Human Error or System Error:
Are We Committed to Managing It?

Key Dismukes, Ph.D.
Chief Scientist for Aerospace Human Factors
NASA Ames Research Center

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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
Individual / Team Performance

Organizational/Industry Factors:
- goals – production vs. safety
- training
- policy
- procedures
- regulations
- norms for actual operations

Individual Factors:
- goals
- technical & interpersonal skills
- experience and currency
- physiological state
- attitudes

Inherent characteristics and limitations of human perception and cognition

Conditions (e.g., weather)

Events

Task Demands

Equipment and interface design
Confluence of Factors in a CFIT Accident
(Bradley, 1995)

Non-precision approach ≥ 250 foot terrain clearance

Weather conditions

Strong crosswind

Autopilot would not hold
PF selected Heading Select

Additional workload

Increased vulnerability to error
Crew error (70 feet) in altimeter setting

Approach controller failed to update altimeter setting

Rapid change in barometric pressure

Tower window broke
Tower closed
Altimeter update not available

170 foot error in altimeter reading

PF used Altitude Hold to capture MDA

PM used non-standard callouts to alert PF

Altitude Hold may allow altitude sag 130 feet in turbulence

Training & Standardization issues?

Aircraft struck trees 310 feet below MDA

Are most pilots aware of this?

Airline’s use of QFE altimetry

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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
• 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 feel they would not make unsafe decisions because of economic considerations, but:
  - Perception of risk can be biased *unconsciously*
  - Pilots are very mission oriented
  - Disappointment of diverting is an emotional influence
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 unstabilized 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 clearances à high energy arrivals à unstabilized 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?
Factors External to the Crew

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
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)


- Can download papers from: http://human-factors.arc.nasa.gov/ihs/flightcognition/

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