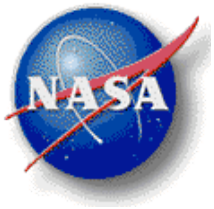

Checklists and Monitoring: Why Vital Defenses Against Equipment Failures and Errors Sometimes Fail

Key Dismukes
NASA Ames Research Center

In collaboration with Ben Berman,
Loukia Loukopoulos, and Immanuel Barshi

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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

Human Performance Issues Even More Critical in Future Systems

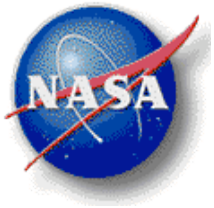
- Human role moving toward overseeing and monitoring
  - Flight trajectories more complicated and dynamic
  - Systems more automated
- Automation can help or hurt
- Design of new systems, procedures, and training requires:
  - Deep understanding of flight operations, task demands imposed, and human information processing

Our Research Domain: Why Skilled Experts Make Errors Leading to Accidents

- Highlights from recently completed study and an ongoing study
- Completed book (August): *The Multitasking Myth: Handling Complexity in Real-World Operations*
  - Examined cognitive demands of normal cockpit operations
  - Analyzed airline operating procedures and training
  - Identified prototypical forms of error
  - Developed measures to reduce vulnerability errors and accidents
- Methods:
  - Ethnographic observation (from cockpit jumpseat)
  - Cognitive analysis of task demands, accidents and incidents

Airline Cockpit Procedures

- Highly scripted in flight operations manuals (FOM)
- Found divergence between *ideal* world of manuals and *real* world of operations
- In FOM:
  - Tasks are described as linear/sequential
  - Task demands are predictable in timing and character
  - Initiation and execution of tasks controlled entirely by crew
- Jumpseat observations:
  - Pilots often forced to juggle multiple tasks concurrently
  - Pilots are often interrupted, must defer tasks, and perform tasks out of normal sequence
  - Work is non-linear, only partly predictable and only partly under pilot control
- Perturbations of the ideal associated with vulnerability to error
  - Not addressed in FOM or training

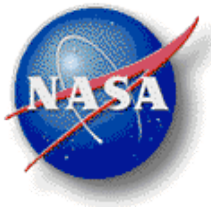


Focused on Inadvertent Errors of Omission

- Serious consequences and pilots typically fail to catch these errors
- Found four prototypical situations for error:
  - Interruptions and distractions
  - Tasks that cannot be executed in normal sequence
  - Unanticipated new tasks that must be deferred
  - Multiple tasks that must be interleaved

WHY?

- Why do highly experienced pilots forget to perform routine tasks?
- Importance of task does not prevent forgetting
- Prospective memory (the need to remember to perform deferred tasks) is burgeoning research field
  - Providing a plausible account of why experts forget
  - Laying foundation for measures to prevent forgetting



Checklists and Crew Monitoring

- Essential defenses against threats, equipment malfunctions, and errors
- Pilots must monitor flight path, aircraft configuration, state of systems, and actions of other pilot
- Studying why these two defenses sometimes fail
- Methods:
  - Ethnographic observation of line operations from jumpseat
  - Cognitive analysis of task demands and crew performance

Where We Are in Study

- Completed data collection from 60 flights
- Major U.S. airline, major international airline, and regional airline
- Six aircraft types: EMB; A320; B-767; B-737; B-757; B-777
- 600 errors observed (deviations from SOP, regulations or good operating practice)
- Data: Narrative description of error, context, who made error and who caught error
- Analysis underway (highlights only, today)

Categories of Error

(number of instances)

Checklists		
Item omitted or incomplete		50
Flow & Check run as Read & Do	46	
Responded to item challenged without looking	36	
Poor timing of checklist initiation	32	
Checklist performed from memory	17	
Checklist not called for	13	
Monitoring		
Callout omitted or late	214	
Verification omitted		123
Failed to monitor aircraft at level out	64	
Head down at critical juncture	5	

Checklist Item Omitted or Not Complete

- Diverse situations
- One cluster: Checklist interrupted by external agent or event
  - Example: Flight attendant interrupted captain during departure briefing; last item, outbound Taxi Route, not completed
- Another cluster: Checklist item is deferred
  - Captain called for Approach checklist too early for two items to be completed; crew forgot to go back and finish checklist

Why Do Skilled Experts Forget Routine Tasks?

Our experimental research suggests two reasons:

1. Interruptions divert attention so suddenly that intention to resume interrupted task not encoded fully and explicitly
2. Interruption fully occupies attention; cannot maintain goal of resuming interrupted task in working memory
   - After interruption, new task demands occupy attention
   - No cue prompts retrieval of memory of interrupted task

Mandatory Callout Omitted or Late

- Diverse situations
- Omitting callouts for unstablized approaches especially troubling
  - Example: Monitoring pilot did not call “Unstable” when aircraft descended below 500 feet AGL unstablized

    (Stabilized approach = Airspeed, sink rate, glideslope & configuration on target)
- AA 1420 (Little Rock) and SWA 1455 (Burbank) flew unstable approaches and monitoring pilot failed to make required callouts

Mean Error Rates, Standard Deviation, and Range

Monitoring	6.8 ± 3.9 (1 – 19)
Checklist Use	3.2 ± 4.8 (0 – 14)

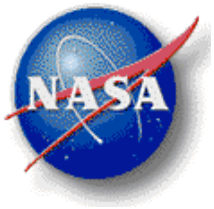
Within-crew variability or between-crew variability?

Improving Checklist Use and Monitoring—Countermeasures to Error

- Design of some procedures is problematic
  - Example: Taxi Checklist creates conflicting demands for attention
- Solution: Redesign procedures to reduce multitasking and prospective memory demands
  - Example: Eliminate Taxi Checklist and move critical items to Before Taxi

Training

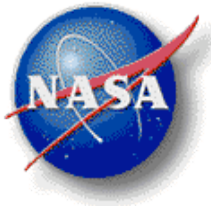
- Too often focused only on telling pilots what to do
  - Research: Humans deal with situations and unanticipated demands far better when understand underlying factors
- Our research lays foundation for training about why and when vulnerable to error and how to manage
  - Example: Initiation of tasks can be timed to reduce diversion of attention
  - Example: “Looking without seeing” prevented by slow, deliberate execution, requiring full attentive processing



Summary

Future flight decks will require procedures and training for safety and efficiency

- Cannot be add-on after system design
- Must be grounded in deep analysis of real-world operations



More Information

- Loukopoulos, L. D., Dismukes, R. K., & Barshi, I. (in press). *Multitasking: Managing Complexity in Real-world Operations*. Burlington, VT: Ashgate.
- 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.
- Dismukes, R. K., Berman, B. A., & Loukopoulos, L. D. (2007). *The Limits of expertise: Rethinking pilot error and the causes of airline accidents*. Burlington, VT: Ashgate.
- Dodhia, R. D., & Dismukes, R. K. (in press). Interruptions create prospective memory tasks. *Applied Cognitive Psychology*.
- FlightCognition Lab website:

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