The Limits of Expertise: Rethinking Pilot Error and the Causes of Airline Accidents

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Human Factors
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Most Airline Accidents Attributed to Crew Error

What does this mean?

- Why do highly skilled pilots make fatal errors?
- How should we think about the role of errors in accidents?

Draw upon cognitive science research on skilled performance of human operators

Approach

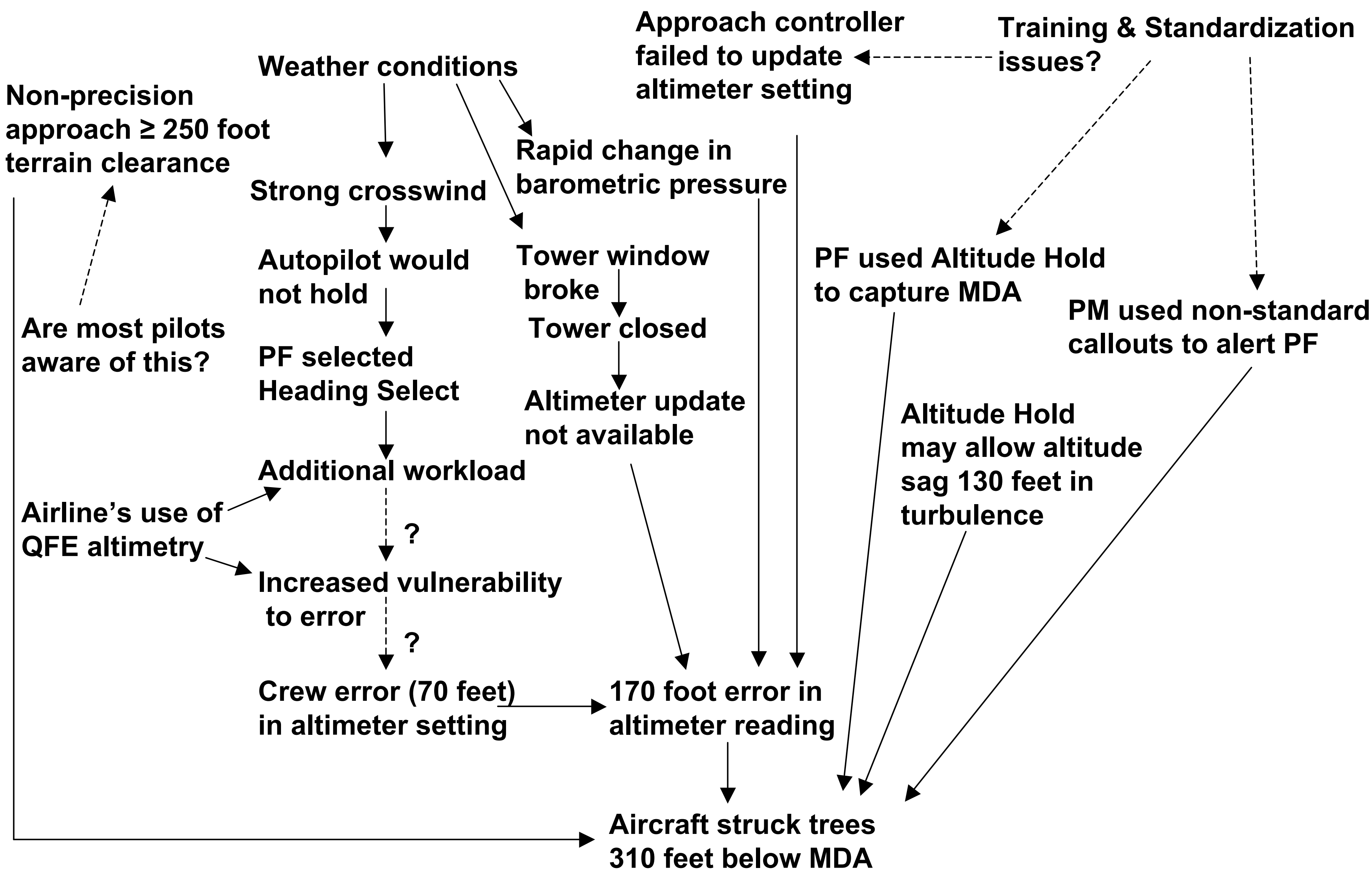
- Reviewed NTSB reports of the 19 U.S. airline accidents between 1991-2000 attributed primarily to crew error
- Asked: Why might any airline crew in situation of accident crew – knowing only what they knew – be vulnerable?
- Can never know with certainty why accident crew made specific errors but can determine why the population of pilots is vulnerable
- Considers variability of expert performance as function of interplay of multiple factors

A Truism

- No one thing “causes” accidents
- Confluence of multiple events, task demands, actions taken or not taken, and environmental factors

Confluence of Factors in a CFIT Accident

(Bradley, 1995)



Hindsight Bias

- Knowing the outcome of an accident flight reveals what crew should have done differently
- Accident crew does not know the outcome
  - They respond to situation as they perceive it at the moment
- Principle of "local rationality": experts do what seems reasonable, given what they know at the moment and the limits of human information processing
- Errors are not *de facto* evidence of lack of skill or lack of conscientiousness

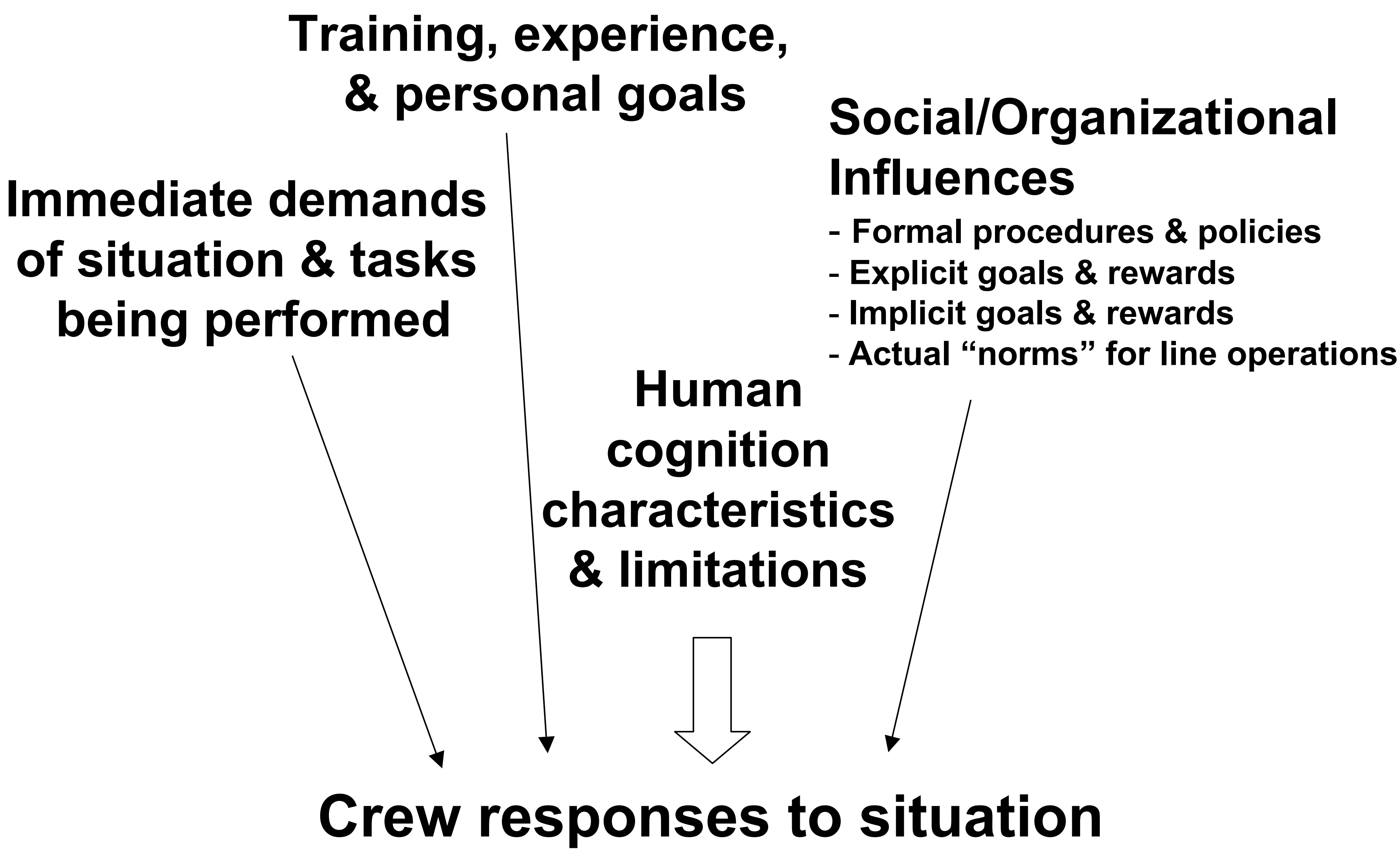
Two Fallacies About Human Error

<u>Myth</u>: Experts who make errors performing a familiar task reveal lack of skill, vigilance, or conscientiousness

<u>Fact</u>: Skill, vigilance, and conscientiousness are essential but not sufficient to prevent error

<u>Myth</u>: If experts can normally perform a task without difficulty, they should always be able to perform that task correctly

<u>Fact</u>: Experts periodically make errors as consequence of subtle variations in task demands, information available, and cognitive processing


Training, experience,
& personal goals
Social/Organizational
Influences
- Formal procedures & policies
- Explicit goals & rewards
- Implicit goals & rewards
- Actual “norms” for line operations
Immediate demands
of situation & tasks
being performed
Human
cognition
characteristics
& limitations
Crew responses to situation

Each Accident Has Unique Surface Features and Combinations of Factors

- Countermeasures to surface features of past accidents will not prevent future accidents
- Must examine deep structure of accidents to find common factors

Six Overlapping Clusters of Error Situations

1) Inadvertent slips and oversights while performing highly practiced tasks under normal conditions
2) Inadvertent slips and oversights while performing highly practiced tasks under challenging conditions
3) Inadequate execution of non-normal procedures under challenging conditions
4) Inadequate response to rare situations for which pilots are not trained
5) Judgment in ambiguous situations
6) Deviation from explicit guidance or SOP

Clusters of Error Situations

(continued)

1) and 2) Inadvertent slips and omissions:

- Examples:
  - Forgetting to: reset altimeters at FL180, arm spoilers, turn on pitot heat, set flaps to the take-off position
- Errors are usually caught or are inconsequential
- Errors may not be caught when other factors are present: interruptions, time pressure, non-normal operations, stress

Clusters of Error Situations

(continued)

4) Inadequate response to rare situations for which pilots are not trained

- Examples:
  - False stick shaker activation just after rotation (JFK, 1992)
  - Oversensitive autopilot drove aircraft down at Decision Height (O'Hare, 1998)
  - Anomalous airspeed indications past rotation speed (LaGuardia, 1994)
  - Uncommanded autothrottle disconnect with non-salient annunciation (West Palm Beach, 1997)
- Surprise, confusion, stress, and time pressure play a role
- No data on what percentage of airline pilots would respond adequately in these situations

Clusters of Error Situations

(continued)

5) Judgment and decision-making in ambiguous situations

- Examples:
  - Continuing approach in vicinity of thunderstorms (Charlotte, 1994)
  - Not de-icing (Cleveland, 1991) or not repeating de-icing (LaGuardia, 1992)
- No algorithm to calculate when to break off approach; company guidance usually generic
- Crew must integrate incomplete and fragmentary information and make best judgment
  - If guess wrong, crew error is found to be "cause"
- Accident crew judgment & decision-making may not differ from non-accident crews in similar situations:
  - Lincoln Lab study: Penetration of storm cells on approach not uncommon
  - Other flights may have landed or taken off without difficulty a minute or two before accident flight
- Questions:
  - What are actual industry norms for these operations?
  - Sufficient guidance for crews to balance competing goals?
  - Implicitly tolerate/encourage less conservative behavior as long as crews get by with it?

Clusters of Error Situations

(continued)

6) Deviation from explicit guidance or SOP

- Example: Attempting to land from unstabilized approach resulting from slam-dunk approach
- Simple willful violation or more complex issue?
  - Are stabilized approach criteria published/trained as guidance or absolute bottom lines?
  - Competing pressures for on-time performance, fuel economy
  - What are norms in company and the industry?
- Pilots may not realize that struggling to stabilize approach before touchdown imposes such workload that they cannot evaluate whether landing will work out

Cross-Cutting Factors Contributing to Crew Errors

- Situations requiring rapid response
- Challenges of managing concurrent tasks
- Equipment failure and design flaws
- Misleading or missing cues normally present
- Plan continuation bias
- Stress
- Shortcomings in training and/or guidance
- Social/organizational issues

Cross-Cutting Factors

(continued)

Situations requiring rapid response

- Nearly 2/3 of 19 accidents
- Examples: upset attitudes, false stick shaker activation after rotation, anomalous airspeed indications at rotation, autopilot-induced oscillation at Decision Height, pilot-induced oscillation during flare
- Very rare occurrences, but high risk
- Surprise is a factor
- Inadequate time to think through situation
  - automatic response required

Cross-Cutting Factors
(continued)

Challenges of managing concurrent tasks

- Workload high in some accidents (e.g., Little Rock, 1999)
  - Overloaded crews failed to recognize situation getting out of hand
  - Crews became reactive instead of proactive/strategic
  - Monitoring and cross-checking suffered
- But: adequate time available for all tasks in many accidents
  - Inherent cognitive limitations in switching attention: preoccupation with one task of many; forgetting to resume interrupted or deferred tasks

Cross-Cutting Factors

(continued)

Plan continuation bias (e.g., Burbank, 2000)

- Unconscious cognitive bias to continue original plan in spite of changing conditions
- Appears stronger as one nears completion of activity (e.g., approach to landing)
  - Why are crews reluctant to go-around?
- Bias may prevent noticing subtle cues indicating original conditions have changed
- Default plan always worked before
- Reactive responding is easier than proactive thinking

Cross-Cutting Factors
(continued)

Stress

- Stress is normal physiological/behavioral response to threat
- Acute stress hampers performance
  - Narrows attention (“tunneling”)
  - Reduces working memory capacity
- Combination of surprise, stress, time pressure, and concurrent task demands can be lethal setup

Cross-Cutting Factors
(continued)

Social/Organizational Issues

- Actual norms may deviate from Flight Operations Manual
  - Little data available on extent to which accident crews' actions are typical/atypical
- Competing pressures not often acknowledged
  - Implicit messages from company may conflict with formal guidance
    - e.g. on-time performance vs. conservative response to ambiguous situations
  - Pilots may not be consciously aware of influence of internalized competing

Implications and Countermeasures

- Focus on deep structure, not superficial manifestations
- “Complacency” is not an explanation for errors
- Most accidents are systems accidents
  - Many factors contribute to and combine with errors
  - Unrealistic to expect human operators to never make an error or to automate humans out of the system
- Design overall operating system for resilience to equipment failure, unexpected events, uncertainty, and human error
- Equipment, procedures, & training must be designed to match human operating characteristics

Implications and Countermeasures

(continued)

- Need better info on how airspace system typically operates and how crews respond
  - e.g., frequency/site of slam-dunk clearances, last-minute runway changes, unstabilized approaches
- FOQA and LOSA are sources of information
- Must find ways to share FOQA and LOSA data industry-wide to develop comprehensive picture of system vulnerabilities
- NASA research for next generation FOQA: Aviation Performance Measurement System (APMS)
  - Dr. Tom Chidester: >1% of 16,000 flights: high energy arrivals ⟶ unstabilized approaches ⟶ landing exceedances

Implications and Countermeasures

(continued)

- When FOQA and LOSA uncover norms deviating from formal guidance, must find why (e.g., must identify and change forces discouraging crews from abandoning unstabilized approaches)
  - Conflicting messages from company (e.g., concern for on-time performance and fuel costs)?
  - Viewed as lack of skill?
  - Fear of recrimination?
  - Fail to recognize logic for unstabilized approach criteria?
- Countermeasure: Publish and check bottom lines; reward adherence

Implications and Countermeasures: Procedures

- Airlines should periodically review normal and non-normal procedures for design factors that invite errors, e.g.:
  – Checklists run during periods of high interruptions
  – Allowing critical items to “float” in time (e.g., setting take off flaps during taxi)
  – Silent annunciation of critical checklist items
  – Pilot Monitoring forced to go head down in critical period
- Formalize, train, and test monitoring and cross-checking

Implications and Countermeasures: Training

Train pilots, managers, instructors, and designers about human cognitive operating characteristics:

1. Dangers of repetitious operations:
   - Checklists are vulnerable to “looking without seeing”, and forgetting items when interrupted or deferred
   - Briefings can become mindless recitations
   - Crews can become reactive rather that proactive/strategic
2. Dangers of plan continuation bias and of juggling multiple tasks concurrently
3. Effects of acute stress on performance

Implications and Countermeasures: Training

(continued)

Countermeasures:

1. Use briefings and inquiry to look ahead, question assumptions about situation, identify threats, and prepare options and bottom lines
2. Ask “What if our plan does not work?”
3. Reduce checklist vulnerability
   – Execute items in a slow, deliberate manner, pointing and touching
   – Anchor checklist initiation to salient event (e.g. top of descent)
   – Create salient reminder cues when items are interrupted or deferred
4. Stress inoculation training
   – Awareness of cognitive effects
   – Slow down and be deliberate
   – Extra attention to explicit communication and workload management

Implications and Countermeasures: Policy

Acknowledge inherent trade-offs between safety and system efficiency

- Include all parties in analysis of trade-offs
- Make policy decisions explicit and implement guidance
- Accept consequences if policy not sufficiently conservative

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More information on NASA Human Factors Research:

http://human-factors.arc.nasa.gov/his/flightcognition/

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