Pilot Performance, Error, Automation, and Workload

Barbara Burian, Ph.D.
Key Dismukes, Ph.D.
Steve Casner, Ph.D.
Pilot Performance, Error, Automation, and Workload

Issues

• Working Memory, Prospective Memory, Long-term Memory
• Concurrent Task, Workload, and Resource Management
• Situation Awareness
• Shifting Mental Sets
• Attention, Tunneling, Fixation
• Habit Capture
• Dealing with Interruptions and Distractions
• Performing Mental Calculations, Problem Solving
• Judgment and Decision Making
• Effects of Stress, High Workload, Time Pressure
**Issues**

**Synopsis:** A Piper Navajo pilot fails to activate VOR DME A IAP to TEB and Track Dev results.

**Narrative:** GPS usage is high workload. Lots of interface with automation. Raw data backup is essential. The potential for distraction in high density terminal areas is very real when using GPS’s full capability. This reporter completed simulator training using this particular GPS only 30 days ago - - and still got it wrong.

(ASRS Report, Accession # 686537)
Pilot Performance, Error, Automation, and Workload

Human Error Countermeasures: Concurrent Task Demands and Prospective Memory

• Key Dismukes

Pilots’ A Priori Beliefs About Advanced Cockpit Systems vs. Actual Performance

• Steve Casner

Single Pilot Cognitive Performance and Workload Management in Technically Advanced Aircraft – Very Light Jets

• Barbara Burian
Human Error Countermeasures: Concurrent Task Demands and Prospective Memory

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Single Pilot Cognitive Performance and Workload Management in Technically Advanced Aircraft – Very Light Jets

- Barbara Burian
Concurrent Task Demands and Prospective memory

Key Dismukes

**Issue:** Many cockpit tasks require pilots to “multi-task”--switch attention among demands of diverse tasks. Prospective memory errors (forgetting to perform intended actions) often occur when pilots are interrupted or become preoccupied with one demanding task to the neglect of other tasks.

**Approach:** (1) Jumpseat observations of concurrent task demands in line operations, to determine types of error made and contributing factors, (2) analysis/interpretation of data using theoretical model of concurrent task management and prospective memory, (3) development of countermeasures that can be implemented in IIFD

[1] Project co-funded with FAA
Pilot Performance, Error, Automation, and Workload

Human Error Countermeasures: Concurrent Task Demands and Prospective Memory
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Single Pilot Cognitive Performance and Workload Management in Technically Advanced Aircraft – Very Light Jets
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Pilots’ A Priori Beliefs About Advanced Cockpit Systems vs. Actual Performance
Steve Casner

**Purpose** - To document pilots’ beliefs about how advanced cockpit systems affect pilot workload and performance. To compare pilots’ beliefs with actual usage, workload, and performance during flight.

**Methods**

142 pilots were surveyed to discover their preferences for using advanced cockpit systems in flight - and their beliefs about how advanced cockpit systems affect their performance.

16 pilots flew instrument procedures with and without different combinations of automated cockpit systems. These systems include: a GPS navigation computer, autopilot, moving map display, and electronic flight instrument system.

**Pilots’ stated preferences, workload, and performance were measured.**
Results
Early results indicate several points of incongruence between pilots’ stated preferences and their behavior and performance in flight.

Example: Pilots erroneously believe that most every automated system categorically reduces workload.

Example: Some automated systems prompt new kinds of errors in significant numbers.

Specific training guidelines may be needed to align pilot beliefs about automation and performance outcomes.
Pilot Performance, Error, Automation, and Workload

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Single Pilot Cognitive Performance and Workload Management in Technically Advanced Aircraft – Very Light Jets

HondaJet

Embraer Phenom 100

Eclipse 500

Cessna Citation Mustang
# Characteristics of Some Very Light Jets

Jet aircraft weighing 10,000 lbs. or less

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<tr>
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Burian – IIFDT/RAHS

Very Light Jets Glass Cockpits

Eclipse 500 Avio

Cessna Mustang G1000

Embraer Phenom 100
Purpose of the Study

Identify the kinds of problems that potential VLJ customers/pilots are having:

- in the aircraft they currently fly
- in the flight regimes in which VLJs (will) operate

Provide background information for future work examining:

- single pilot resource management
- concurrent task management
- cognitive and operational demands of flying single-pilot jets and technically advanced aircraft

Methodology

Analyzed

• ASRS Incident Reports \((n = 170)\), and
• NTSB Accident Reports (final reports with probable cause determinations) \((n = 218)\)
• of incidents/accidents occurring over a 12-month period (July 2005 through June 2006)

Involving four types of aircraft:

• Advanced single-engine \((n = 173, 44.6\%)\)
• Light twin \((n = 108, 27.8\%)\)
• Business jet \((n = 92, 23.7\%)\)
• Turboprop \((n = 15, 3.9\%)\)

“Private” Flights \((n = 253)\) compared to “Professional” Flights \((n = 134)\)
Results

NBAA Risk Areas:

• Inadequate cross-wind takeoff/landing preparation
• Inadequate preparation for high-rate/high-speed climbs
• Low-fuel arrivals
• Single pilot adherence to checklists (and preflight inspection and preparation procedures)
• Crew Resource Management / Single Pilot Resource Management (Inadequate exercise of “command”)

Other Areas of Concern:

• Cognitive performance
• Avionics
• Currency
• Collisions and Incursions
• Landing Problems
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- Avionics *
- Currency
- Collisions and Incursions
- Landing Problems
Cognitive Performance

Variables of Interest:

• Distraction
• Memory problems
• Poor decision making
• Poor risk perception
• Lost situational awareness
• Cognitive processing difficulty (confusion, difficulty performing mental calculations, habit capture, etc.)

Conservative approach to Coding:

• Only coded if pilot mentioned or overwhelming evidence was provided in the report narratives

“I was distracted by the funny noise in the cabin.”
Cognitive Performance Problems were Common:

- 66.5% ($n = 258$) of all reports involved at least one cognitive performance issue (69.4% ASRS; 64.2% NTSB)

- for example, 31.2% ($n = 121$) of the reports involved the pilot losing situational awareness
Cognitive Performance Problems were Common:

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Cognitive Performance and Avionics Problems
Cognitive Performance and Avionics

Number of Problems Using Avionics by Type of Cognition Problem

Problems Using Avionics (N = 41)

- Distracted: 17
- Memory: 0
- Cognitive Processing: 29
- Decision Making: 16
- Risk Perception: 4
- Lost Situation Awareness: 40

Cognition Problems
Cognitive Performance Problems were Common:

- 66.5% \((n = 258)\) of all reports involved at least one cognitive performance issue (69.4% ASRS; 64.2% NTSB)
- for example, 31.2% \((n = 121)\) of the reports involved the pilot losing situational awareness

Cognitive Performance and Avionics Problems

Cognitive Performance and GA vs. Professional flights:

- did not differ significantly in terms of experience of cognitive performance problems
Cognitive Performance difficulties directly affect safety

Flight Path Deviations (altitude deviation, heading/track deviation, airspace violation, upset attitude, etc.) occurred in:

- 31 (67.4%) of the 46 events involving pilot distraction
- 54 (38.3%) of the 141 reports involving cognitive processing difficulties (e.g., confusion)
- 68 (56.2%) of the 121 reports involving a loss of situational awareness
Cognitive Performance difficulties directly affect safety

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Thus:

- Cognitive Performance problems are pervasive and are often inter-related
- They affect all types of pilots and have important safety implications
So What?
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Provide background information for future work examining:

- single pilot resource management
- concurrent task management
- cognitive and operational demands of flying single-pilot jets and technically advanced aircraft
So What?

Feed into other ARMD work:

• Design Requirements and Guidelines for Development of Advanced Technology

• Data for more accurate Human Performance Models

• Data for Simulation Studies

• More Accurate Operational Assumptions – Air-Ground, 4-D trajectory, NGATS/NextGen
Study Issues, Methodology, and Findings
(Dismukes, Casner)

AvSafety Milestones Addressed

FY07 Deliverables, Publications, Presentations
http://human-factors.arc.nasa.gov/eas
http://human-factors.arc.nasa.gov/ihs/flightcognition/
http://automation.arc.nasa.gov
Back-Up Slides:
Barbara Burian
FY07 Highlights - Burian

Milestones:

1.5.4: Complete validation of operational protocols and crew training guidelines for integrated flight deck

1.5.7: Validated models of attention allocation & prospective memory to develop error mitigation strategies

1.5.11: Complete pattern analysis of concurrent task demands, interruptions, & procedural execution disruptions

Issues:

Human Error and Cockpit Checklist and Procedure Design, Content, and Use

FY07 Highlights – Burian, cont.

Deliverables:


Burian, B. K. (2007). Emergency and Abnormal Situations in Aviation: Sharing Approaches Across Industries. Presentation at the Abnormal Situations Management Consortium 50th & 52nd Quarterly Meetings, Phoenix, AZ; Richmond, CA.


Back-Up Slides:
Key Dismukes
Issue: Checklists and monitoring are two of the most crucial defenses against malfunctions and errors, yet the NTSB has identified failures in checklist use and monitoring as contributing to many aviation disasters.

Approach: (1) Jumpseat observations of checklist use and monitoring in line operations, to determine types of error made and contributing factors, (2) analysis/interpretation of data using theoretical model of concurrent task management and prospective memory, (3) development of countermeasures that can be implemented in IIFD

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Progress to Date

Data collected and data analyzed from first jumpseat study

- Hosted by two major U.S. airlines; B737 and Airbus 320 fleets
- 22 flights with different crews
- Each flight involved 10 checklists and continuous monitoring demands

Second jumpseat study begun with major Canadian airline

- Airbus 319/320 and Embraer 175/190
- >20 flights will be observed, some with same crew
- Will allow observation of different types of procedures and operations
Preliminary Findings

Good:

• Most checklists performed correctly
• Equipment problems caught with checklists
• Most callouts according to SOP
• Pilots sometimes caught errors made by the other pilot

Not-so-good:

• 3.1 checklist errors/flight (average)
• Checklist error range: 0 to 10. Standardization issue?
• 3.7 monitoring errors/flight (average)
• Monitoring error range: 1 to 6
Checklist Performance Errors
(number observed)

- Begun from memory
- Done entirely from memory
- Responding without looking
- Responding, then looking
- Calling out items without looking up from card
- Item not set properly and not caught
- Not initiated on time
- Self-initiated, prematurely
- Interrupted/suspended, not completed
- Extra item performed
- Responded “Set” in lieu of numerical value
- Flow not performed
Monitoring Performance Errors
(82 instances)

- Undesired aircraft state not challenged
- Checklist distracted from monitoring
- Communication error not caught
- Vertical mode not monitored
- Callout cued by automation, not independent
- Level-off not monitored
- Automation/FMC input not corrected
- FMC input executed without verification
- Enroute charts not unfolded
- TOD not monitored
- Not looking while calling out mode changes
- Not looking during engine start
Why Do Checklists and Monitoring Sometimes Fail?

Too often the assumed answer is “complacency”, “lack of discipline”, “lack of diligence”
- These are misleading labels, not explanations

“Blame the pilot” perspective ignores reality of:
- Cognitive mechanisms for processing information
- Competing demands for attention in actual line operations
- Design of cockpit automation interfaces

Correct answer requires analysis of concurrent task demands and theoretical account of how skilled operators allocate attention and draw upon prospective memory
FY07 Deliverables


Back-Up Slides:
Steve Casner
Pilots’ A Priori Beliefs About Advanced Cockpit Systems vs. Actual Performance
Steve Casner

Purpose - To document pilots’ beliefs about how advanced cockpit systems affect pilot workload and performance. To compare pilots’ beliefs with actual usage, workload, and performance during flight.

Methods
16 pilots will fly instrument procedures with and without different combinations of automated cockpit systems. These systems include: a GPS navigation computer, autopilot, moving map display, and electronic flight instrument system.

Pilot preferences, workload, and performance are being measured.

Results
Early results indicate several points of incongruence between pilots’ stated preferences and their behavior and performance in flight. Specific training guidelines may be needed to align pilot beliefs about automation and performance outcomes.
How Do Pilots Perceive Advanced Cockpit Systems To Affect Workload and Performance?

How Do Pilots Prefer To Fly The Aircraft?

How Is Performance Affected: Workload, Errors?
Primary flight display vs. Conventional instruments

Which do pilots prefer? How is workload affected? Errors?

GPS vs. Radio navigation
Autopilot vs. Manual control

Which do pilots prefer? How is workload affected? Errors?

Map display vs. CDI
Early results suggest that pilots’ preferences and actual performance are not aligned in some areas, suggesting the need for explicit training about the impact of advanced systems.

Example: Pilots erroneously believe that most every automated system categorically reduces workload.

Example: Some automated systems prompt new kinds of errors in significant numbers.