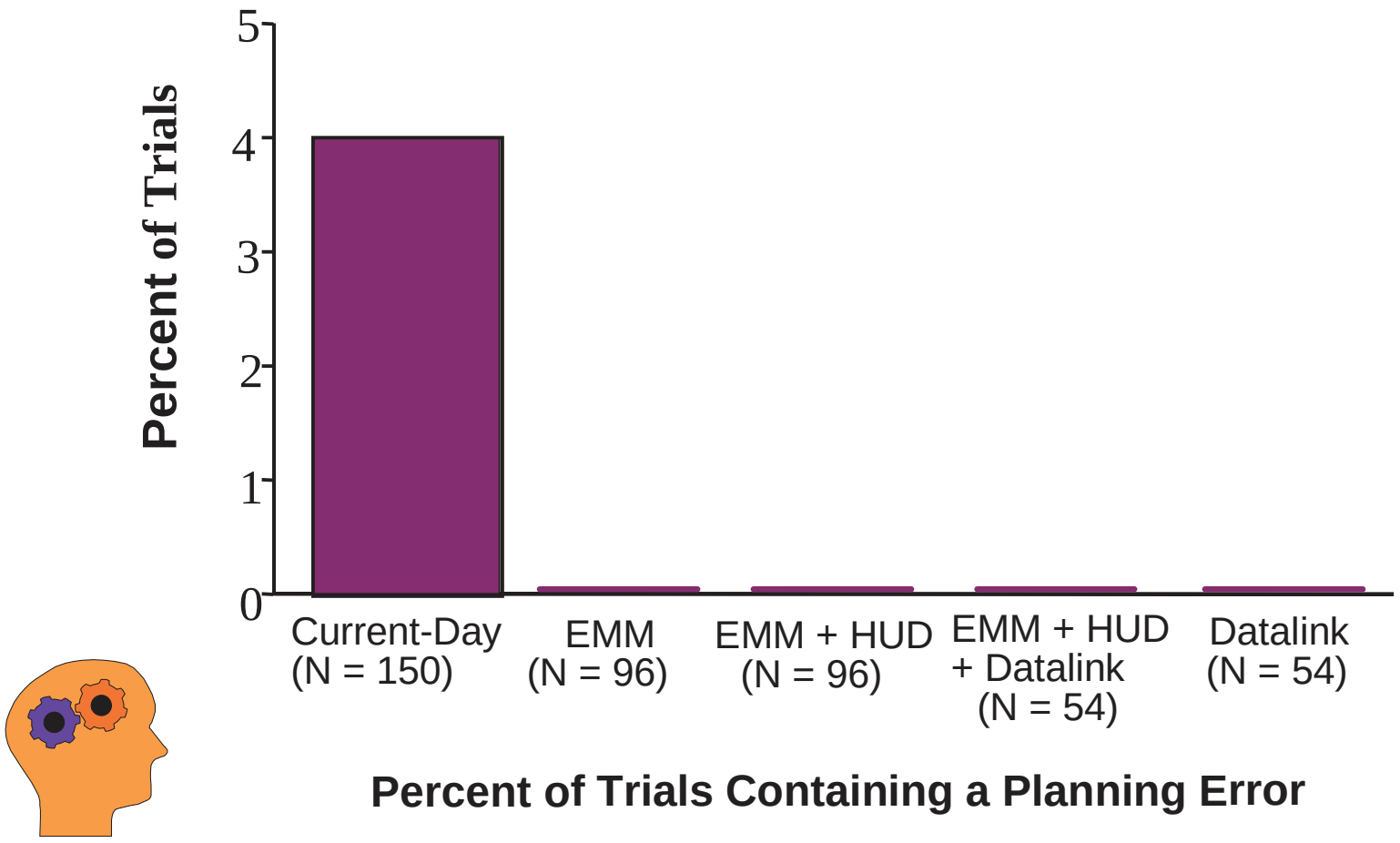
- Reduces reliance on memory
- Aids readback
- Reduces workload
- Preserves integrity of clearance

Rwy 14R > Tango 5 > Tango > Mike > Foxtrot > Concourse G
2500 ft. to Mike

Mitigating Planning Errors

(Formulating an Erroneous Taxi Plan)

Planning errors were mitigated by cockpit technologies that provided an unambiguous record of the clearance.

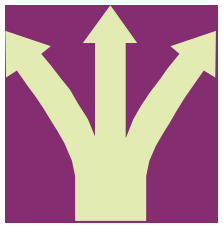


Decision Errors

- Taxi route is properly received and communicated, however pilots make an erroneous choice at a decision point.
- Examples:
  - Turning left instead of right
  - Taxiing straight instead of turning

Decision errors accounted for

42% of all errors (11 out of 26)



Operational Demands Contribute to Decision Errors

(Making an erroneous choice at a decision point)

Excessive Workload:

- Change frequency
- Contact tower
- Contact company for gate
- Receive taxi clearance
- Write/remember clearance
- Read back clearance
- Communicate clearance
- Check Jeppesen chart
- Cockpit clean-up
- Post-land checklist
- Unknown gate assignment
- Gate changes
- Taxi route changes
- Flight Attendants requests
- Passenger special needs
- Passenger announcements
- Paperwork
- Preparation for next leg

55% of decision errors occurred at the first decision point of the route. Captain was taxiing without First Officer support (6/11).

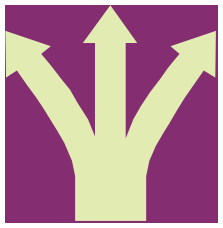
Operational demands occupy first officers, leaving captains to navigate with out support

Inadequate Navigation Awareness Contributes to Decision Errors

(Making an erroneous choice at a decision point)

- Inadequate Global Awareness (7 of 11 errors)
  - Unsure of location of objects (runways, concourses) relative to own location

- Inadequate Local Awareness (4 of 11 errors)
  - Unsure of position on the airport surface, and position relative to cleared route.



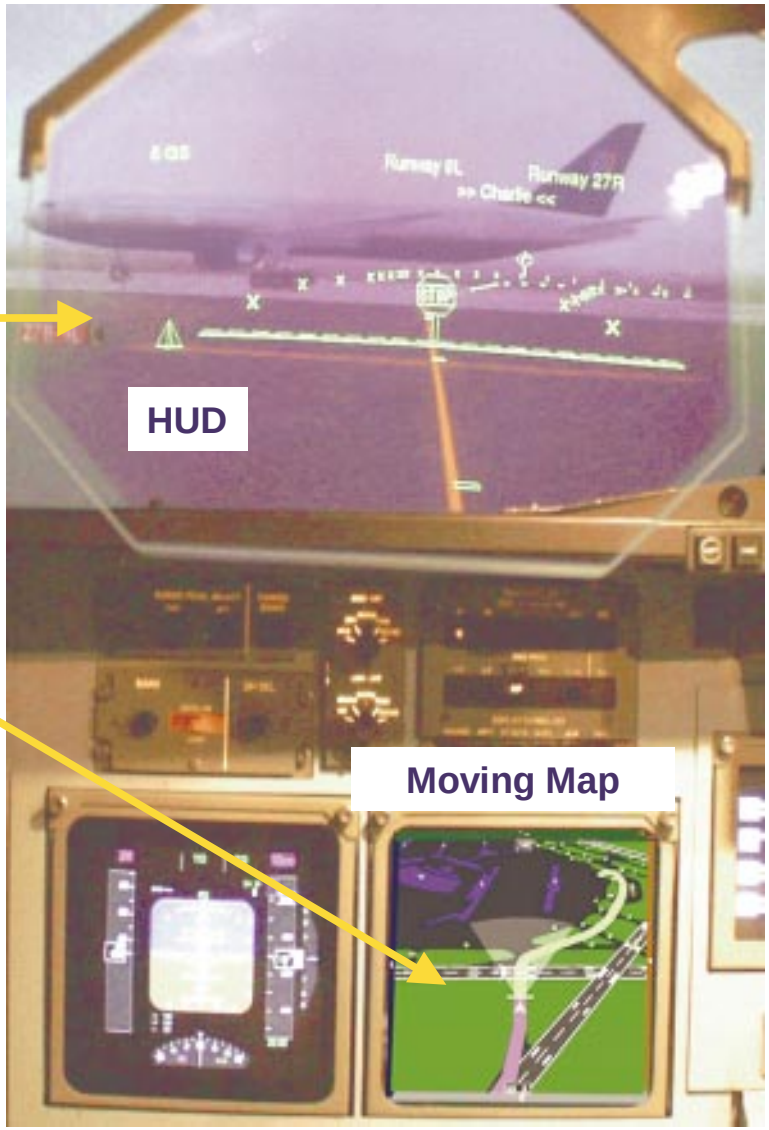
Ref: Lasswell & Wickens, 1995

Mitigating Decision Errors

(Making an erroneous choice at a decision point)

T-NASA Taxi Head Up Display (HUD) provides Local Awareness allowing pilots to identify their cleared route relative to their current position.

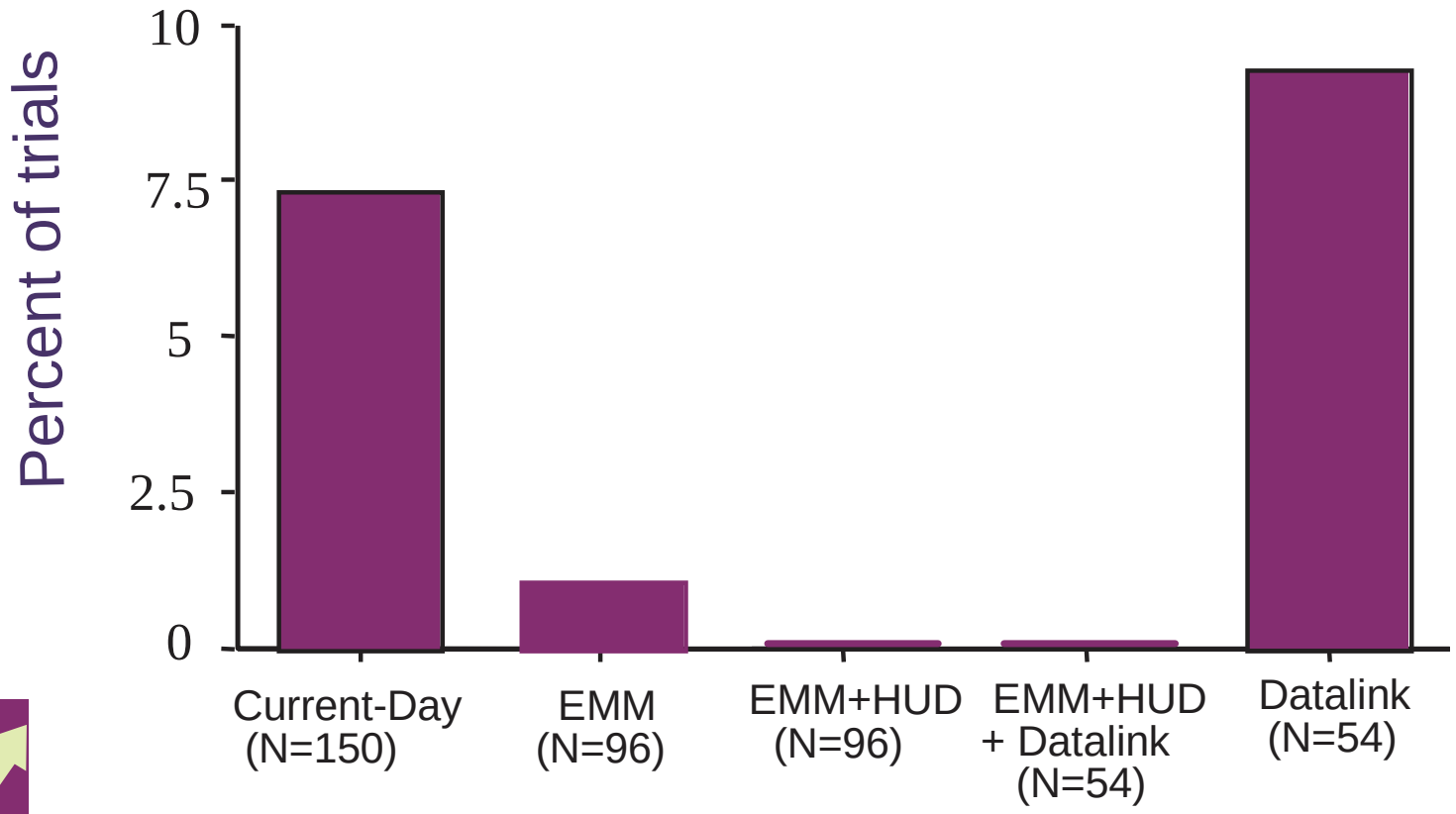
The T-NASA Electronic Moving Map (EMM) provides Global Awareness by depicting the airport layout, runway and concourse locations.



Mitigating Decision Errors

(Making an erroneous choice at a decision point)

Decision errors were mitigated by technologies that enhanced local and global navigation.



Execution Errors

- Failure to carrying out a turn maneuver or navigating an intersection.

- Examples
  - Following the wrong taxi line
  - Misinterpreting signage

Execution errors accounted for

35% errors (9 of 26)

The "Sea of Blue" Contributes to Execution Errors

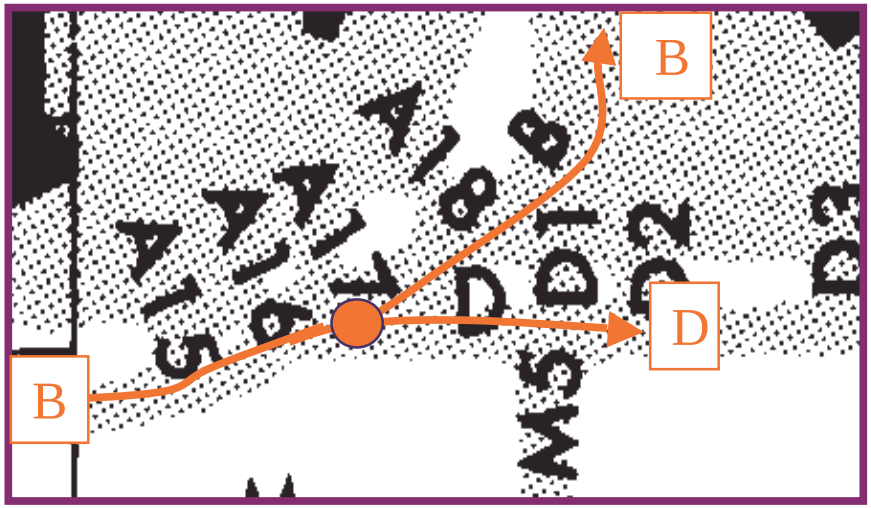
(Errors in carrying out a navigation maneuver)

The 'Sea of Blue' lights on the airport surface at night can be disorienting

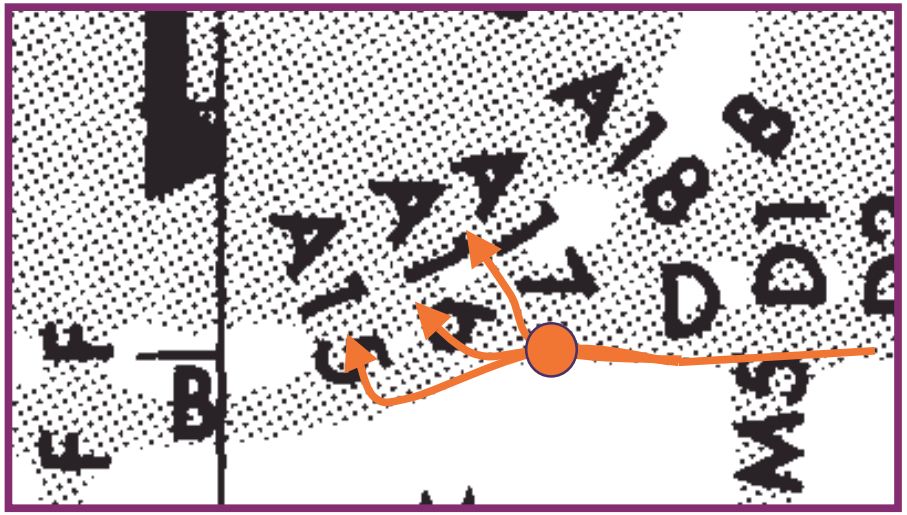
Complex Taxiways Contribute to Execution Errors

(Errors in carrying out a navigation maneuver)

- 78% of execution errors occurred at ‘complex’ intersections (7 of 9) where signage and paint were insufficient to discern the cleared route.
- Problem areas:
  - Multiple intersecting taxiways
  - 2 or more taxiways in same direction
  - Taxiways change names but not direction



Taxiway changes name from Bravo to Delta. Bravo veers left.

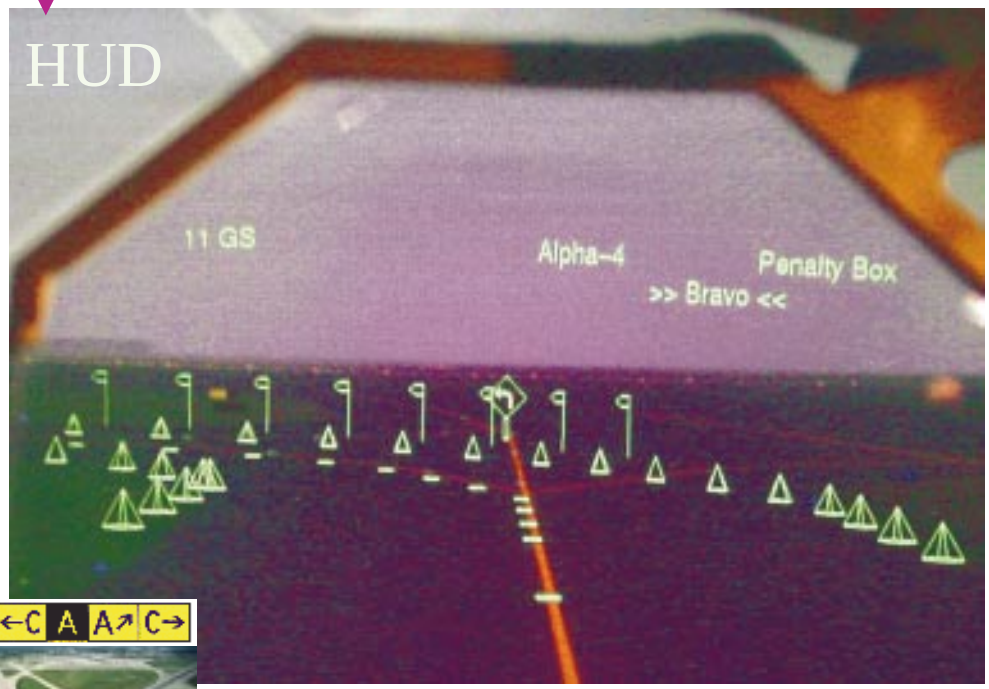


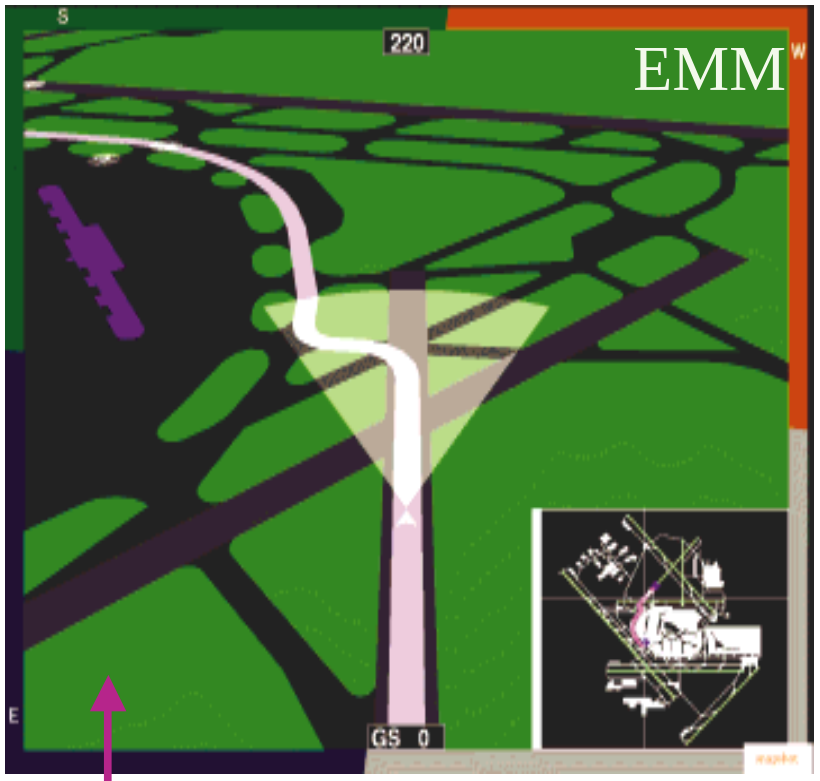
Pilots must choose from 3 taxiways leading towards the same direction.

Mitigating Execution Errors

(Errors in carrying out a navigation maneuver)

The T-NASA HUD compensates for degraded visibility and inadequate navigational cues by disambiguating turns (providing local guidance)



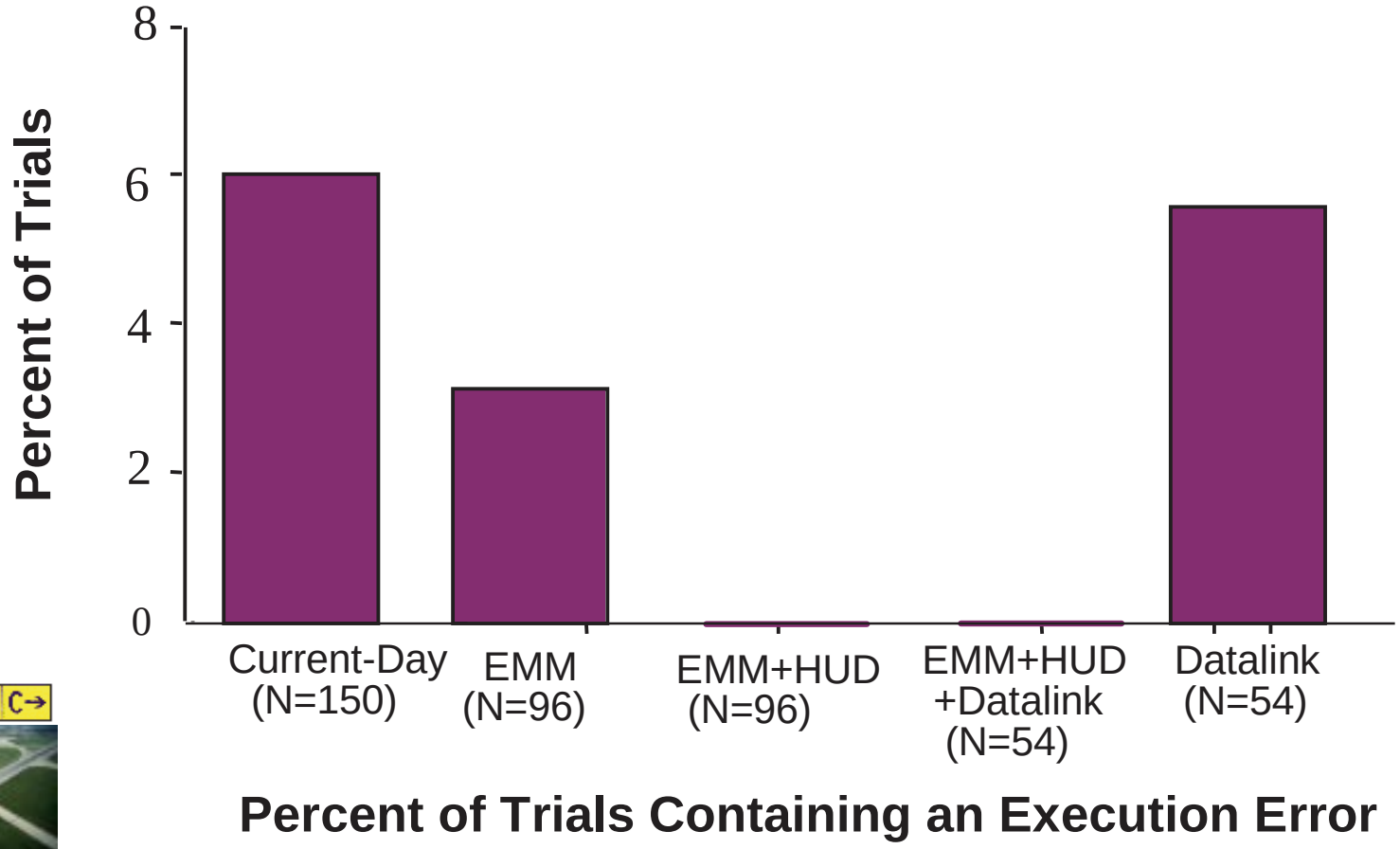


The EMM may facilitate navigation at complex intersections and disambiguate airport signage.

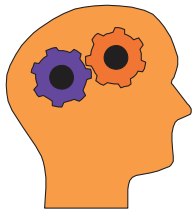
Mitigating Execution Errors

(Errors on carrying out a navigation maneuver)

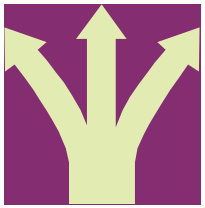
Execution errors were mitigated by technologies that augmented the visual world and helped pilots discern the environment.



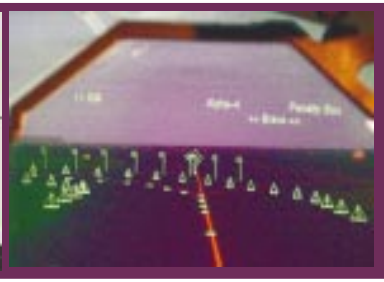
Conclusion: Advanced Cockpit Technologies Can Mitigating Navigation Error



Mitigate planning errors by enhancing communication & understanding of clearance



Mitigate decision errors by enhancing navigational awareness, lowering workload



Mitigate execution errors by disambiguating the external environment

Improved Route Conformance
Improved Runway Safety