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Human Systems integration division

Flight Cognition Laboratory

The Hidden Complexity of Cockpit Operations

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21st Annual European Air Safety Seminar
Cyprus, 16-18 March, 2009

errorManagement

FSF AeroSafety World - December 2008

COVER STORY

DEADLY OMISSIONS

Human memory fails in predictable patterns that can be avoided by paying close attention to SOPs when distractions occur.

BY ALAN DEAN AND SHAWN PRUCHNICKI

In August 1987, a McDonnell Douglas DC-9 flight crew taxiing to Runway 03C at Detroit Metropolitan Wayne County Airport (DTW) failed to conduct the taxi checklist. Consequently, the flaps were never set for takeoff, causing the lift-deficient aircraft to crash immediately after takeoff. As a result, 156 souls perished when the aerodynamically stalled aircraft crashed in a parking lot just off the end of the runway.

Nearly 21 years later, in January 2008, a Bombardier CRJ200 crew committed the identical checklist omission at another major U.S. Midwest airport. However, instead of the omission culminating in a fatal accident, a "config flaps" aural warning sounded and the takeoff was safely aborted.

In the case of the DTW DC-9, the aural warning never sounded. And, although the reason for the failure of the warning system was never determined, it is important to understand that the system's failure is the only variable that separates the DC-9 crash from the CRJ aborted takeoff. Aside from this single difference, these two events are human factors equivalents of identical twins.

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This Spanair MD-82 crashed on takeoff from Madrid with retracted flaps.

Alarmingly, these types of events may be more common than realized. Preliminary investigation of the August 2008 Spanair McDonnell Douglas MD-82 takeoff accident in Madrid, Spain, found that the aircraft's flaps were in the retracted position. A recent study of the U.S. National Aeronautics and Space Administration's Aviation Safety Reporting System data base revealed numerous reports of airline crews failing to properly configure flaps for takeoff. Seeking to understand the human factors commonalities of these types of incidents, we assembled summaries of the DC-9 and CRJ events.

Boarding of the DC-9 had been delayed by weather for nearly one hour. After passengers were boarded, the before starting engines checklist was accomplished and the aircraft departed from the gate. Ground control responded to the first officer's (FO's) taxi request with routing to a different runway than originally anticipated. The controller also advised the crew that the automatic terminal information service (ATIS) recording had been updated to include a warning that low-level wind shear advisories were in effect due to convective activity in the area.

As the captain (CA) initiated taxi, the FO obtained the new ATIS information and recalculated takeoff performance numbers. While the FO was "head down," visually focused inside the cockpit, the CA passed by an assigned taxiway. Ground control redirected them, and the taxi resumed with some miscellaneous conversation regarding the earlier weather delay. This delay was significant because the crew's next flight was to an airport with an arrival curfew.

Seven minutes after leaving the gate, the DC-9 crew was cleared to taxi into position and hold on the runway. Although the CA failed to call for the before takeoff checklist, the FO verbalized all associated items prior to receiving a takeoff clearance. As the CA commenced the takeoff roll, the FO was initially unable to engage the autothrottle system. This issue was resolved as the aircraft rapidly approached 100 kt. Next, the cockpit voice recorder (CVR) captured the FO verbalizing "V1," then "rotate," closely followed by the sounds of the stick shaker and subsequent ground impact.

The CRJ crew had completed the before taxi checklist after passenger boarding and requested permission to taxi. As the CA called "flaps 20, taxi checklist," he initiated a right turn as instructed by the controller but quickly realized that this would send them in the wrong direction. Stopping the aircraft, he interrupted the FO's checklist routine in order to seek clarification. Once that issue was resolved, they maneuvered along a congested ramp toward their assigned runway. As soon as they reached the runway, the tower controller cleared the crew for immediate takeoff. The line-up checklist was called for and the FO read it, concluding with, "Takeoff config okay … line-up check complete." Aircraft control was then transferred to the FO, who began advancing the thrust levers. The "config flaps" aural warning immediately sounded, and at approximately 30 kt the CA aborted the takeoff.

FSF AeroSafety World - February 2009

"Accident categories in 2008 were mostly familiar, including <u>the unwelcome return of the no-flaps takeoff.</u>"

COVERSTORY

Steady State

BY JAMES M. BURIN

Accident categories in 2008 were mostly familiar, including the unwelcome return of the no-flaps takeoff.

A Boeing 737 was destroyed in a runway excursion on takeoff at Denver International Airport.

"Average to below average" is the best way to describe the year 2008 in terms of safety performance for all segments of professional aviation, including commercial and corporate jets and commercial turboprops. The big killers remain, particularly loss of control in commercial jets and controlled flight into terrain (CFIT) in commercial turboprops. Even though there are occasionally new types of accidents — for example, the British Airways Boeing 777 landing accident at London Heathrow — the majority of accidents in 2008 are types we have seen before, including CFIT, runway excursion and no-flap/no-slat takeoff. This raises the question, why are we failing to fully benefit from aviation safety lessons learned? The total fatality count in all commercial jet, commercial turboprop and corporate jet major accidents was 688, down from 763 in 2007 and well under the 903 deaths reported in 2006.

Last year, the commercial jet fleet grew approximately 3 percent over 2007 numbers, while the commercial turboprop fleet stayed virtually unchanged. The corporate jet numbers showed the largest change, with a 9 percent increase. Some 8 percent of the world's commercial jet fleet is Eastern-built, while approximately one-third of the turboprop fleet is Eastern-built.

The active fleets, the aircraft actually in service, are somewhat smaller. Approximately 7 percent of the jet fleet is inactive, while 14 percent of the turboprop fleet is inactive.

A deadly omission (among other things)

- 20 August 2008: MD-82 on takeoff from Madrid
  - Flaps not in takeoff position

- NASA ASRS: since 2000, pilots have reported their failure to properly set the flaps for takeoff 55 times

Hanging by a thread…

- ASRS #658970, night of May 2005
- DCA, VMC
- Crew of B737-800 reporting:
- “As we started the taxi, I called for the taxi checklist, but became confused about the route and queried the first officer to help me clear up the discrepancy. We discussed the route and continued the taxi ... . We were cleared for takeoff from runway 1, but the flight attendant call chime wasn't working. I had called for the Before Takeoff checklist, but this was interrupted by the communications glitch. … On takeoff, rotation and liftoff were sluggish. At 100-150 ft as I continued to rotate, we got the stick shaker. The first officer noticed the **no-flap condition** and placed the flaps to 5. (No takeoff warning horn — discovered popped circuit breaker back at the gate).”

Feeling lucky today?

- ASRS #719068, evening of Dec 2006
- BOG, VMC
- Crew of B757 reporting:

- “During climb-out, the first officer informed me that we **had just done a flaps 1 takeoff**. I was very surprised and could not understand how we both missed that. We had done the Before Takeoff checklist and I remember looking at the gauge and even touching the flap handle and saying flaps 5. We had a long taxi and had to wait for a few minutes on the taxiway so there was no rush at all ... .”

Inadvertent (deadly) Procedural Omissions

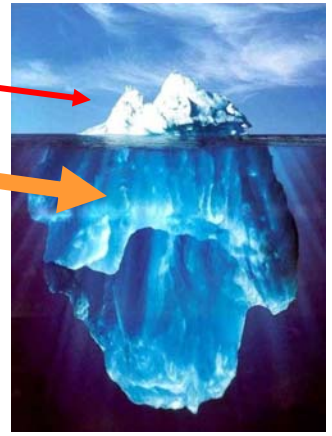
Dismukes, 2006:

- 27 accidents in U.S. (1987-2001) in which crew error cited causal or contributing factor
- In 5, the crew **forgot** to perform a flight-critical task and did not catch error with the associated checklist

- **Detroit (1987): DC-9 crashed shortly after take-off**
  - NTSB: Flaps/slats not set to take-off position
- **Dallas (1988): B-727 crashed shortly after take-off**
  - NTSB: Flaps/slats not set to take-off position
- **LaGuardia (1994): MD-82 ran off runway end after high-speed rejected take-off**
  - NTSB: pitot heat not turned on - anomalous airspeed indications
- **Houston (1996): DC-9 landed gear-up**
  - NTSB: Hydraulic pump not set to high position
- **Little Rock (1999): MD-80 crashed into approach lights at departure end of runway**
  - NTSB: ground spoilers not armed before landing (combination with other errors)

Were these accidents unique?

- **No**, they are just the tip of the iceberg



ASRS reports tell us about:

- Rejected take-off – forgot flaps
- Runway incursion – forgot to monitor
- Broken tow-bar – forgot to clear pushback crew
- Taxiing into a ditch – forgot to brief
- Engine flame-out – forgot to stop fuel transfer
- Overtemping engine – forgot fuel shut-off
- Departing with inadequate fuel – forgot to check on preflight
- Leaving APU running during takeoff – forgot checklist item
- Packs failed in cruise – forgot
- Took off without PDC – forgot to request
- Nose gear failed to retract – forgot to turn hydraulics pumps on
- Deviated from speed or altitude restriction – forgot to enter on MCP
- Flying wrong departure route – forgot to follow new instructions

= Compromises to safety

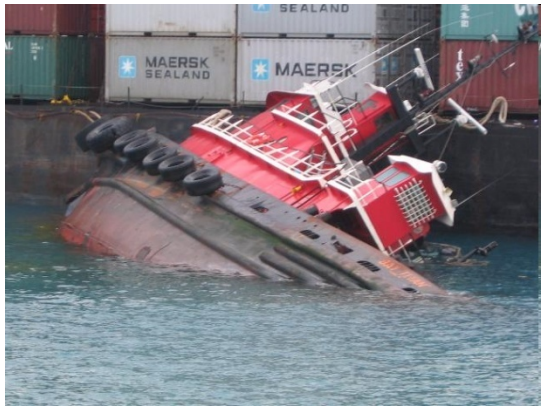
= Unnecessary costs and delays

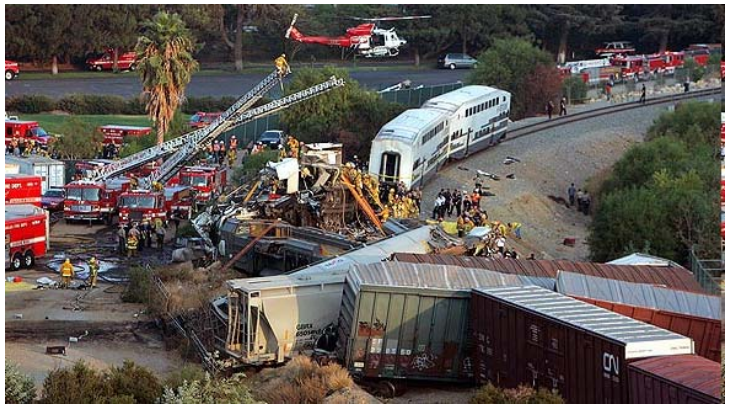
Were these omissions due to …

*Lack of experience?

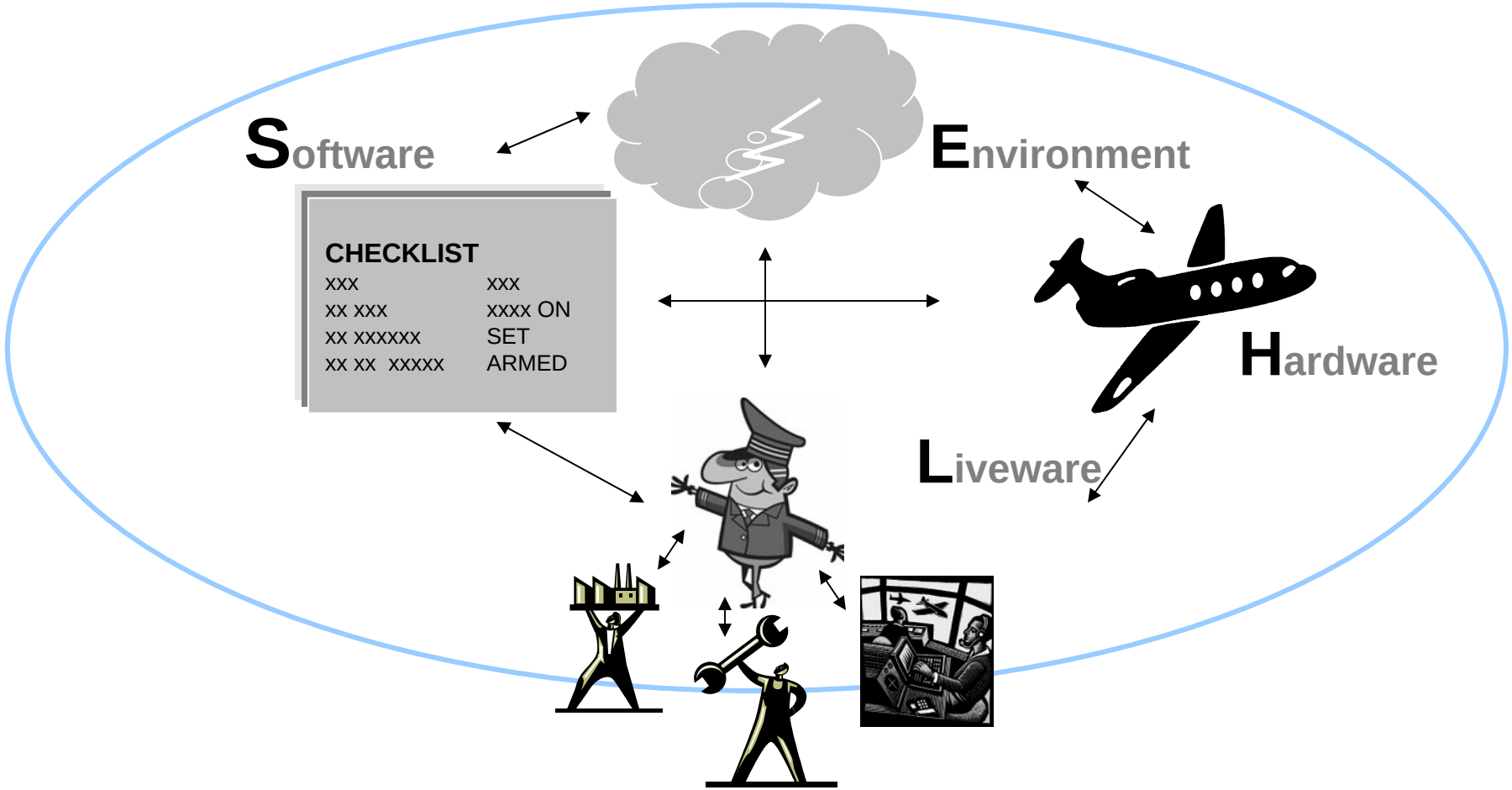
*Low importance of forgotten task?

*High workload?





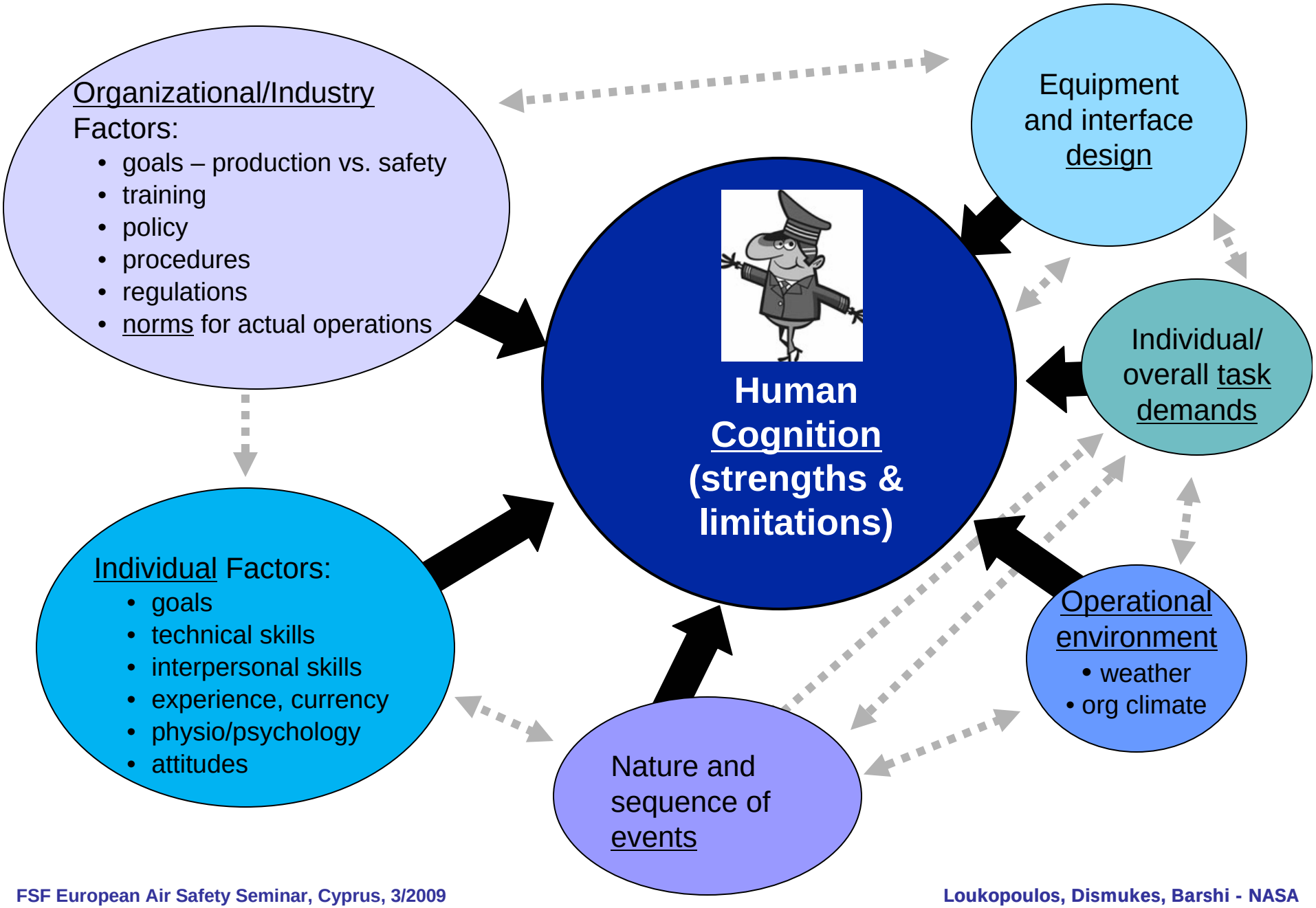
Whole System Approach



SHEL model

Adapted from Edwards, 1988

Individual / Team Performance



Our Research

Characterization of the context of flight operations

= observation of operations from the cockpit jumpseat during routine flights

Loukopoulos, Dismukes, Barshi, 2001; 2003

Dismukes & Berman, 2007

Taxi

CAPTAIN

MONITOR Ground

"Flaps 5, taxi clearance"

MONITOR Ground, Company

FIRST OFFICER

Set flaps, verify in position

Obtain clearance

TAXI CLEARANCE

Start taxiing

BEFORE TAKEOFF PROCEDURE (down to the line) Item to check (action required)
Recall (check)
xxx xxxx (xxxxx)
Flaps (_, green light)
xxxxxxx (xx)
Cabin door (lock)
xxx xxxxx (xx xxxxxx)
Takeoff briefing (review)

BEFORE TAKEOFF PROCEDURE (down to the line) Item to check (action required)
xxx xxxx (xxxxx)
Flight controls (check)
Flaps (_, green light)
xxxxxxx (xx)

MONITOR CA taxiing

Ask for checklist

BEFORE TAKEOFF CHECKLIST (down to the line)	
Challenge	**Response**
xx xxxxx xx	xx xxxxx
Flight controls	Checked
xx	xxxxxx xx xx
Flaps	Set _, green light
Takeoff Briefing	Completed
xxx	xx

Begin checklist

Checklist complete

BEFORE TAKEOFF PROCEDURE (below the line) Item to check (action required)
ENGINE START switches (CONT)
LANDING lights and STROBE light switches (as desired)
xxx xxxxx (xx xxxxxx)

BEFORE TAKEOFF PROCEDURE (below the line) Item to check (action required)
xxx xxxxx (xx xxxxxx)
FMC position update (as desired)
Transponder (On)

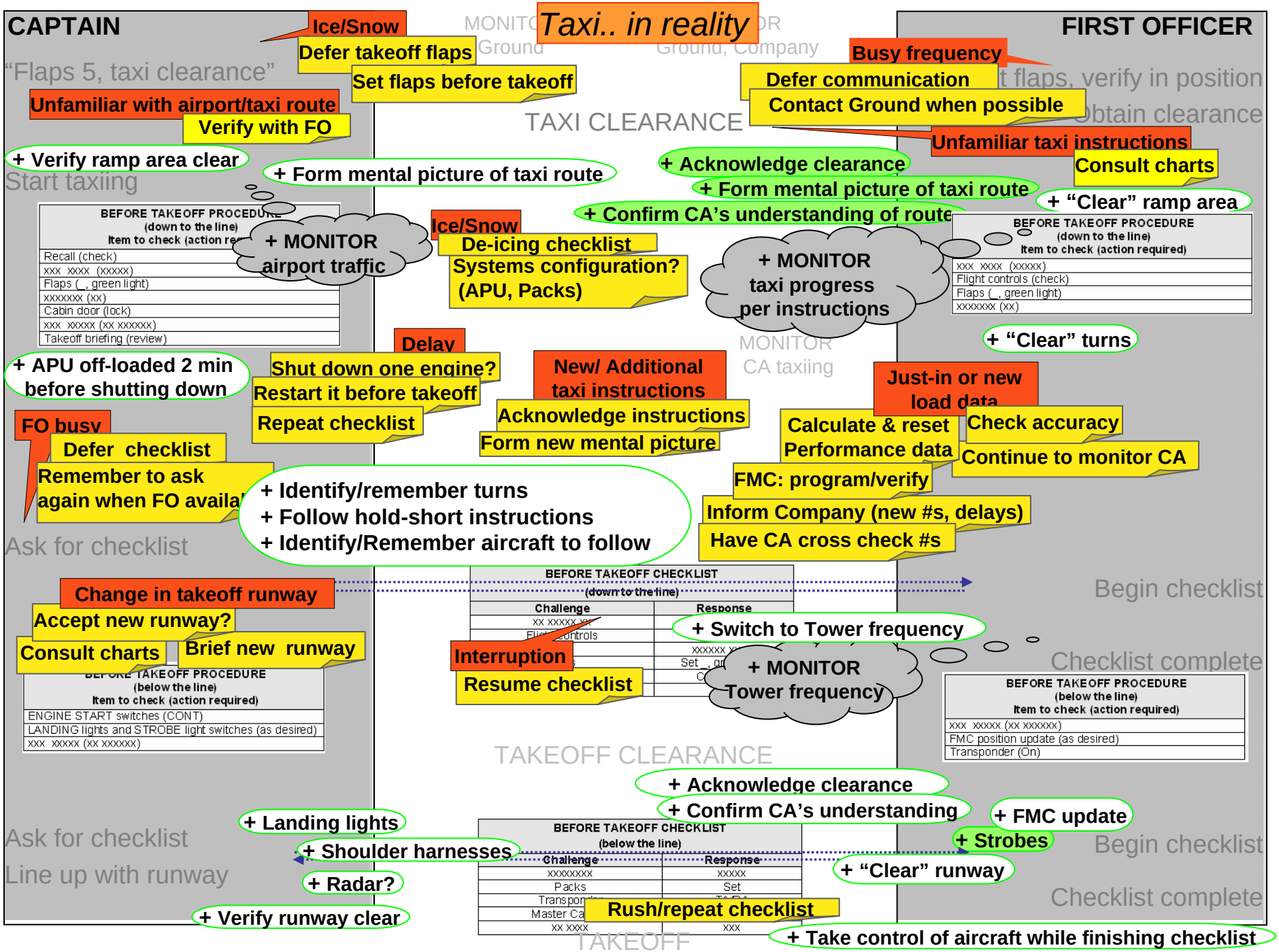
Ask for checklist

Line up with runway

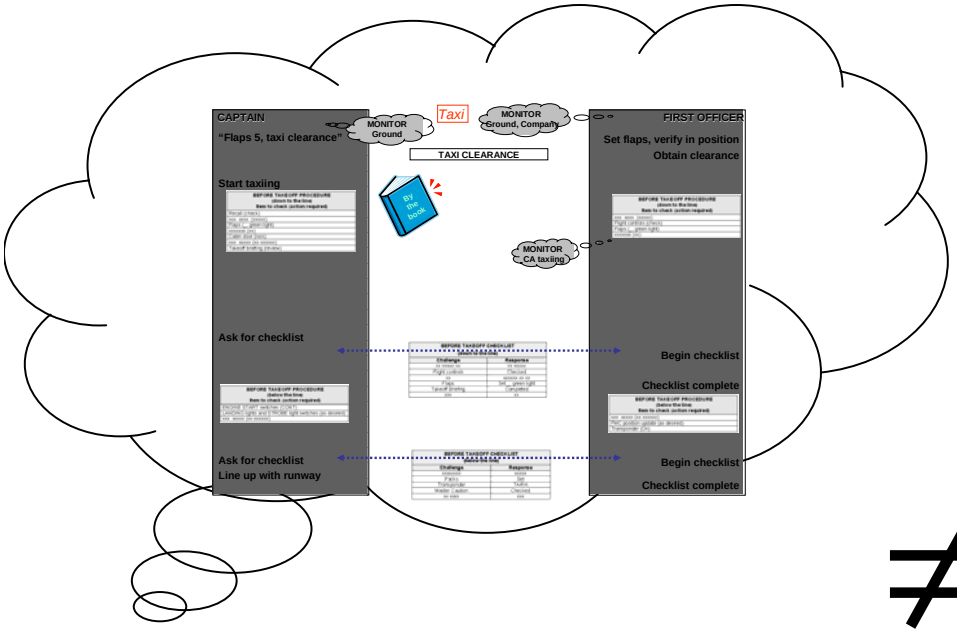
BEFORE TAKEOFF CHECKLIST (below the line)	
Challenge	**Response**
xxxxxxxx	xxxxx
Packs	Set
Transponder	TA/RA
Master Caution	Checked
xx xxxx	xxx

Begin checklist

Checklist complete


CAPTAIN
FIRST OFFICER
Taxi.. in reality
Ice/Snow
Defer takeoff flaps
Set flaps before takeoff
"Flaps 5, taxi clearance"
Unfamiliar with airport/taxi route
Verify with FO
+ Verify ramp area clear
Start taxiing
TAXI CLEARANCE
Busy frequency
Defer communication
Contact Ground when possible
Unfamiliar taxi instructions
Consult charts
+ Acknowledge clearance
+ Form mental picture of taxi route
+ Confirm CA's understanding of route
+ "Clear" ramp area
+ Form mental picture of taxi route
BEFORE TAKEOFF PROCEDURE
(down to the line)
Item to check (action required)
Recall (check)
xxx xxxx (xxxxx)
Flaps (_, green light)
xxxxxxx (xx)
Cabin door (lock)
xxx xxxxx (xx xxxxxx)
Takeoff briefing (review)
+ MONITOR airport traffic
Ice/Snow
De-icing checklist
Systems configuration? (APU, Packs)
+ MONITOR taxi progress per instructions
BEFORE TAKEOFF PROCEDURE
(down to the line)
Item to check (action required)
xxx xxxx (xxxxx)
Flight controls (check)
Flaps (_, green light)
xxxxxxx (xx)
MONITOR CA taxiing
+ "Clear" turns
Delay
Shut down one engine?
Restart it before takeoff
Repeat checklist
+ APU off-loaded 2 min before shutting down
New/ Additional taxi instructions
Acknowledge instructions
Form new mental picture
Just-in or new load data
Calculate & reset Performance data
Check accuracy
Continue to monitor CA
FO busy
Defer checklist
Remember to ask again when FO availa
+ Identify/remember turns
+ Follow hold-short instructions
+ Identify/Remember aircraft to follow
FMC: program/verify
Inform Company (new #s, delays)
Have CA cross check #s
Ask for checklist
Change in takeoff runway
Accept new runway?
Consult charts
Brief new runway
BEFORE TAKEOFF CHECKLIST
(down to the line)
Challenge
Response
Begin checklist
+ Switch to Tower frequency
Interruption
Resume checklist
+ MONITOR Tower frequency
Checklist complete
BEFORE TAKEOFF PROCEDURE
(below the line)
Item to check (action required)
ENGINE START switches (CONT)
LANDING lights and STROBE light switches (as desired)
xxx xxxxx (xx xxxxxx)
BEFORE TAKEOFF PROCEDURE
(below the line)
Item to check (action required)
xxx xxxxx (xx xxxxxx)
FMC position update (as desired)
Transponder (On)
TAKEOFF CLEARANCE
+ Acknowledge clearance
+ Confirm CA's understanding
+ FMC update
+ Strobes
+ "Clear" runway
+ Landing lights
+ Shoulder harnesses
+ Radar?
+ Verify runway clear
BEFORE TAKEOFF CHECKLIST
(below the line)
Challenge
Response
Packs
Set
Rush/repeat checklist
Ask for checklist
Line up with runway
Begin checklist
Checklist complete
TAKEOFF
+ Take control of aircraft while finishing checklist

Ideal vs. Real



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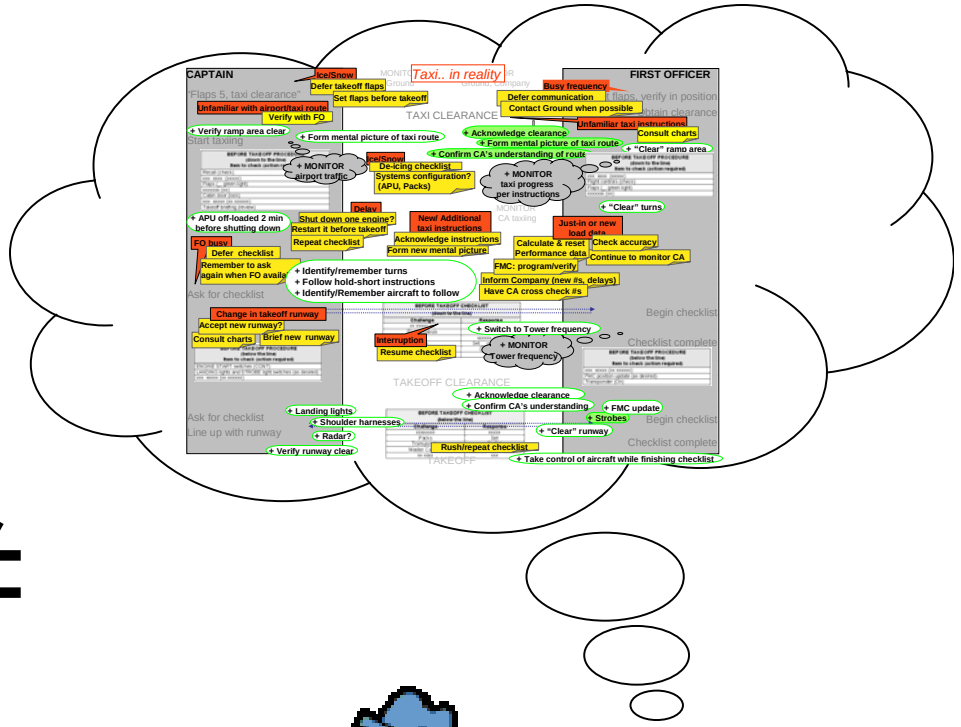
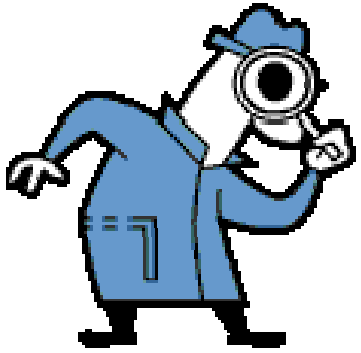
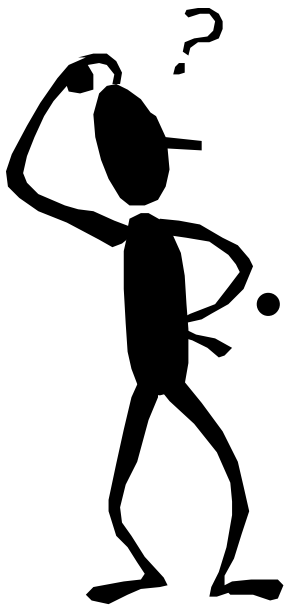






OK, so What?

- Pilots become accustomed to concurrent task demands, interruptions, distractions and disruptions.

and the truth is …

- Pilots routinely manage multiple, competing, concurrent task demands <u>just fine</u>…

Taxi Errors

CAPTAIN | **FIRST OFFICER**

Omitted call for flaps - rushed to clear ramp/gate area for arriving aircraft - aborted takeoff

Request taxi clearance — Obtain clearance

Started taxi without clearance - trouble-shooting problem with engine start - nearly hit ground handler

Started taxi without clearance – rushed by other aircraft waiting to pull into gate; radio congestion; marshaller's headset inoperative – query by Ground controller

CA taxis without having fully understood instructions - busy looking at other aircraft on taxiway and ramp – warning issued by Ground controller

Started taxi without clearance - crew discussing taxi instructions - struck pushback tug

Incorrect trim setting - checklist interrupted after item had been read but not verified – aborted takeoff

Omitted flaps - crew discussing problem with APU, delayed flaps due to snow - aborted takeoff

Failed to start engine #-2 - distracted while discussing special operations for destination; omitted checklists - delay takeoff

Neglected to set flaps - preoccupied with new departure clearance and packs-off operation - aborted takeoff

FO failed to monitor CA - busy checking and correcting calculations of load data - aircraft taxied past hold short line

FO failed to monitor CA – busy with flow; night taxi – taxied in wrong direction

Flaps incorrectly set, missed noticing during checklist - crew busy with fuel problem, runway changes, programming FMC - aborted takeoff

Ask for checklist — Omitted checking into bleed air indicator light-busy with delayed engine start and checklists – crew rushed to perform delayed engine start – flew with potential equipment problem — in checklist

Confuse own position on taxiway diagram - new terminal; studying NOTAMs; runway change – taxied into ditch

FO failed to monitor CA - busy reprogramming FMC for runway change - taxied past intended taxiway

Fail to confirm flap position - evaluating heavy rain showers; rushed to accept takeoff clearance - aborted takeoff

FO failed to monitor CA - busy with pre-takeoff preparations - aircraft crossed hold short line

Omitted checklist - busy with delayed engine start and checklists; rushed to accept takeoff clearance - flaps not set, aborted takeoff

Omitted flaps - checklist interrupted by thrust reverser light; crew busy troubleshooting - aborted takeoff

Misunderstood Tower instruction - new FO on IOE, CA coaching FO - taxied onto runway without clearance

Flaps incorrectly set - late paperwork and runway change; programming FMC;short taxi; rushed to accept takeoff clearance - aborted takeoff

Ask for checklist — in checklist

Line up wit — Omit checklist - running late, checklist interrupted by Tower, unexpected clearance for takeoff - aborted takeoff

xxxxxxxx
Packs
Transponder
Master Caution
xx xxxx

Omitted flaps-checklist interrupted by Tower; crew rushed to accept takeoff clearance-aborted takeoff

Checklist complete

Checklist errors

Dismukes & Berman, 2007

- Checklist errors per flight: 3.2 ± 2.9 (range: 0-14)
- Of 194 observed errors, 50 errors involved checklists
  - Checklist item deferred and later forgotten
    e.g., early call for Approach checklist - last two items deferred
  - Checklist interrupted by external agent/event
    e.g., departure briefing interrupted – last item never completed

FLIGHT COGNITION LABORATORY

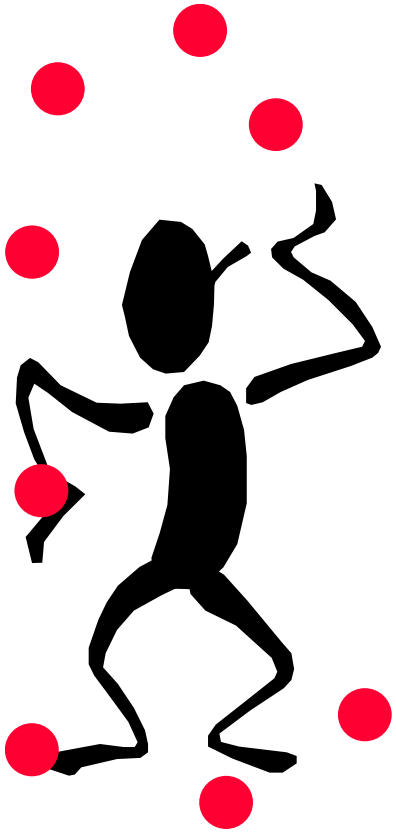
Vulnerable to Omissions when…

(4 Prototypical Situations)

- **Interrupted**
  - e.g., interrupted while conducting a checklist – forget to return to line item at which interrupted
- **Must perform tasks outside normal** (habitual) **sequence**
  - e.g., defer setting flaps until reaching runway for takeoff because of slush on taxiway – forget to extend flaps before takeoff
- **Must perform new, unanticipated tasks** (in lieu of habitual actions)
  - e.g., fly different heading than normal upon departure – forget to comply with new instruction and fly usual heading instead
- **Must interleave multiple tasks**
  - e.g., re-program FMC during taxi – forget to monitor aircraft

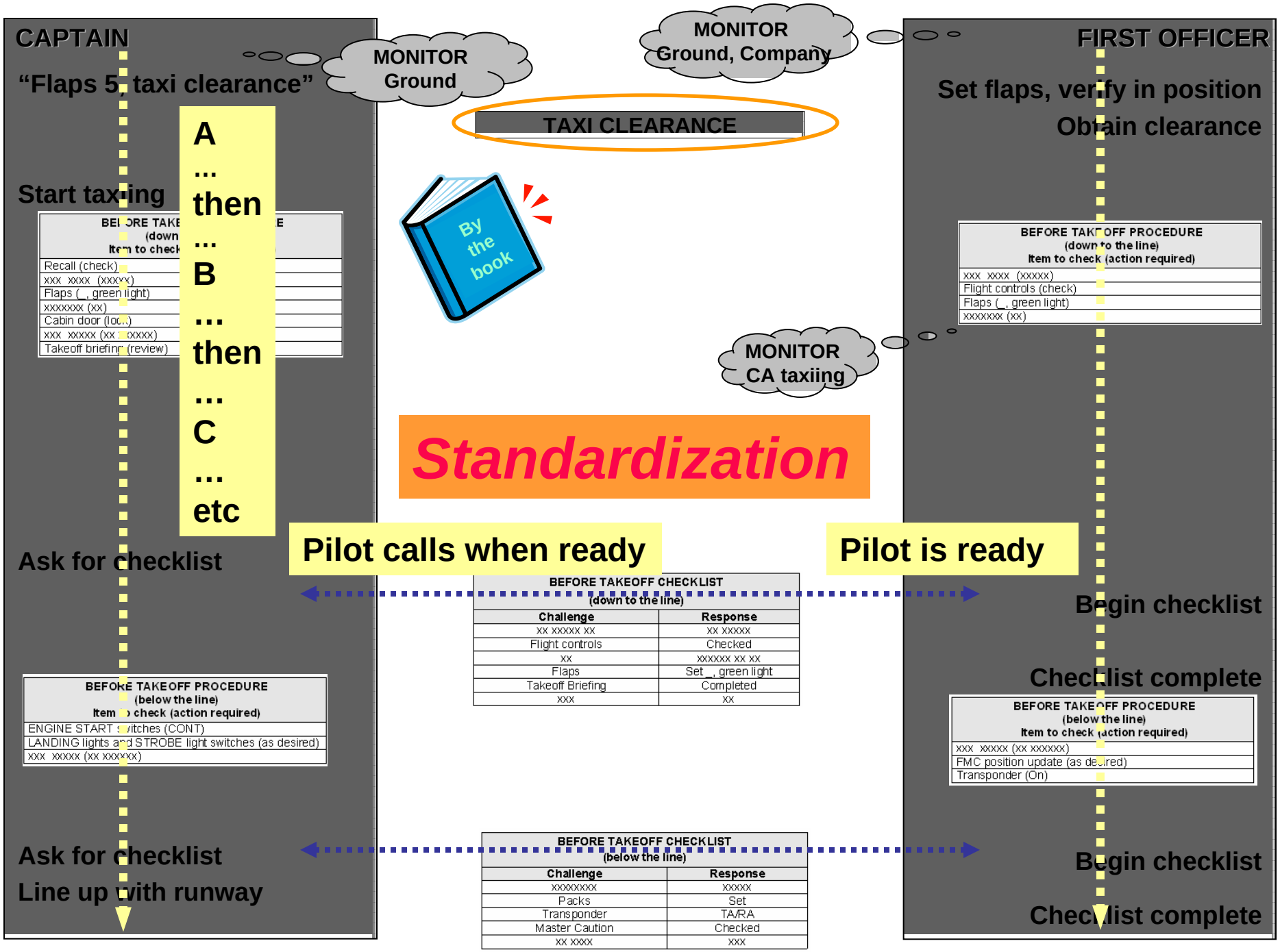
OK, but WHY?

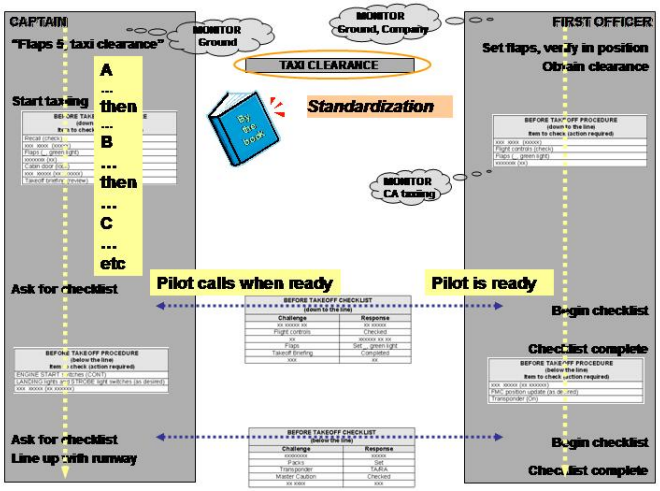
- Individuals forget to act because the cognitive demands of these situations interact with the way the human brain processes information



- Situations appear diverse but share underlying feature:

Multitasking: juggling multiple tasks concurrently


CAPTAIN
"Flaps 5, taxi clearance"
MONITOR
Ground
MONITOR
Ground, Company
FIRST OFFICER
Set flaps, verify in position
Obtain clearance
TAXI CLEARANCE
A
...
then
...
B
...
then
...
C
...
etc
Start taxiing
By the book
BEFORE TAKEOFF PROCEDURE
(down to the line)
Item to check (action required)
Recall (check)
xxx xxxx (xxxxx)
Flaps (_, green light)
xxxxxxx (xx)
Cabin door (lock)
xxx xxxxx (xx xxxx)
Takeoff briefing (review)
BEFORE TAKEOFF PROCEDURE
(down to the line)
Item to check (action required)
xxx xxxx (xxxxx)
Flight controls (check)
Flaps (_, green light)
xxxxxxx (xx)
MONITOR
CA taxiing
Standardization
Pilot calls when ready
Pilot is ready
Ask for checklist
BEFORE TAKEOFF CHECKLIST
(down to the line)
Challenge | Response
xx xxxxx xx | xx xxxxx
Flight controls | Checked
xx | xxxxxx xx xx
Flaps | Set _, green light
Takeoff Briefing | Completed
xxx | xx
Begin checklist
Checklist complete
BEFORE TAKEOFF PROCEDURE
(below the line)
Item to check (action required)
ENGINE START switches (CONT)
LANDING lights and STROBE light switches (as desired)
xxx xxxxx (xx xxxxxx)
BEFORE TAKEOFF PROCEDURE
(below the line)
Item to check (action required)
xxx xxxxx (xx xxxxxx)
FMC position update (as desired)
Transponder (On)
Ask for checklist
Line up with runway
BEFORE TAKEOFF CHECKLIST
(below the line)
Challenge | Response
xxxxxxxx | xxxxx
Packs | Set
Transponder | TA/RA
Master Caution | Checked
xx xxxx | xxx
Begin checklist
Checklist complete



In theory…

Activities are:

- **<u>Linear</u>: task B always follows task A, in this sequence**
- **<u>Controllable</u>: tasks initiated by pilot, independently**
- **<u>Predictable</u>: information available when needed, communications possible when necessary**

CAPTAIN

“…axi clearance”

TAXI CLEARANCE

TRIGGER for flaps

FIRST OFFICER

Set flaps, verify in position

Obtain clearance

Start taxiing

BEFORE TAKEOFF PROCEDURE (down to the line) Item to check (action required)
Recall (check)
xxx xxxx (xxxxx)
Flaps (_, green light)
xxxxxxx (xx)
Cabin door (lock)
xxx xxxxx (xx xxxxxx)
Takeoff briefing (review)

Automaticity

BEFORE TAKEOFF PROCEDURE (down to the line) Item to check (action required)
xxx xxxx (xxxxx)
Flight controls (check)
Flaps (_, green light)
xxxxxxx (xx)

MONITOR
CA taxiing

EXPECTATION
(If already taxiing, flaps have been set)

“Before Takeoff …”

TRIGGER for checklist

TRIGGER for flaps

BEFORE TAKEOFF CHECKLIST (down to the line)	
Challenge	Response
xx xxxxx xx	xx xxxxx
Flight controls	Checked
xx	xxxxxx xx xx
Takeoff Briefing	Completed
x	

Begin checklist

“Checklist complete”

BEFORE TAKEOFF PROCEDURE (below the line) Item to check (action required)
ENGINE START switches (CONT)
LANDING lights and STROBE light switches (as desired)
xxx xxxxx (xx xxxxxx)

EXPECTATION
(If CA asking for Before Takeoff checklist, the Taxi checklist has been completed)

“Checklist – below the line”

BEFORE TAKEOFF CHECKLIST (below the line)	
Challenge	Response

Begin checklist

Line up with runway

EXPECTATION
(If approaching runway, checklists has been completed)

“Checklist complete”

On the line

CAPTAIN

"Flaps 5, taxi clearance"

TAXI CLEARANCE

Start taxiing

BEFORE TAKEOFF PROCEDURE (down to the line) Item to check (action required)
Recall (check)
xxx xxxx (xxxxx)
Flaps (_, green light)
xxxxxxx (xx)
Cabin door (lock)
xxx xxxxx (xx xxxxxx)
Takeoff briefing (review)

MONITOR
CA taxiing

Environmental Cues

"Before Takeoff checklist"

BEFORE TAKEOFF CHECKLIST (down to the line)	
Challenge	**Response**
xx xxxxx xx	xx xxxxx
Flight controls	Checked
xx	xxxxxx xx xx
Flaps	Set _, green light
Takeoff Briefing	Completed
xxx	xx

BEFORE TAKEOFF PROCEDURE (below the line) Item to check (action required)
ENGINE START switches (CONT)
LANDING lights and STROBE light switches (as desired)
xxx xxxxx (xx xxxxxx)

"Checklist – below the line"

BEFORE TAKEOFF CHECKLIST (below the line)	
Challenge	**Response**
xxxxxxxx	xxxxx
Packs	Set
Transponder	TA/RA
Master Caution	Checked
xx xxxx	xxx

Line up with runway

FIRST OFFICER

Set flaps, verify in position

Obtain clearance

BEFORE TAKEOFF PROCEDURE (down to the line) Item to check (action required)
xxx xxxx (xxxxx)
Flight controls (check)
Flaps (_, green light)
xxxxxxx (xx)

Begin checklist

"Checklist complete"

BEFORE TAKEOFF PROCEDURE (below the line) Item to check (action required)
xxx xxxxx (xx xxxxxx)
FMC position update (as desired)
Transponder (On)

Begin checklist

"Checklist complete"

CAPTAIN

+ Ask FO for takeoff flaps

"Flaps 5, taxi clearance"

Unfamiliar with airport/taxi route

Verify with FO

+ Verify ramp area clear

Start taxiing

BEFORE TAKEOFF PROCEDURE (down to the line) Item to check (action required)
Recall (check)
xxx xxxx (xxxxx)
Flaps (_, green light)
xxxxxxx (xx)
Cabin door (lock)
xxx xxxxx (xx xxxxxx)
Takeoff briefing (review)

+ APU off-loaded? min before shutting do

FO busy

Defer checklist

Remember to ask again when FO available

Ask for checklist

Change in takeoff runway

Accept new runway?

Consult charts

Brief new runway

BEFORE TAKEOFF PROCEDURE (below the line) Item to check (action required)
ENGINE START switches (CONT)
LANDING lights and STROBE light switches (as desired)
xxx xxxxx (xx xxxxxx)

Ask for checklist

Line up with runway

+ Verify runway clear

Ice/Snow

Defer takeoff flaps

Set flaps

+ Form mental picture of taxi route

+ MONITOR airport traffic

Ice/Snow

De-icing checklist

Systems configuration? (APU, Packs)

Delay

Shut down one engine?

Before takeoff checklist

+ Identify/remember turns

+ Follow hold-short instructions

+ Identify/Remember aircraft to follow

Should

Radar

BEFORE TAKEOFF CHECKLIST (down to the line)	
Challenge	Response
xx xxxxx xx	xxxxx
Flight controls	checked
xx	xx xx xx
Flaps	green light
Briefing	completed

xxxxx	xxxxx
Packs	Set
Transponder	TA/RA
Master Caution	checked
xx xxxx	xxx

TAKEOFF

MONITOR Ground

MONITOR Ground, Company

Busy frequency

Defer communication

Contact Ground when possible

EARANCE

+ Acknowle

+ Form mental picture of taxi route

+ Confirm CA's understanding of route

+ MONITOR taxi progress per instructions

MONITOR CA taxiing

New/ Additional

Just-in or new

ta

heck accuracy

Continue to monitor CA

FMC: program/verify

Inform Compa (no #s, delays)

Have CA

Switch to Tower frequency

MONITOR

ency

nce

Rush/repeat checklist

FIRST OFFICER

+ Set takeoff flaps

Set flaps, verify in position

Obtain clearance

Unfamiliar taxi instructions

Consult charts

+ "Clear" ramp area

BEFORE TAKEOFF PROCEDURE (down to the line) Item to check (action required)
xxx xxxx (xxxxx)
Flight controls (check)
Flaps (_, green light)
xxxxxxx (xx)

+ "Clear" turns

ecklist

nplete

Item to check (action required)
xxx xxxxx (xx xxxxxx)
FMC position update (as desired)
Transponder (On)

+ FMC update

+ Strobes

Begin checklist

+ "Clear" runway

Checklist complete

+ Take control of aircraft while finishing checklist

BREAK in Predictability

TRIGGER for flaps

BREAK in Linearity

EXPECTATION

(If already taxiing, flaps have been set)

BREAK in Controllability

Need for

CONCURRENT TASK MANAGEMENT

(≠ than high workload)

The Multitasking Myth

- We typically overestimate our ability to **multitask**
- In reality, our ability to multitask is a function of:
  - the degree to which tasks are practiced together
  - the degree to which each individual task requires conscious effort and attention
  - the cues available to prompt recall of intended actions
- Multitasking situations substantially increase our vulnerability to errors
  - Common error: forgetting/failing to perform procedural step

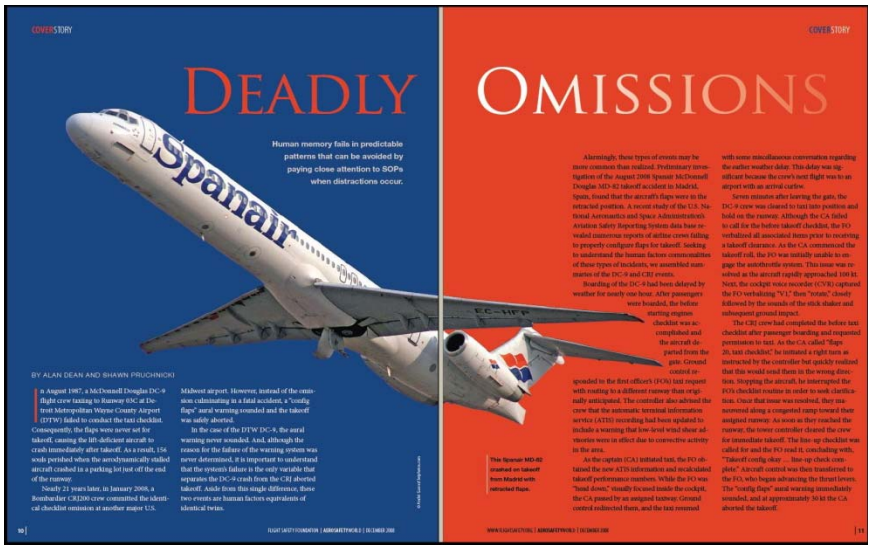
So, how do we manage these "deadly omissions?"

Our research:

-characterization of context within which human performance takes place

-ideal vs. real

-nature of human cognition (strengths, limitations, vulnerabilities)


COVERSTORY

DEADLY OMISSIONS

Human memory fails in predictable patterns that can be avoided by paying close attention to SOPs when distractions occur.

BY ALAN DEAN AND SHAWN PRUCHNICKI

In August 1987, a McDonnell Douglas DC-9 flight crew taxiing to Runway 03C at Detroit Metropolitan Wayne County Airport (DTW) failed to conduct the taxi checklist. Consequently, the flaps were never set for takeoff, causing the lift-deficient aircraft to crash immediately after takeoff. As a result, 156 souls perished when the aerodynamically stalled aircraft crashed in a parking lot just off the end of the runway.

Nearly 21 years later, in January 2008, a Bombardier CRJ200 crew committed the identical checklist omission at another major U.S. Midwest airport. However, instead of the omission culminating in a fatal accident, a "config flaps" aural warning sounded and the takeoff was safely aborted.

In the case of the DTW DC-9, the aural warning never sounded. And, although the reason for the failure of the warning system was never determined, it is important to understand that the system's failure is the only variable that separates the DC-9 crash from the CRJ aborted takeoff. Aside from this single difference, these two events are human factors equivalents of identical twins.

Alarmingly, these types of events may be more common than realized. Preliminary investigation of the August 2008 Spanair McDonnell Douglas MD-82 takeoff accident in Madrid, Spain, found that the aircraft's flaps were in the retracted position. A recent study of the U.S. National Aeronautics and Space Administration's Aviation Safety Reporting System data base revealed numerous reports of airline crews failing to properly configure flaps for takeoff. Seeking to understand the human factors circumvention of these types of incidents, we assembled summaries of the DC-9 and CRJ events.

Boarding of the DC-9 had been delayed by weather for nearly one hour. After passengers were boarded, the before starting engines checklist was accomplished and the aircraft departed from the gate. Ground control suspended to the first officer's (FO's) taxi request with routing to a different runway than originally anticipated. The controller also advised the crew that the automatic terminal information service (ATIS) recording had been updated to include a warning that low-level wind shear advisories were in effect due to convective activity in the area.

As the captain (CA) initiated taxi, the FO obtained the new ATIS information and recalculated takeoff performance numbers. While the FO was "head down," visually focused inside the cockpit, the CA passed by an assigned taxiway. Ground control redirected them, and the taxi resumed with some miscellaneous conversation regarding the earlier weather delay. This delay was significant because the crew's next flight was to an airport with an arrival curfew.

Seven minutes after leaving the gate, the DC-9 crew was cleared to taxi into position and hold on the runway. Although the CA failed to call for the before takeoff checklist, the FO verbalized all associated items prior to receiving a takeoff clearance. As the CA commenced the takeoff roll, the FO was initially unable to engage the autothrottle system. This issue was resolved as the aircraft rapidly approached 100 kt. Next, the cockpit voice recorder (CVR) captured the FO verbalizing "V1," then "rotate," closely followed by the sounds of the stick shaker and subsequent ground impact.

The CRJ crew had completed the before taxi checklist after passenger boarding and requested permission to taxi. As the CA called "flaps 20, taxi checklist," he initiated a right turn as instructed by the controller but quickly realized that this would send them in the wrong direction. Stopping the aircraft, he interrupted the FO's checklist routine in order to seek clarification. Once that issue was resolved, they maneuvered along a congested ramp toward their assigned runway. As soon as they reached the runway, the tower controller cleared the crew for immediate takeoff. The line-up checklist was called for and the FO read it, concluding with, "Takeoff config okay … line-up check complete." Aircraft control was then transferred to the FO, who began advancing the thrust levers. The "config flaps" aural warning immediately sounded, and at approximately 50 kt the CA aborted the takeoff.

This Spanair MD-82 crashed on takeoff from Madrid with retracted flaps.

=> control measures at the

- level of the individual
- level of the organization

Individual

- Dispel the Myth of Multitasking

- Realize the limits of ability to concurrently handle tasks
- Accept / recognize risk of vulnerability to unintentional omissions
- Guard against omissions by being more deliberate about:
  - Performing checklists (slow down, use tactile means (point, touch)
  - Monitoring (essential rather than secondary task)
  - Anchoring checklist initiation and other “floating” tasks to salient events
  - Recognizing when interrupted
  - Creating salient reminder cues when activities are deferred

Organization - training

- Recognize *realistic* rather than *theoretical* performance of humans in generating errors as they work

- Explain why even expert pilots are vulnerable to error
- Evaluate and share personal techniques to reduce vulnerability to error
- Teach monitoring as essential rather than secondary task
- Explain advantages and disadvantages of automaticity, expectations, triggers, cues, etc.
- Expand workload management portion of CRM
  - Beyond handling high workload
  - Include issue of multitasking
  - Add ways to avoid getting in multitasking situations
  - Teach multitasking safeguards: creating reminders, anticipating missing cues, anchoring items, resisting rushing

Organization – procedure design

- Align procedures with realities of operating conditions and human information processing
- Periodically analyze SOPs for conflicts and hidden traps
  - Start with incident reports
  - Create team of experienced pilots
  - Consult with human factors experts
  - Review normal/non-norm procedures for design factors that :
    - Require critical activities in periods of anticipated interruptions
    - Allow critical items to “float” in time – not anchored properly
    - Prescribe silent annunciation of critical checklist items
    - Force the pilot monitoring to go head-down during critical periods

An Operational Example

- U.S. airline overhaul of normal procedures
- Resident Review Team + NASA experts:
  I. Barshi & R. Mauro
- Taxi Checklist produced conflict between:
  - Procedural demands: preparing aircraft for departure and
  - Operational demands: controlling movement of aircraft (following taxi route), maintaining awareness of airport layout, aircraft position, position of other aircraft, communication
- Rejected takeoffs and runway incursions

An Operational Example

- Revised Taxi procedures: eliminated opportunities for any of 4 prototypical multitasking situations:
  - Re-distributed tasks among flight crew
  - Trimmed checklists
  - Provided guidance against rushing and for stopping the aircraft if necessary
  - Re-considered obsolete operational factors
  - Anchored “floating” items
  - Facilitated crew coordination

Organization - policy

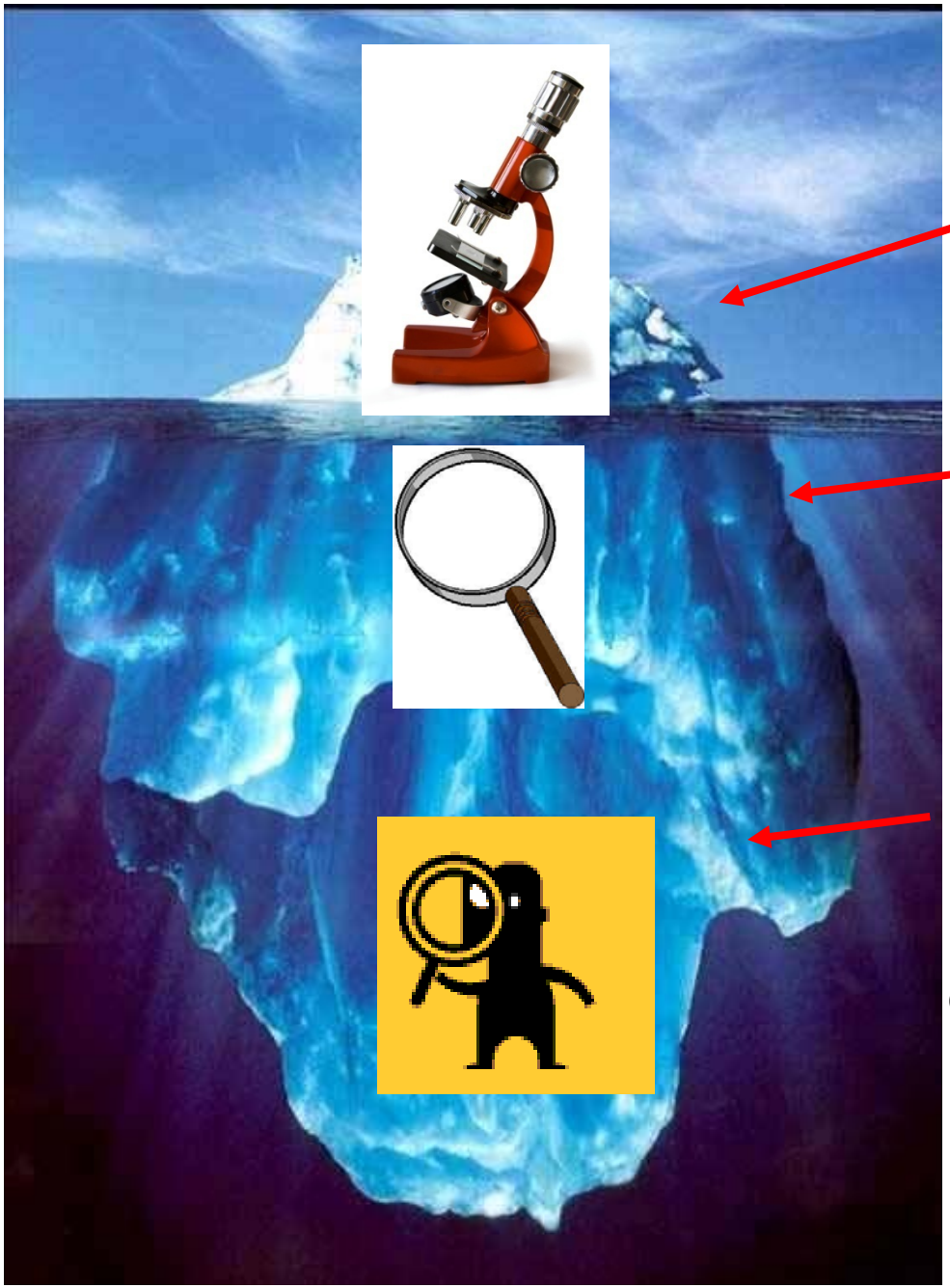
- Discard “blame and punish” mentality
- Periodically analyze SOPs to identify aspects that contribute to vulnerability
- Ensure company policies & practices do not implicitly reward rushing and risky decision-making
- You get what you give:
  - Training (sim) checks and Line checks must include evaluation of how crews manage concurrent task demands
  - Consider the (explicit or implicit) reward structure

Routine Monitoring of the System

Invaluable sources of information

- FOQA, ASAP data, etc.
- “Data without the need for triggers”

  ICAO SMManual, Doc 9589, Version 2, 2009
- LOSA and similar-type observations



Accidents

Incidents

Events that are not reported and/or not even recognized

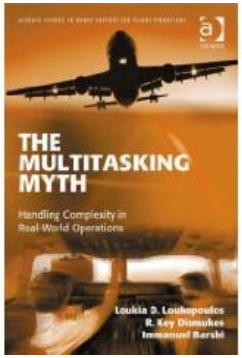
FLIGHT COGNITION LABORATORY

THANK YOU for your attention

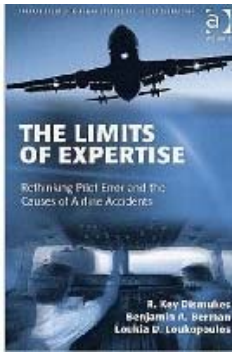
Additional Information

- Can download papers and presentations from:
  http://human-factors.arc.nasa.gov/ihs/flightcognition/
  http://www.errorManagement.eu

- Loukopoulos, Dismukes, & Barshi (2009). The Multitasking Myth: Handling Complexity in Real-World Operations (Ashgate)



- Dismukes, Berman, & Loukopoulos (2007). The Limits of Expertise: Rethinking Pilot Error and the Causes of Airline Accidents (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.