Human Error or System Error:

Are We Committed to Managing It?

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Human Systems
Integration Division

Forgetting to Perform Procedural Tasks

- 20 August 2008: MD-82 on takeoff from Madrid
  - Flaps not in takeoff position
  - Takeoff configuration warning did not sound
- Similar accidents occurred in U.S. in August 1988 (B727), August 1987 (MD-82)
  - Flaps not set and warning system failed
- 27 major airline accidents in U.S. between 1987 and 2001 attributed primarily to crew error
  - In 5 the crew forgot to perform a flight-critical task
  - Did not catch with the associated checklist

Most Accidents Attributed to Pilot Error

- How should we think of this?

- Why do experienced professional pilots make mistakes performing routine tasks?
  - Lack the right stuff?
  - Not conscientious or not vigilant?
  - Some other answer?

- How we answer these questions is the foundation of aviation safety

Overview of Talk

- Research community's perspective on why experienced pilots are vulnerable to error
- Describe specific situations in which vulnerability to error is high
- Practical countermeasures for pilots, companies, and the industry
- Derived from series of NASA studies of airline operations
  - Applicable to business operations (often more challenging than airline ops)
  - Private flying has special issues not discussed today

Consensus from Decades of Human Factors Research

- Simply naming human error as “cause” is simplistic
  - Does little to prevent future accidents
- Must avoid hindsight bias
- “Blame and punish” mentality blocks path to improving safety
- Irresponsibility is rare among professional pilots
  - Must look for more subtle, complex answers in most cases

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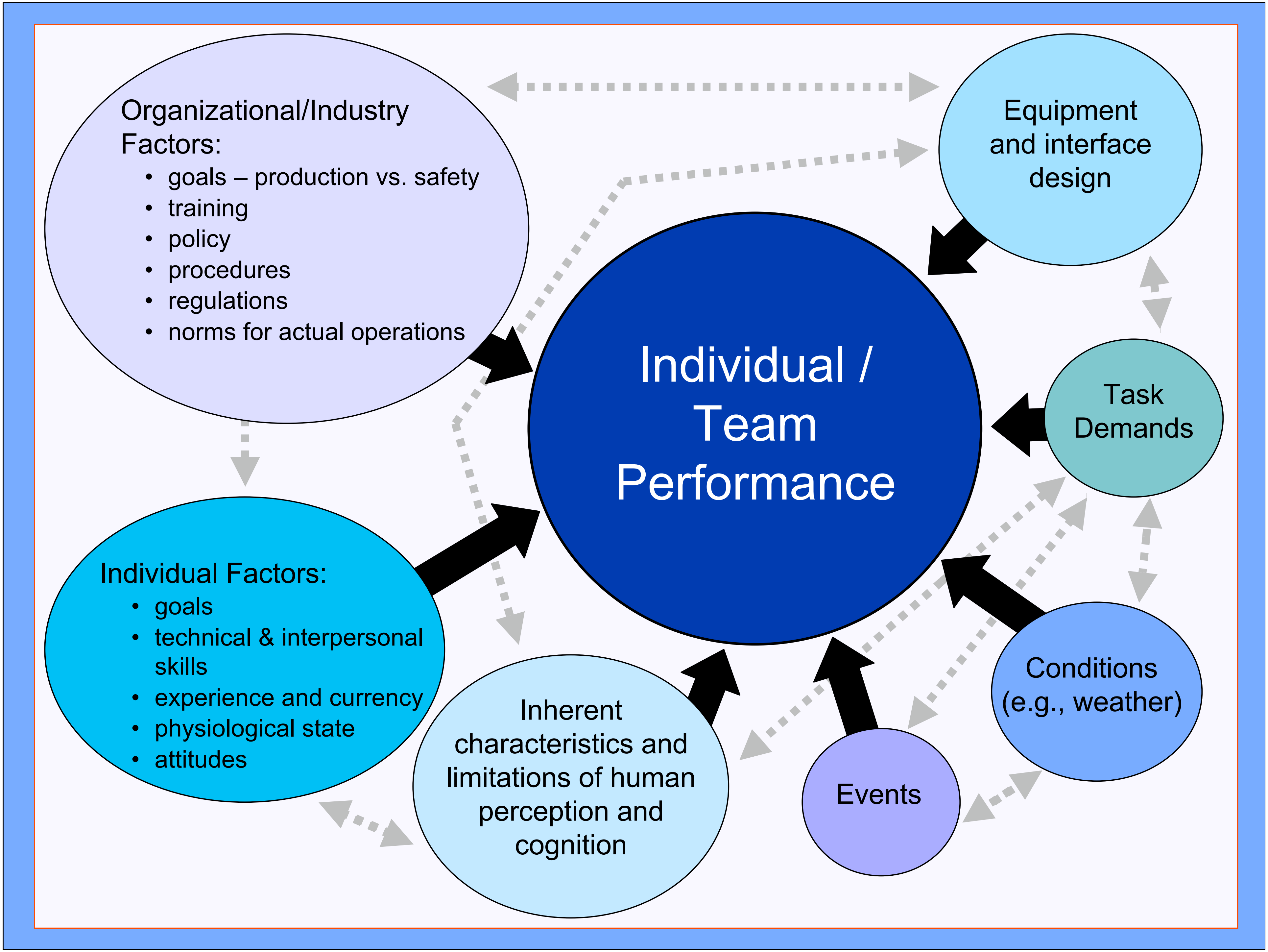
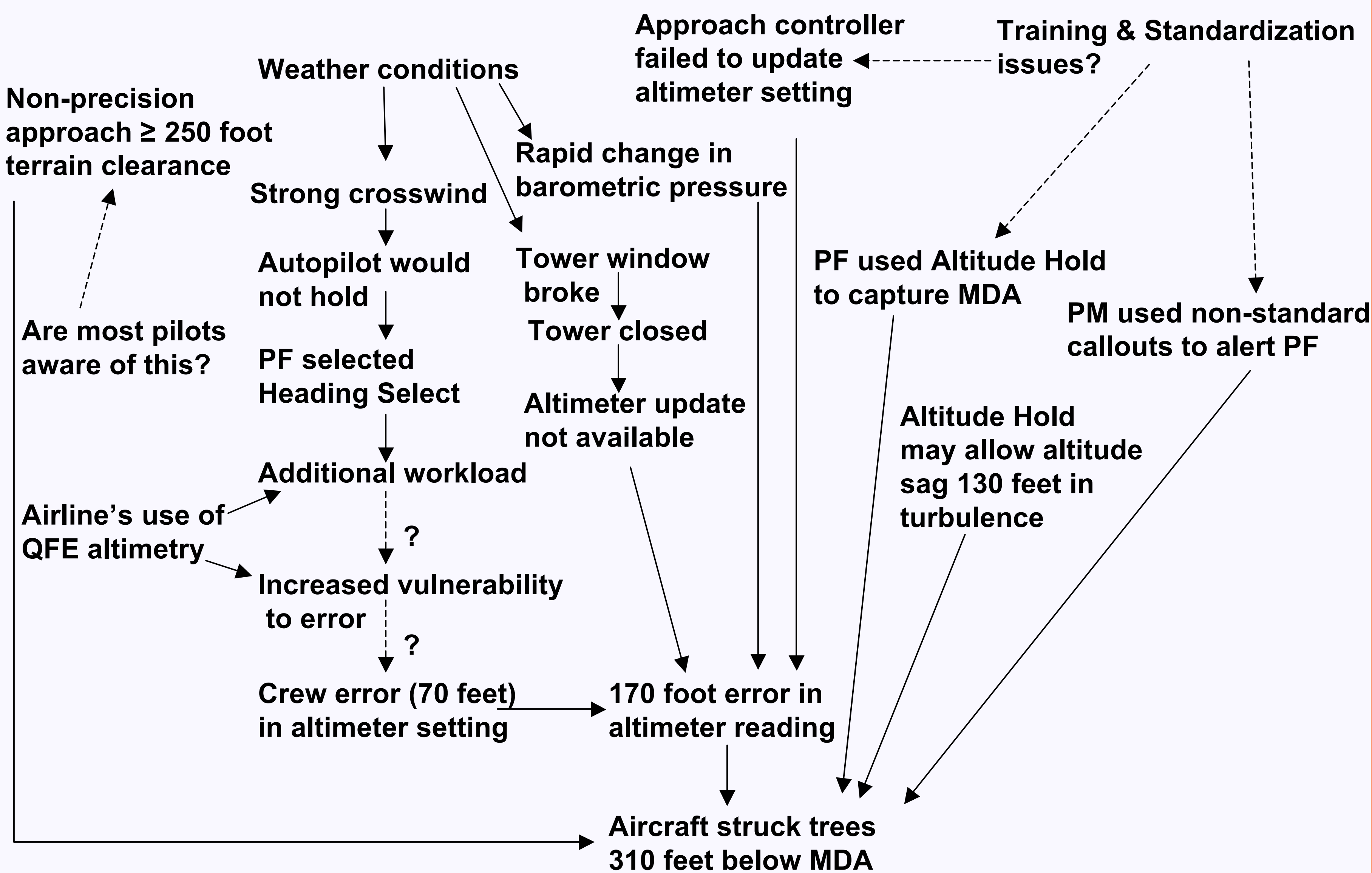


Organizational/Industry Factors:
• goals – production vs. safety
• training
• policy
• procedures
• regulations
• norms for actual operations
Equipment and interface design
Individual / Team Performance
Task Demands
Individual Factors:
• goals
• technical & interpersonal skills
• experience and currency
• physiological state
• attitudes
Inherent characteristics and limitations of human perception and cognition
Events
Conditions (e.g., weather)

Confluence of Factors in a CFIT Accident

(Bradley, 1995)



How Can We Prevent Multiple Factors from Converging to Cause Accidents?

- Must look for underlying themes and recurring patterns

- Must develop tools to help pilots and organizations to recognize nature of vulnerability

Some Major Themes and Recurring Patterns

(not an exhaustive list)

- Plan continuation bias
- Snowballing workload
- Concurrent task demands and prospective memory failures
- Ambiguous situations without sufficient information to determine best course of action
- Procedural drift
- Situations requiring very rapid response
- Organizational issues

Plan Continuation Bias

- Tendency to continue original or habitual plan of action even when conditions change
- "Get-there-itis"
- Operates sub-consciously
- Pilot fails to step back and re-assess situation and revise plan

Example: Flight 1420 DFW to Little Rock

- 2240: Departed DFW over two hours late
- 2254: Dispatch: Thunderstorms left and right but LIT clear; suggest expedite approach
- Crew concluded (from radar) cells were about 15 miles from LIT and they had time to land
- Typical airline practice to weave around cells
  - -Hold or divert if necessary but usually land
- Crews are expected to use best judgment with only general guidance

Flight 1420 (continued)

- 2234 to 2350 (landing): Crew received series of wind reports
  - Wind strength/direction varied, with worsening trend
  - Crew discussed whether legal to land (tactical issue), but not whether to continue the approach (strategic issue)
- 2339:32: Controller reported wind shift: now 330 at 11
- 2339:45: Controller reported wind-shear alert: Center field 340 at 10; North boundary: 330 at 25; Northwest boundary: 010 at 15
  - Alert contained 9 separate chunks of information
  - Average human working memory limit is 7 chunks

Flight 1420 (continued)

- Crew requested change from 22L to 4R to better align with winds
  - Flight vectored around for new visual approach
- Vectoring turned aircraft radar antenna away from airport
  - Crew could not observe airport on radar for 7 minutes
- Crew's response to wind reports was to try to expedite visual approach to beat the storm
- 2344: Crew lost visual contact and requested vectors for ILS 4R
  - Vectors took aircraft deeper into storm
  - Crew requested tight approach, increasing time pressure

Flight 1420 (continued)

- By now crew was extremely busy, tired at the end of long duty day, and in a difficult, stressful situation
- 2347: New weather report: RVR 3000; wind 350 at 30G45

  -FO read back incorrectly as 030 at 45 (which would have been within crosswind limits)

  -Controller failed to catch incorrect readback (hearback often fails)

Flight 1420 (continued)

- 2347:44: Captain: “Landing gear down”
  - -Sixth of 10 items on Before Landing checklist
  - -FO lowers landing gear
- Distracted, FO forgot to arm ground spoilers and other remaining checklist items
  - -Captain failed to notice omission
- Crew was extremely busy for 2 & ½ minutes from lowering gear to touchdown
- Fatigue: Awake 16 hours and on dark side of clock
- Stress, normal response to threat, but:
  - -Narrows attention, preempts working memory
- Combination of overload, fatigue, and stress impairs crew performance drastically

Flight 1420 (continued)

- Overloaded, captain forgot to call for final flaps but was reminded by FO
- Lost sight of runway and reacquired just above DH; unstabilized in alignment and sink rate
  - -Company had not established explicit policy *requiring* go-around
  - -Either landing or go-around would be in middle of thunderstorm
- 2350:20: Aircraft touched down right of centerline
  - -Veered right and left up to 16 degrees before departing runway
- Unarmed spoilers did not deploy
- Captain used normal reverse thrust—1.6 EPR
  - -Limited to 1.3 EPR on wet runways to limit rudder blanking
- 2350:44: Crashed into structure at departure end of runway
  - -Aircraft destroyed; 10 killed, many injured

Flight 1420 (conclusion)

- Many factors and many striking features (much detail omitted)

- Crew responded to events as they happened, trying to manage, but:
    - Never discussed abandoning the approach
    - Striking example of plan continuation bias

- Experts in all domains are vulnerable to plan continuation bias

- What causes this vulnerability?
    - Still under research; multiple factors probably contribute

Plan Continuation Bias--Likely Factors

- Habitual plan has always worked in past (e.g., threading around storm cells)
  - -MIT study: T-Storm penetration common on approach
  - -Leads to inaccurate mental model of level of risk
- Norms: We tend to do things the way our peers do
- Information often incomplete or ambiguous and arrives piecemeal
  - -Difficult to integrate under high workload, time pressure, stress, or fatigue
- Expectation bias makes us less sensitive to subtle cues that situation has changed
- Framing bias influences how we respond to choices
- Competing goals: Safety versus on-time performance, fuel costs & customer satisfaction

Plan Continuation Bias (conclusion)

- How much does economic pressure influence pilot decisions in business aviation?
    - -More direct contact with customers than in airlines
- All pilots feels they would not make unsafe decision because of economic considerations, but:
    - -Perception of risk can be biased *unconsciously*
    - -Pilots are very mission oriented
    - -Disappointment of diverting is an emotional influence

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Snowballing Workload

- Under high workload our cognitive resources are fully occupied with immediate demands
- No resources left over to ask critical questions
- Forced to shed some tasks, individuals often become reactive rather than proactive
  - React to each new event rather than thinking ahead strategically
- As situation deteriorates, we experience stress:
  - Compounds situation by narrowing attention and pre-empting working memory
- Catch-22: High workload makes it more difficult to manage workload
  - By default, continue original plan, further increasing workload
  - When most need to be strategic we are least able to be strategic

Multitasking Leads to Prospective Memory Failures

- Overload is not the only workload management issue and may not be the worst
- Having to juggle several tasks concurrently creates insidious vulnerability
- Why would highly experienced pilots, controllers, mechanics and other operators forget to perform simple, routine tasks (prospective memory failure)?
- In 5 of 27 major U.S. airline accidents attributed to crew error, inadvertent omission of procedural step played a central role:
  - -Forgetting to set flaps/slats, to set hydraulic boost pumps to high, to turn on pitot heat before takeoff, to arm spoilers before landing
- Inadvertent omissions frequently reported to ASRS
- NASA study: The Multitasking Myth: Handling Complexity in Real-World Operations

Six Prototypical Situations for Forgetting Tasks

1) Interruptions—forgetting to resume task after interruption over

2) Removal of normal cue to trigger habitual task, e.g.:
   - -“Monitor my frequency, go to tower at…”
   - - Consequence: Landing without clearance

3) Habitual task performed out of normal sequence. e.g.:
   - -Deferring flaps to taxi on slushy taxiway

4) Habit capture—atypical action substituted for habitual action
   - -Example: Modified standard instrument departure

5) Non-habitual task that must be deferred
   - -“Report passing through 10,000 feet”

6) Attention switching among multiple concurrent tasks
   - -Example: Programming revised clearance in FMS while taxiing

Carelessness???

- Research: Expert operators in every domain sometimes forget to perform intended actions
- Human brains not wired to be completely reliable in these six prototypical situations
- Good news: We can reduce vulnerability through countermeasures

Factors External to Crew

Ambiguous situations with insufficient information to determine best course of action:

-Examples: Departing/arriving at airports in vicinity of thunderstorms; repeating de-icing

-No algorithm available to calculate hazard; company guidance typically generic; crew must decide by integrating fragmentary & incomplete information from diverse sources

-Accident crew typically blamed for poor judgment

-Evidence that crews before and after accident crew made same decision, using same info, but lucked out:

- --MIT radar study: airliners penetrate thunderstorms
- --Airliners taking off immediately before accident aircraft

-Blame accident crew or focus on industry norms?

- --Sufficient guidance to balance competing goals?
- --Conservative-sounding formal policies but implicit encouragement to be less conservative?

Procedural Drift

Example: Landing from unstablized approach

-May seem a clear-cut case of pilots violating SOP

-Company guidance often advisory rather than mandatory

-Evaluation requires data on what other pilots do in same situation (“norms”)

-Chidester et al analysis of FOQA data: Slam-dunk clearancesàhigh energy arrivalsàunstabilized approaches

--1% of 16,000 airline approaches were high-energy arrivals and landed from unstabilized approaches

-Rather than blaming accident pilots perhaps should focus on finding why stabilized approach criteria are too often not followed?

Situations Requiring Very Rapid Response

- 12 of 19 accidents: crews had only a few seconds to recognize and respond to unexpected situation
  - -Examples: upset attitudes, false stick-shaker activation just after rotation, erratic airspeed indications at rotation, pilot-induced oscillation during flare, autopilot-induced oscillation at decision height.
- Researchers surprised because great majority of threatening situations do not require rapid response and rushing should be avoided
  - -Although rapid response situations are extremely rare, when they occur it is very difficult for pilots to respond correctly
- How should industry respond?
  - -Blame accident pilots (gets everyone else off the hook)?
  - -Improve equipment reliability and interface design to support rapid response?
  - -Accept that not all situations can be managed reliably?

Organizational Factors

- Will not discuss as a separate theme
- Centrally involved in all the themes and recurring patterns already discussed
- SMS?

Help is on the Way! Countermeasures

- Can substantially reduce risk in these situations
- Countermeasures individual pilots, companies, and the industry can take

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Industry-level Countermeasures

- Know the enemy! (In aviation safety as in military operations)
  - -ASAP, ASRS, LOSA, and FOQA provide data on how normal line operations are actually conducted and the problems that arise
  - -Tragically, several airlines have dropped ASAP
  - -Business aviation needs similar programs adapted to specific environment of business operations
- Do the research (knowledge doesn't drop out of the sky)
  - -Airline safety improved substantially in part due to research on CRM, better checklist design, LOSA, ASRS, and sophisticated computer methods to analyze FOQA data
  - -Little research has addressed the business aviation arena
  - -Federal funding for aviation human factors research has declined
- Abandon simplistic notions of accident causality
  - -Pilot error is symptom not an explanation
  - -Focus on design for resilience, SMS, and TEM

Organization-level Countermeasures

- Avoid complacency from low-accident rates
  - -Many pressures to cut costs; difficult to anticipate effects
- Acknowledge inherent tension between safety and system efficiency
  - -"Safety is our highest priority" is a slogan not a policy
  - -Recognize that pilots internalize organization's goals for on-time performance, passenger satisfaction and containing fuel costs
  - -Reward and check desired conservative behavior with policies, procedures and operating norms
- Periodically review operating procedures: Do they reduce or exacerbate vulnerability to error?
  - -Examples: Better to set flaps and brief departure before aircraft is in motion; long checklists lead to omission errors

Countermeasures for Pilots

*Counter “complacency” by being aggressively proactive:

-Flight planning: Look for hidden threats; ask what might go sour, what cues would signal situation not as expected, and how would we respond?

-En route: Is situation still the one we planned for?

*Identify “bottom lines” in advance, before workload and stress take their toll

-SOPs provide some bottom lines but cannot anticipate all situations

-Example of personal bottom line: Identifying bingo fuel when being vectored around storms

*Workload management:

-Be prepared for effects of snowballing workload; buy time, shed lower priority tasks (I.e., standard CRM)

-Step back mentally periodically and think strategically rather than just reacting tactically to events

-Have a way out already planned

Countermeasures for Pilots (continued)

Not just overload: Recognize vulnerable to forgetting tasks when:

-Interrupted, performing tasks out of normal sequence, deferring tasks

Ways to avoid prospective memory failures:

-Explicitly identify when and where you will complete task

-Say it aloud to encode in memory

-Ask co-pilot to help remember

-Pause before next phase of flight to review actions

-Create distinctive, unusual, and physically intrusive reminder cues

Countermeasures for Pilots (continued)

- Checklists and monitoring are crucial defenses but sometimes fail
- Ongoing NASA study (with Ben Berman):
  - -Checklists often not performed as prescribed
  - -Repetitive nature leads to automatic execution, lack of full attention:
    - --"Looking without seeing"; automatic response to challenge
- Protect checklist and monitoring performance:
  - -Slow down; be deliberate; point and touch; delay verbal response
- Rushing is always problematic
  - -Natural human response to time pressure and threat, but..
  - -Saves at most a few seconds
  - -Drastically increases probability of error

A Pithy Summary

Chief of USMC Aviation Safety:

Fly Smart, Stay Half-Scared, and Always Have a Way Out

More Information

- Dismukes, Berman, & Loukopoulos (2007). The Limits of Expertise: Rethinking Pilot Error and the Causes of Airline Accidents (Ashgate Publishing)
- Loukopoulos, Dismukes, & Barshi (2009). The Myth of Multitasking: Managing Complexity in Real-World Operations (Ashgate Publishing)
- Berman, B. A. & Dismukes, R. K. (2006) Pressing the Approach: A NASA Study of 19 Recent Accidents Yields a New Perspective on Pilot Error. *Aviation Safety World*, 28-33.
- Can download papers from: **http://human-factors.arc.nasa.gov/ihs/flightcognition/**
- This research funded by the NASA Aviation Safety Program and the FAA


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