

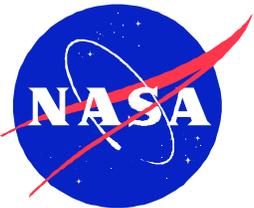
Pilot Navigation Errors: Contributing Factors and Mitigating Strategies

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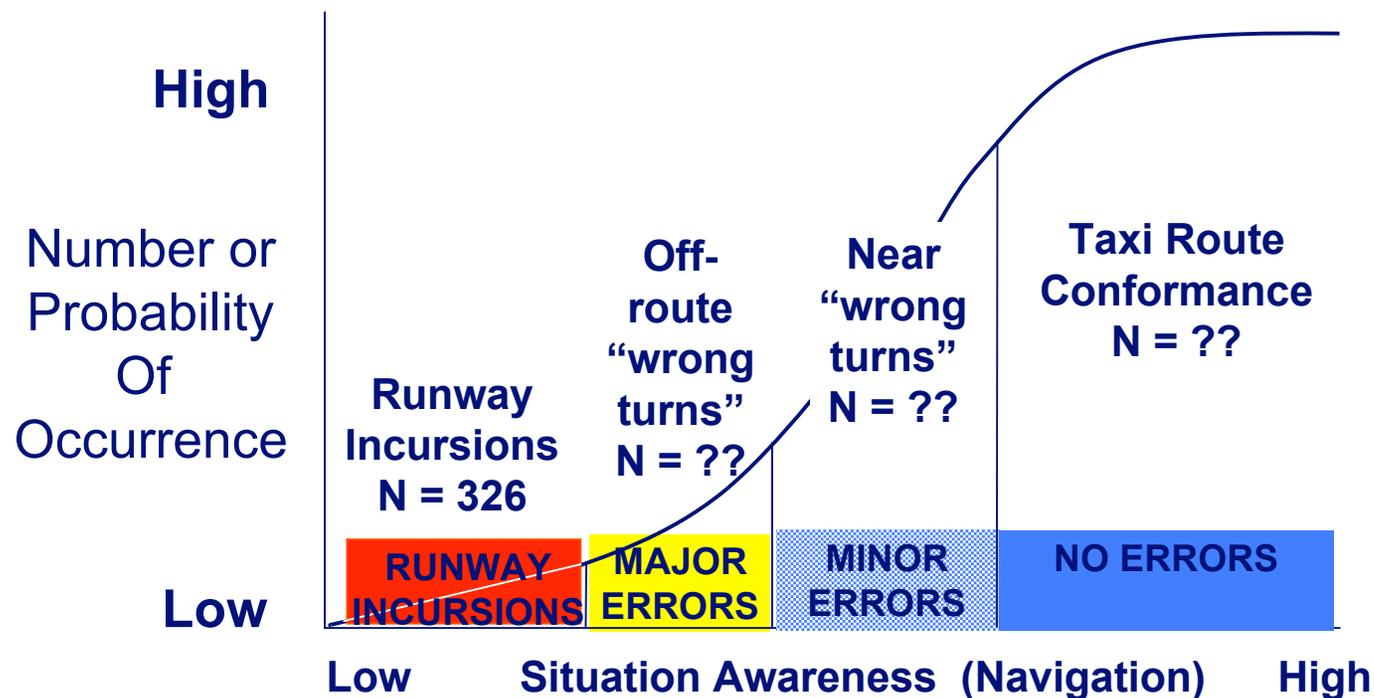


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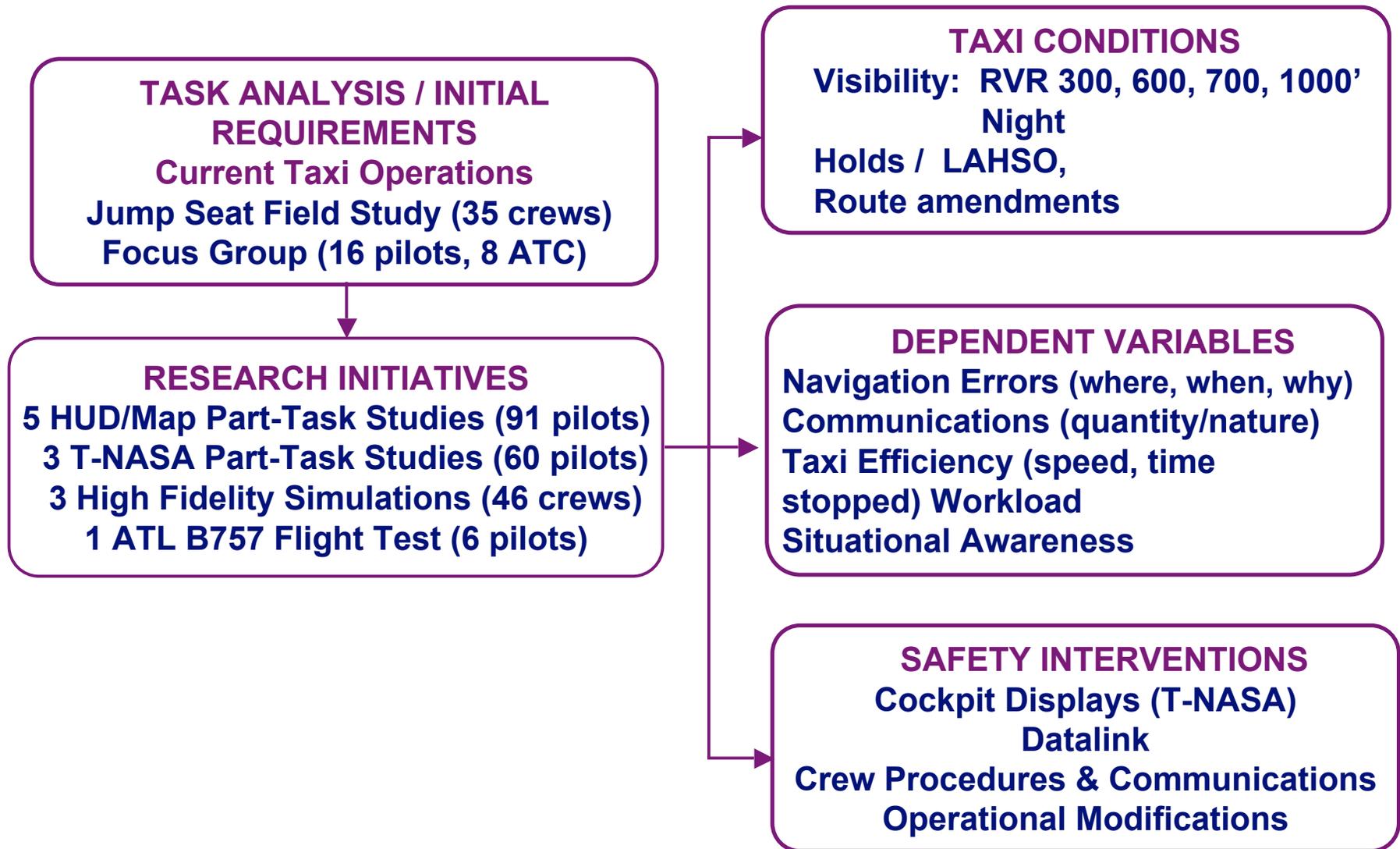
<http://humanfactors.arc.nasa.gov/ihi/hcsl>

Why Study Pilot Navigation Errors?

- ~ 53% (173 / 326) of runway incursions in 2004 were attributed to 'Pilot Deviation' (FAA)
- Understand pilot perspective of surface operations
 - What environmental cues/cockpit activities/situations lead to pilot deviations?



NASA Ames Research (1995 - Present)



NASA Ames Pilot Surface Operation Simulations in NASA's ACFS

Visuals

- Chicago O'Hare database
- Accurate signage and paint
- 180 deg. field of view
- Night VFR, 700 RVR, 1000 RVR

Audio

- Live ATC audio and pilot background chatter

Motion

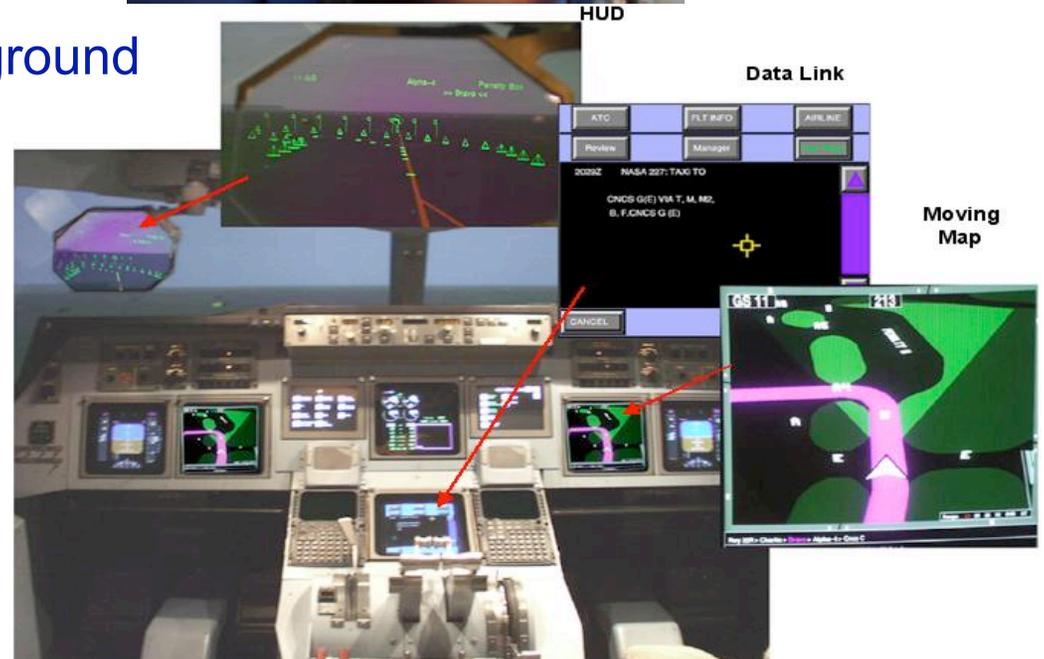
- Full 6 dof motion system
- B757 handling

Scenarios

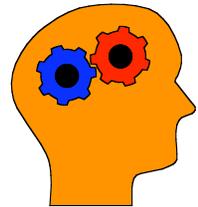
- Land and Taxi-to the Gate
- Two-pilot commercial crews



NASA's
Advanced
Concepts
Flight Simulator



Taxi Error Taxonomy



Formulate Tax Plan

Perceive, understand, and communicate the taxi clearance

23% of errors

Planning Errors



Make Decisions

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

42% of errors

Decision Errors



Execute Plan

Discern cues from the environment to execute required turn maneuvers

35% of errors

Execution Errors

• Error Taxonomy also mapped to ASRS data (Boucek, 2002)

– 174 ASRS reports

32% Planning, 37% Decision, 31% Execution

Route Conformance

26 of 150 trials (17.3%) resulted in a navigation error

Planning Errors

- Occur when pilots formulate an erroneous plan or intention (but then carry out the plan correctly)

Causal Factors

– Miscommunication

- Writing down clearance incorrectly
- Readback errors
- Confusion with another aircraft's clearance

– Erroneous Expectations

- Inadvertently altering the clearance by substituting or omitting a taxiway
- Alter clearance to conform to expectations



Mitigating Planning Errors

(Formulating an Erroneous Taxi Plan)

Standardized Procedures / Training

- Pilots should write down clearances, Conduct full-readbacks
- ATC should highlight deviations from normal operations

Providing a written record in cockpit

- Reduces reliance on memory and aids readback
- Reduces workload
- Preserves integrity of clearance



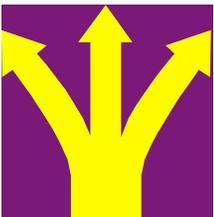
Datalink and Electronic Moving Maps may facilitate pilot-ATC and pilot-pilot communication of taxi clearances.

Decision Errors

- Occur when a taxi route is properly received and communicated, however pilots make an erroneous choice at a decision point
- Examples: Turning left instead of right/ Failing to turn

Causal Factors

- Unsure of own position on the airport surface, and position relative to cleared route.
- Unsure of location of objects (runways, concourses) relative to own location
- Workload



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.



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



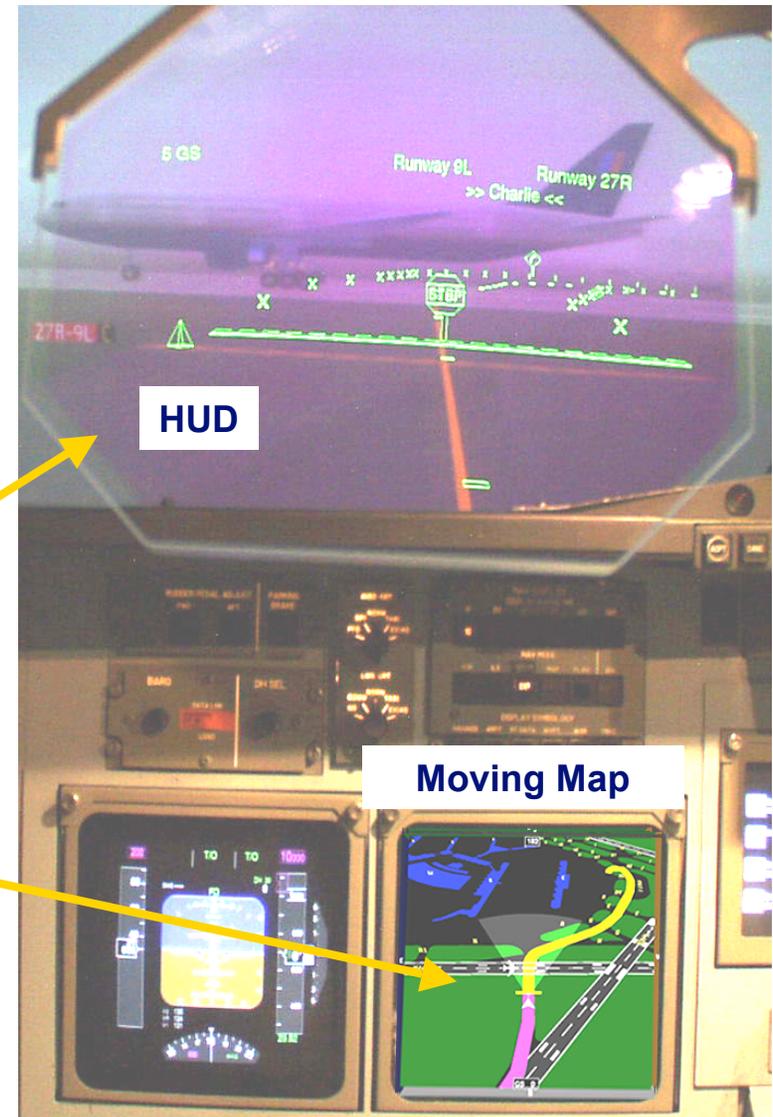
Mitigating Decision Errors

(Making an erroneous choice at a decision point)

- Reduce workload
 - Especially at first turn off
 - Airborne taxi clearances?
- Enhance local guidance
- Enhance global awareness

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

Electronic Moving Maps (EMM) provide Global Awareness by depicting the airport layout, runway and concourse locations.



Execution Errors



- Failure to carry out a turn maneuver or navigate an intersection.

Causal Factors

- Airport Visibility
- Sea of Concrete
- Taxiway Complexity
 - Multiple intersecting taxiways
 - 2 or more taxiways in same direction
 - Taxiways change names but not direction

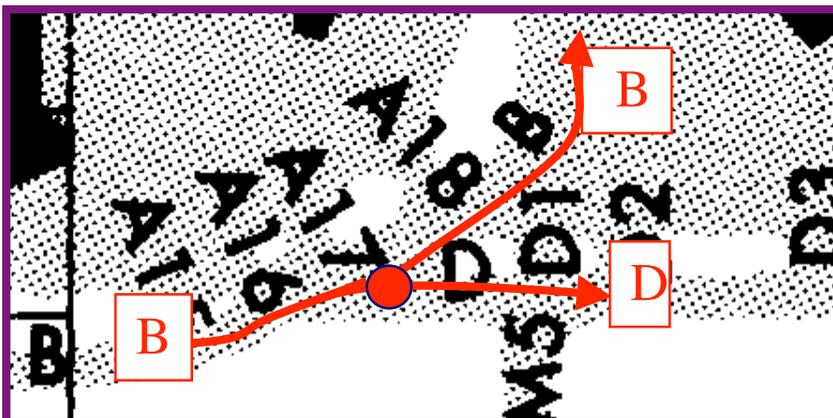
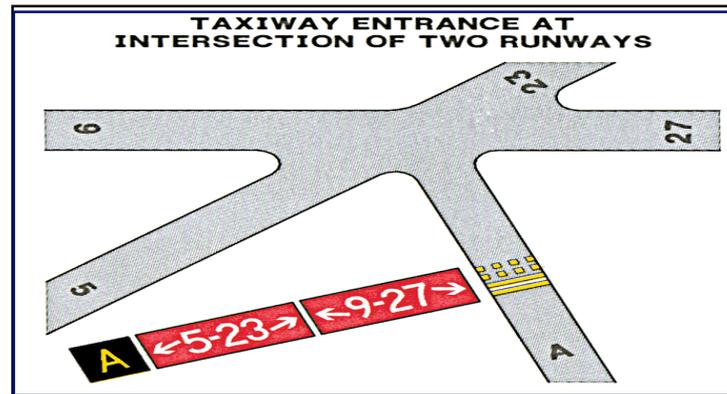
The Sea of Blue



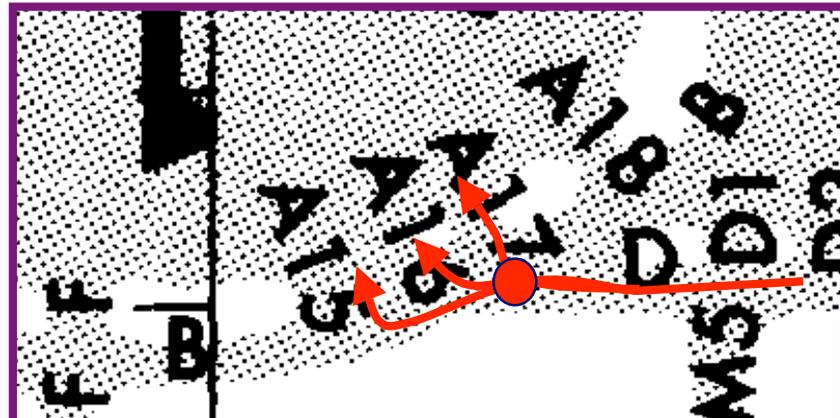
The 'Sea of Blue' lights on the airport surface at night can be disorienting

Complex Taxiway Geometry

- 78% of execution errors occurred at multiple turn decision points. Pilots followed the wrong centerline



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



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

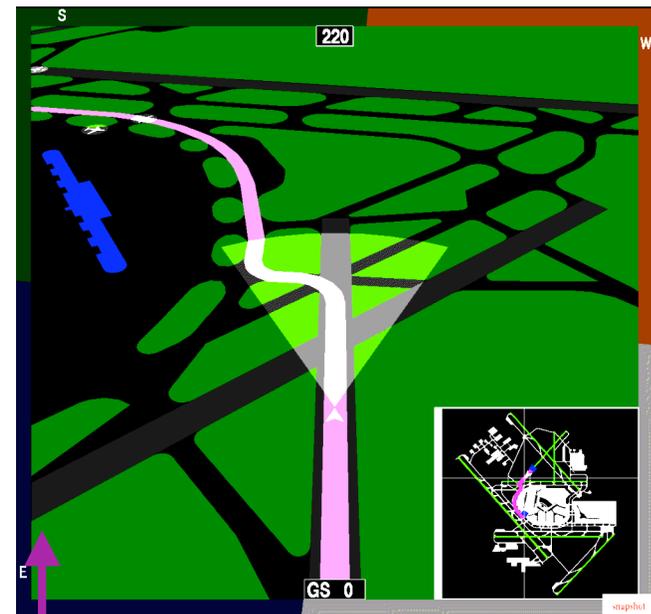
Mitigating Execution Errors

(Errors in carrying out a navigation maneuver)

- Disambiguate environment
- Enhance local awareness

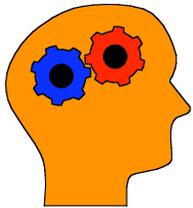
EMM

This Taxi HUD enhances and augments the world with scene-linked symbology. It can compensate for degraded visibility and inadequate navigational cues



This EMM shows the cleared taxi route and aircraft position. It facilitates navigation at complex intersections and disambiguates airport signage.

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

Crew Communication & Procedures

SAFETY INTERVENTIONS TO REDUCE ERROR



Cockpit Technologies



System / Operational Changes





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