

Design for Operations

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A deadly omission (among other things)



- 20 August 2008: MD-82 on takeoff from Madrid
 - Flaps not set for takeoff

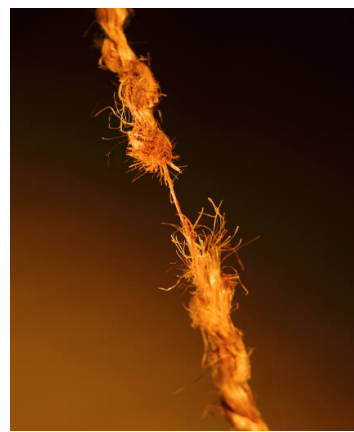
A deadly omission (among other things)



- 20 August 2008: MD-82 on takeoff from Madrid
 - Flaps not set for takeoff
- NASA ASRS: in recent years, pilots have reported their failure to properly set the flaps for takeoff over 60 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)...”







Inadvertent (deadly) Procedural Omissions

Dismukes (2006) looked at 27 major aviation accidents in U.S. (1987-2001) in which crew error cited causal or contributing factor

Typical examples include

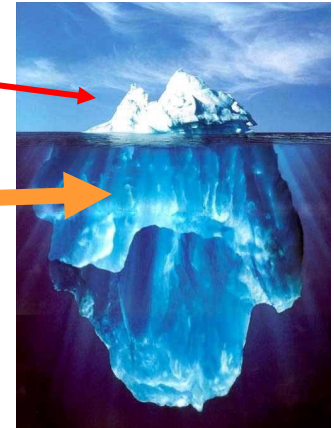
- **Detroit (1987): DC-9 crashed shortly after take-off**
 - NTSB: Flaps/slats not set to take-off position
- **Dallas (1988): B-727 crashed shortly after take-off**
 - NTSB: Flaps/slats not set to take-off position
- **LaGuardia (1994): MD-82 ran off runway end after high-speed rejected take-off**
 - 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
- Departing with inadequate fuel – forgot to check on preflight
- Leaving APU running during takeoff – forgot checklist item
- Took off without PDC – forgot to request
- 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

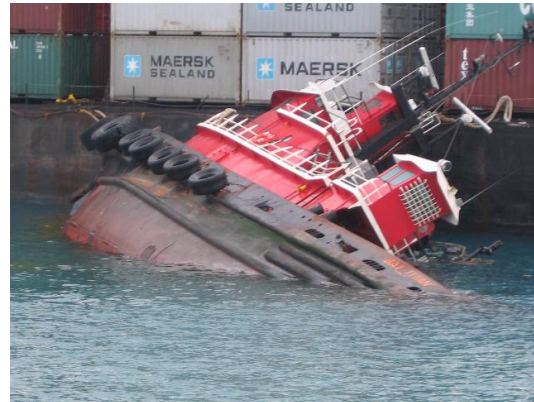
Are pilots alone?



Is Aviation alone?

No.

We see the same problems
in all high-risk
industries.



Loukopoulos/
Dismukes/Barshi

THE MULTITASKING MYTH



ASHGATE STUDIES IN HUMAN FACTORS FOR FLIGHT OPERATIONS



THE MULTITASKING MYTH

Handling Complexity in
Real-World Operations



Loukia D. Loukopoulos
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Data Sources

Personal flying experience

Many different jumpseat observations

- Airline Training
- Analysis of FOMs, SOPs, & Checklists
- Analysis of accident and incident reports
- Extensive interaction with participating carriers and others.

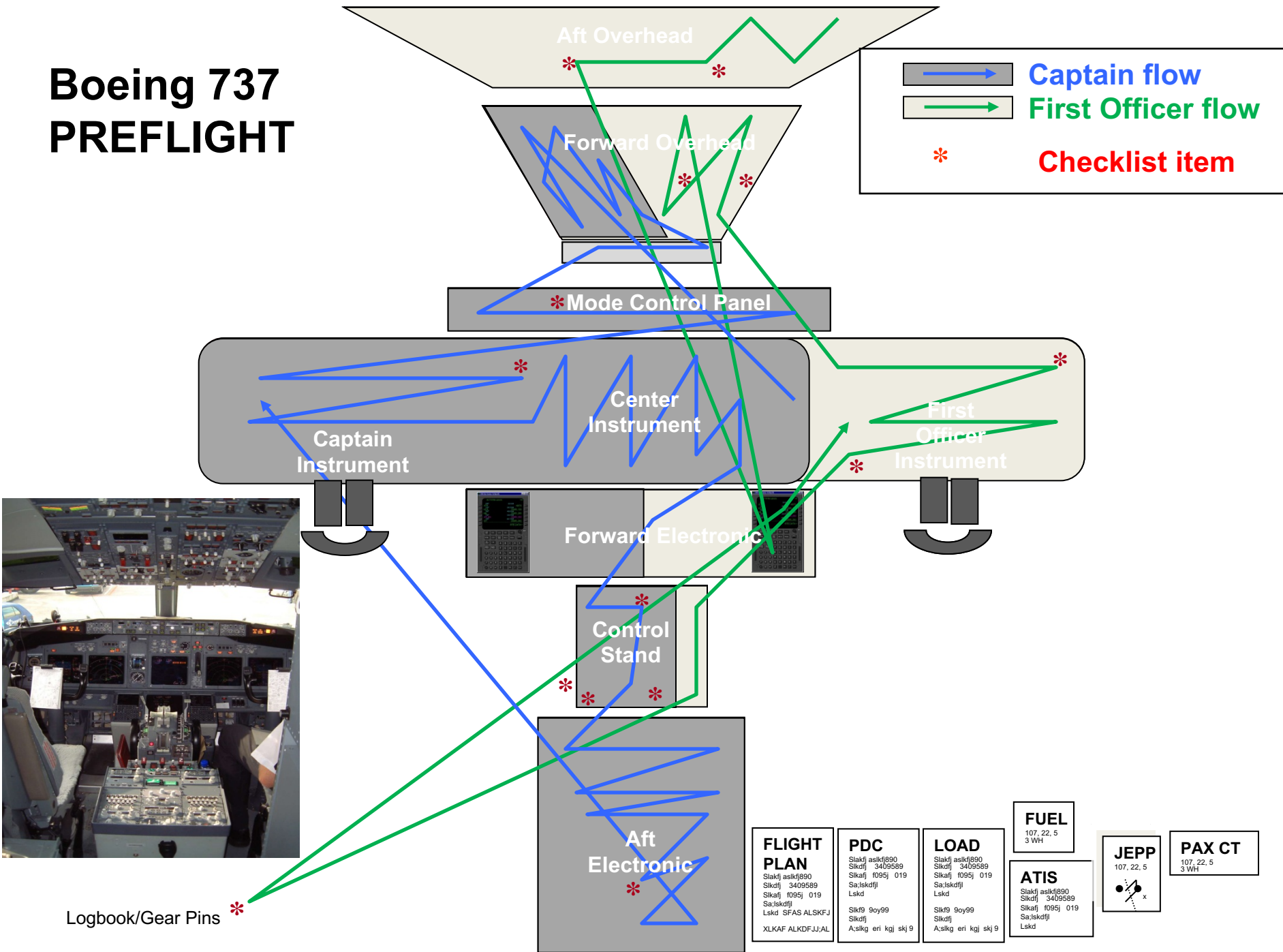
Data Sources

Structured Jumpseat Observations and crew interviews

- Two major US carriers
- Routine, revenue flights, B737
- 1-2 hour legs; 3-day trips
- All phases of flight
- All over the country (domestic ops)



Boeing 737 PREFLIGHT



**BEFORE START**

FLIGHT DECK PREPARATION COMPLETED
LIGHT TEST CHECKED
OXYGEN & INTERPHONE CHECKED
YAW DAMPER.....ON
INSTRUMENT TRANSFER SWITCHES NORMAL
FUEL ____ KGS & PUMPS ON
GALLEY POWERON
EMERGENCY EXIT LIGHTS.....ARMED
PASSENGER SIGNS.....SET
WINDOW HEAT.....ON
HYDRAULICS NORMAL
AIR COND & PRESS..... ____ PACK(S), BLEEDS ON, SET
AUTOPILOTS DISENGAGED
INSTRUMENTSX-CHECKED
ANTISKIDON
AUTO BRAKERTO
SPEED BRAKE DOWN DETENT
PARKING BRAKESET
STABILIZER TRIM CUTOUT SWITCHES NORMAL
WHEEL WELL FIRE WARNING CHECKED
RADIOS, RADAR & TRANSPONDERSET
RUDDER & AILERON TRIM FREE & ZERO
PAPERS..... ABOARD
FMC/CDU.....SET
N1 & IAS BUGS.....SET

CAPTAIN

“Flaps 5, taxi clearance”



MONITOR
Ground

Taxi to the runway

MONITOR
Ground, Company



FIRST OFFICER

Set flaps, verify in position
Obtain clearance

TAXI CLEARANCE



CAPTAIN

"Flaps 5, taxi clearance"

MONITOR
Ground

MONITOR
Ground, Company

FIRST OFFICER

Set flaps, verify in position

Obtain clearance

Start taxiing

TAXI CLEARANCE



MONITOR
CA taxiing

A

...

then

...

B

...

then

...

C

...

etc

BEFORE TAKEOFF
(down to the line)
Item to check (action required)

Recall (check)
xxx xxx (xxxx)
Flaps (, green light)
xxxxxx (xx)
Cabin door (lock)
xxx xxxxx (xx xxxxx)
Takeoff briefing (review)

BEFORE TAKEOFF PROCEDURE
(down to the line)
Item to check (action required)

xxx xxx (xxxx)
Flight controls (check)
Flaps (, green light)
xxxxxxx (xx)

Ask for checklist

Pilot calls when ready

Pilot is ready

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 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)

xxx xxxxx (xx xxxxxx)
FMC position update (as desired)
Transponder (On)

Ask for checklist

Line up with runway

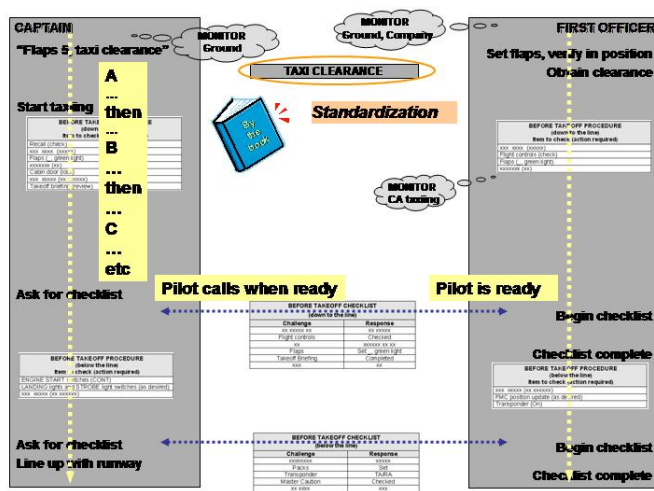
BEFORE TAKEOFF CHECKLIST
(below the line)

Challenge	Response
xxxxxxxx	xxxxxx
Packs	Set
Transponder	TA/RA
Master Caution	Checked
xx xxxx	xxx

Begin checklist

Checklist complete

In THEORY...



Activities are:

- **Linear**: task B always follows task A, in a fixed sequence
- **Controllable**: tasks initiated by each pilot, independently, at their choice
- **Predictable**: information available when needed, communications possible when necessary

CAPTAIN

"Flaps 5, taxi clearance"

Unfamiliar with airport/taxi route

Verify with FO

+ Verify ramp area clear

Start taxiing

+ Form mental picture of taxi route

+ MONITOR airport traffic

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

+ APU off-loaded 2 min before shutting down

Shut down one engine?
Restart it before takeoff

Repeat checklist

FO busy

Defer checklist

Remember to ask again when FO available

Ask for checklist

+ Identify/remember turns
+ Follow hold-short instructions
+ Identify/Remember aircraft to follow

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

+ Shoulder harnesses

+ Radar?

Malfunction

Return to gate

Ice/Snow

Defer takeoff flaps

Set flaps before takeoff

Ice/Snow

De-icing checklist

Systems configuration? (APU, Packs)

Delay

Shut down one engine?
Restart it before takeoff

Repeat checklist

Taxi.. in reality

TAXI CLEARANCE

+ Acknowledge clearance

+ Form mental picture of taxi route

+ Confirm CA's understanding of route

+ MONITOR taxi progress per instructions

MONITOR CA taxiing

New/ Additional taxi instructions

Acknowledge instructions

Form new mental picture

FIRST OFFICER

Busy frequency

Defer communication

Contact Ground when possible

Unfamiliar taxi instructions

Consult charts

+ "Clear" ramp area

+ "Clear" turns

Just-in or new load data

Calculate & reset Performance data

Continue to monitor CA

FMC: program/verify

Inform Company (new #s, delays)

Have CA cross check #s

+ Switch to Tower frequency

+ MONITOR Tower frequency

+ Acknowledge clearance

+ Confirm CA's understanding

+ FMC update

+ Strobes

+ "Clear" runway

+ Take control of aircraft while finishing checklist

BEFORE TAKEOFF CHECKLIST
(down to the line)

Challenge	Response
xx xxxxx (xx xxxxxx)	
Flight controls	
xxxxxx (xx xxxxxx)	
Set, gear	
C	

Interruption

Resume checklist

TAXI CLEARANCE

BEFORE TAKEOFF CHECKLIST
(below the line)

Challenge	Response
xxxxxxxxxx	xxxxxx
Packs	Set
Transponder	Set
Master Cabin	Set
xx xxxxx	xxx

Rush/repeat checklist

TAKEOFF

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

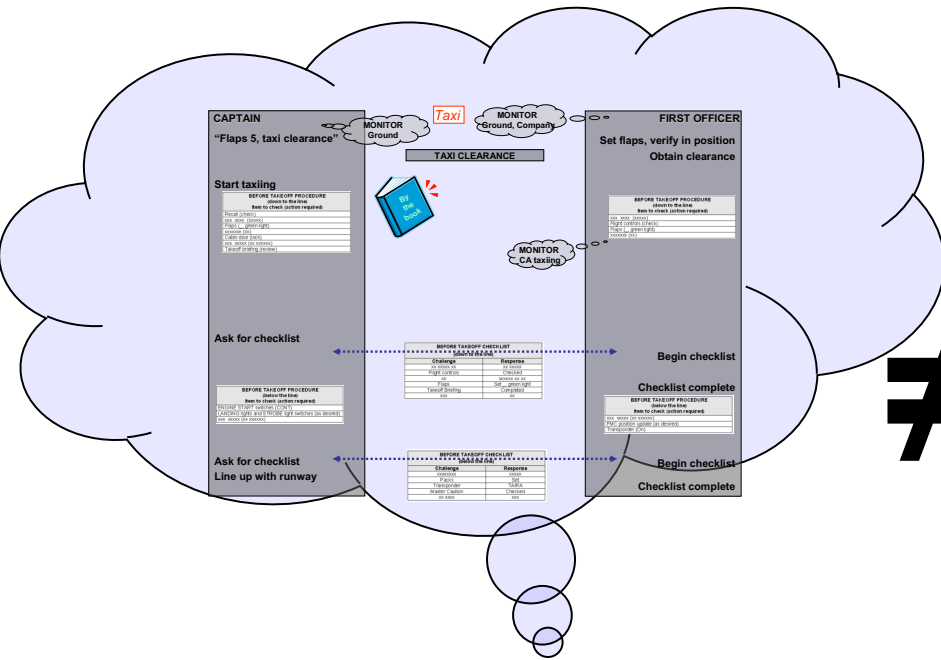
Begin checklist

Checklist complete

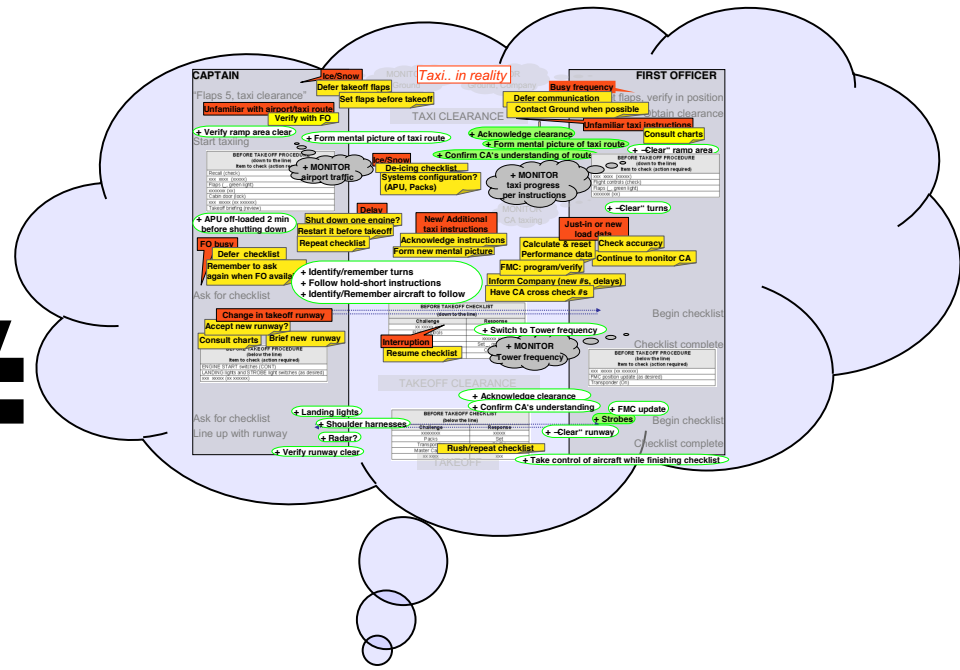
IDEAL

is different from

REAL



≠



OK, so What?

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

and the truth is ...

- Pilots (and others) routinely manage multiple, competing, concurrent task demands just fine...

CAPTAIN

Taxi Errors

FIRST OFFICER

Request taxi clearance

OMITTED CALL FOR FLAPS - RUSHED TO CLEAR RAMP/GATE AREA FOR ARRIVING AIRCRAFT - ABORTED TAKEOFF

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

Start

CA TAXIS WITHOUT HAVING FULLY UNDERSTOOD INSTRUCTIONS - BUSY LOOKING AT OTHER AIRCRAFT ON TAXIWAY AND RAMP — WARNING ISSUED

OUND CONTROLLER

BY GROUND CONTROLLER

BEFORE TAKEOFF PROCEDURE

Recall (check)

STARTED TAXI WITHOUT CLEARANCE - CREW DISCUSSING TAXI INSTRUCTIONS - STRUCK P

INCORRECT TRIM SETTING - CHECKLIST INTERRUPTED AFTER ITEM HAD BEEN READ BUT NOT VERIFIED — ABORTED TAKEOFF

xxxxxxx (xx)

Cabin door (lock)

OMITTED FLAPS - CREW DISCUSSING PROBLEM WITH APU, DELAYED FLAPS DUE TO SNOW - ABORTED TA

xxx xxxxx (xx xxxxxx)

FAILED TO START ENGINE #-2 - DISTRACTED WHILE DISCUSSING SPECIAL OPERATIONS FOR DESTINATION; OMITTED CHECKLISTS - D

NEGLECTED TO SET FLAPS - PREOCCUPIED WITH NEW DEPARTURE CLEARANCE AND PACKS-OFF OPERATION - AB

FO FAILED TO MONITOR CA - BUSY CHECKING AND CORRECTING CALCULATIONS OF LOAD DATA - AIRCRAFT

FO FAILED TO MONITOR CA — BUSY WITH FLOW; NIGHT TAXI — TAXIED IN WRONG

TAXIED PAST HOLD SHORT LINE

FLAPS INCORRECTLY SET, MISSED NOTICING DURING CHECKLIST

CREW BUSY WITH FUEL PROBLEM, RUNWAY CHANGES, PROGRAMMING

OMITTED CHECKING INTO BLEED AIR INDICATOR LIGHT-BUSY WITH DELAYED ENGINE START AND CHECKLISTS —

Ask for checklist

in checklist

CONFUSE OWN POSITION ON TAXIWAY DIAGRAM - NEW TERMINAL, STUDYING NOTAMS, RUNWAY CHANGE

TAXIED INTO

FO FAILED TO MONITOR CA - BUSY REPROGRAMMING FMC FOR RUNWAY CHANGE - TAXIED PAST

list complete

FAIL TO CONFIRM FLAP POSITION - EVALUATING HEAVY RAIN SHOWERS; RUSHED TO ACCEPT TAKEOFF

CLEARANCE - ABOR

FO FAILED TO MONITOR CA - BUSY WITH PRE-TAKEOFF PREPARATIONS - AIRCRAFT CROSSED

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 -

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

in checklist

Ask for checklist

Line up wi

OMIT CHECKLIST - RUNNING LATE, CHECKLIST INTERRUPTED BY TOWER, UNEXPECTED CLEARANCE FOR TAKEOFF - ABORTED TAKEOFF

CLEARANCE - ABORTED

OMITTED FLAPS-CHECKLIST INTERRUPTED BY TOWER; CREW RUSHED TO ACCEPT TAKEOFF CLEARANCE-ABORTED TAKEOFF

Checklist complete

Packs
Transponder
Master Caution
XX XXXX

The reality of cockpit operations

Constant presence of Perturbations that:

- **Interrupt ongoing activity**
- **Force tasks to be performed outside their normal (habitual) sequence**
- **Give rise to new, unanticipated tasks**

Implications:

- **Attention diverted, even if for split second**
- **Actions and tasks suspended**
- **Actions and tasks deferred**
- **Actions and tasks interleaved**
- **Deferred tasks must be remembered later**
- **...There is no PAUSE button!**



A word about Memory and deferred tasks...

Vulnerable to Omissions when...

- **Interrupted** *(4 Prototypical Situations)*
 - 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 ways in which the human brain processes information.

The hidden complexity of cockpit operations

- Complexity is not just a matter of workload
- Situations appear diverse but share underlying features that involve:

Multitasking: multiple tasks, concurrently

- Pilots (all humans) **cannot multitask well** yet they typically do it:
 - without a second thought
 - without an appreciation of their true (in)ability
 - with an incomplete understanding of the risks they are taking when doing so

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 a procedural step
 - Common error: inattention (being distracted)





JKK 5022 Madrid

Omission: setting flaps for takeoff

Crew experienced **perturbations**:

- An interruption (break in predictability)
- The need to re-arrange/repeat tasks
(break in linearity)
- The need to make up for lost time
(break in controllability)
- “Fast-forwarded” based on an expectation, and environmental cues (did not hit the “Pause” button)

So how do you design for operations?

So how do you design for operations?

You start by truly understanding

the operation itself

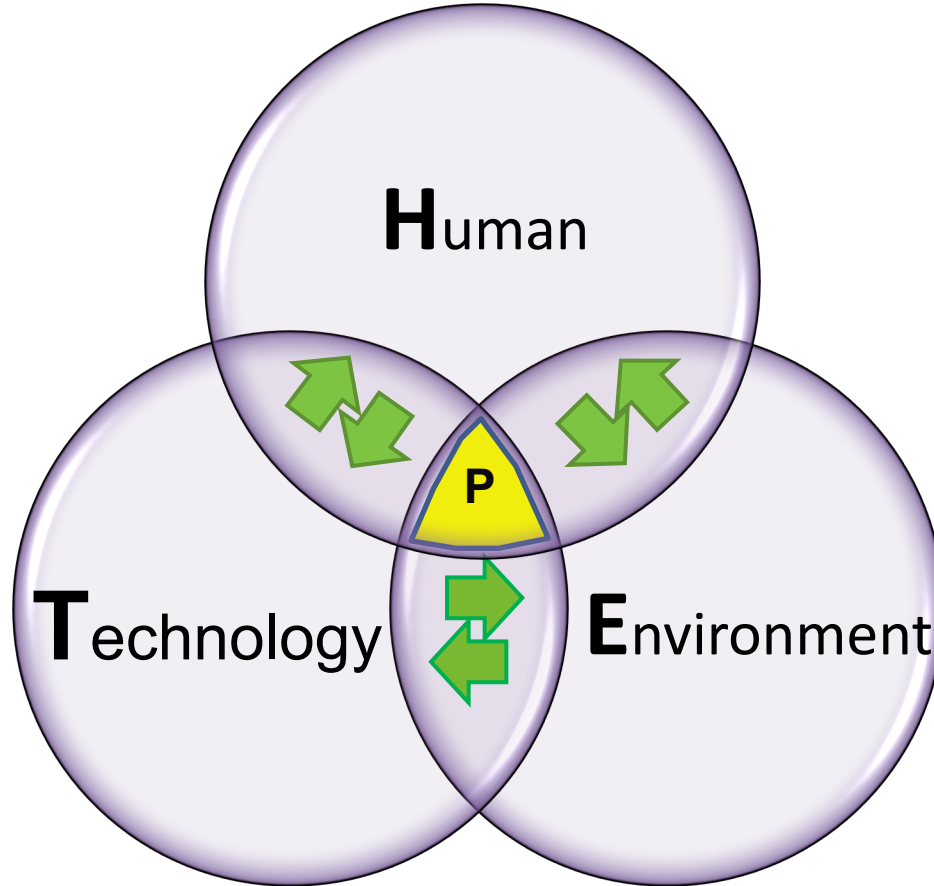
its context

the operators

and the implications of all these,

And you design for the real situation, not the ideal.

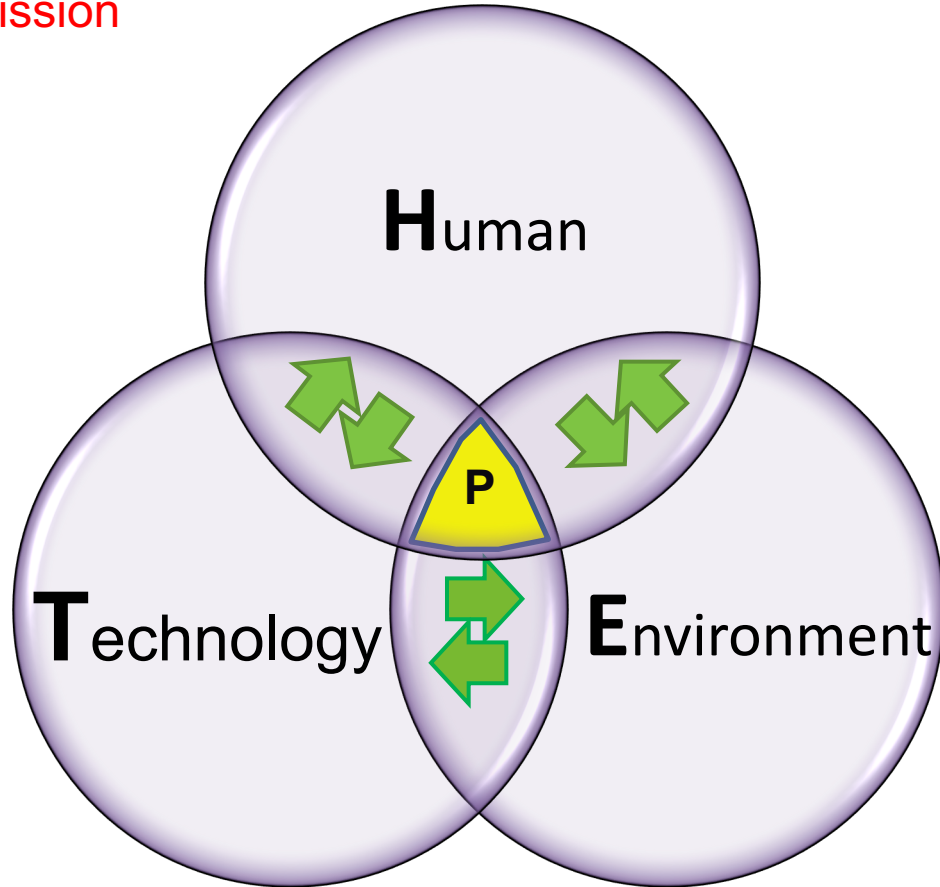
Follow THE Model



Design and procedures govern interactions within

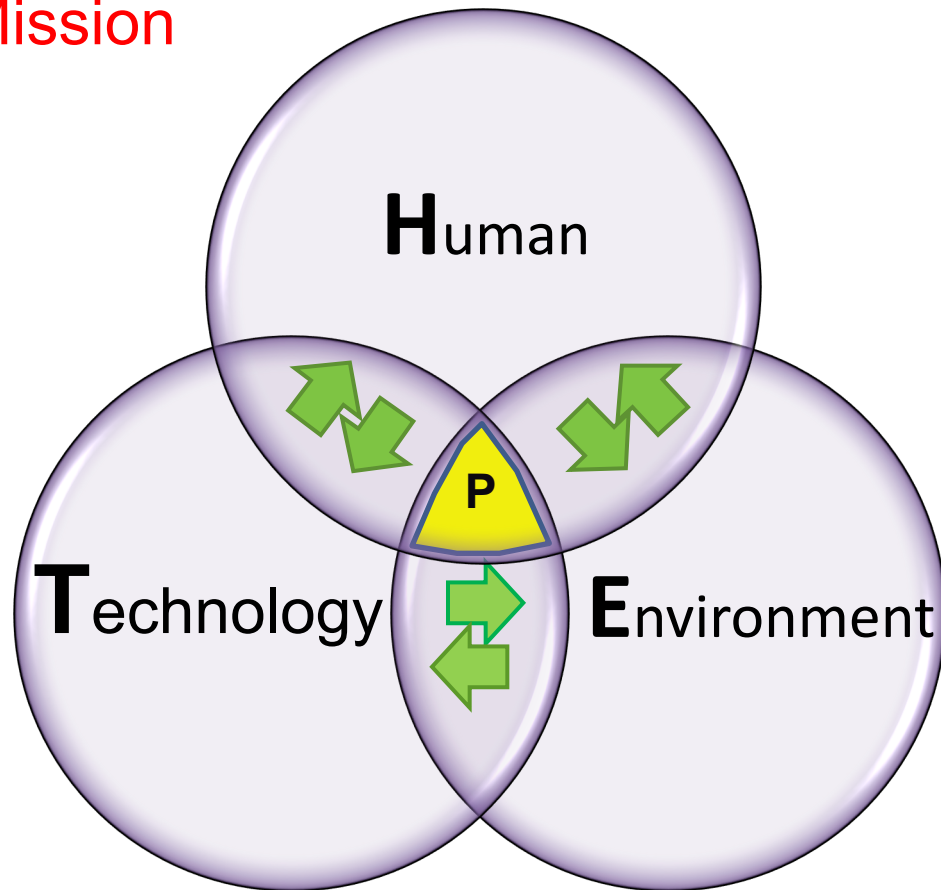
THE Model

Mission



Culture

Mission



**Figure 1. Mean Number of Problems on Target
Items per Flight**

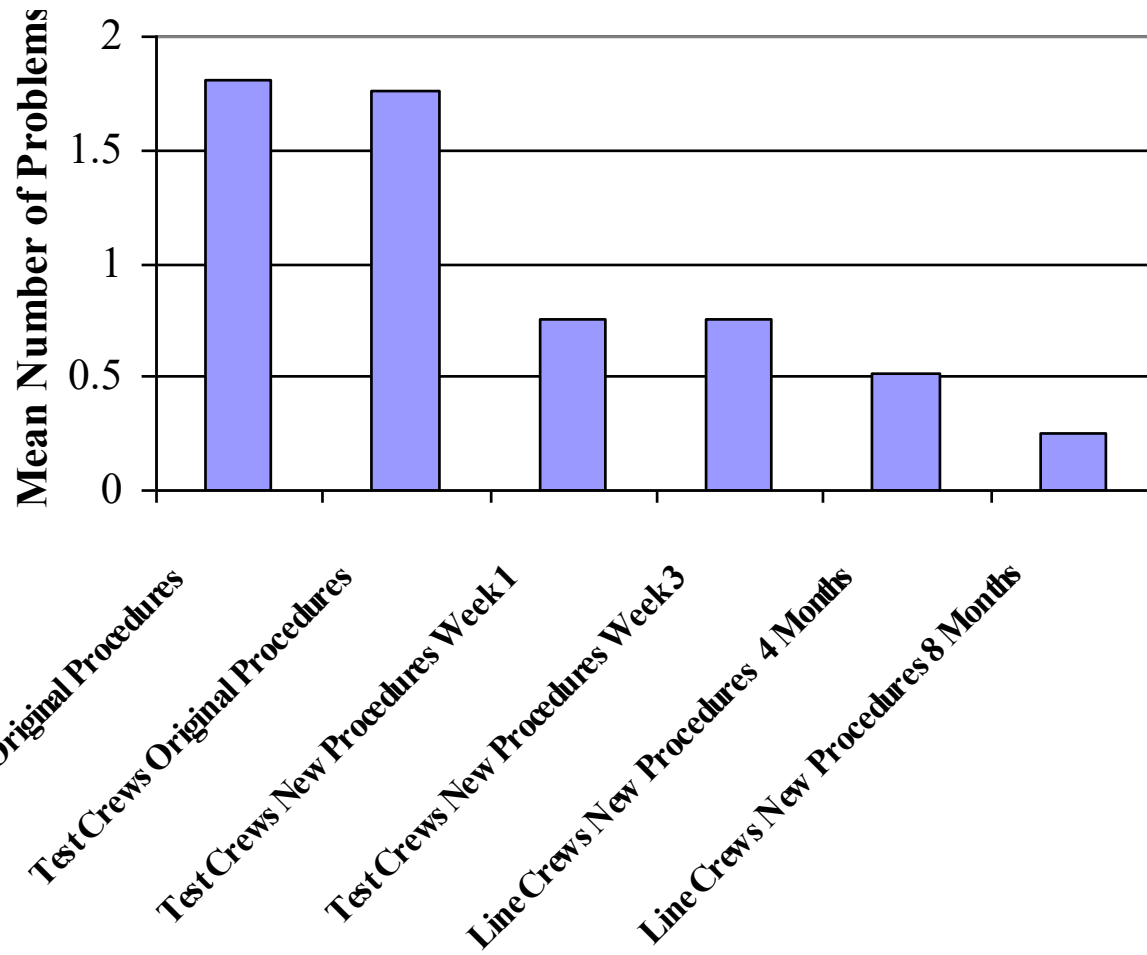


Figure 2. Average standard deviation in proportion of problems

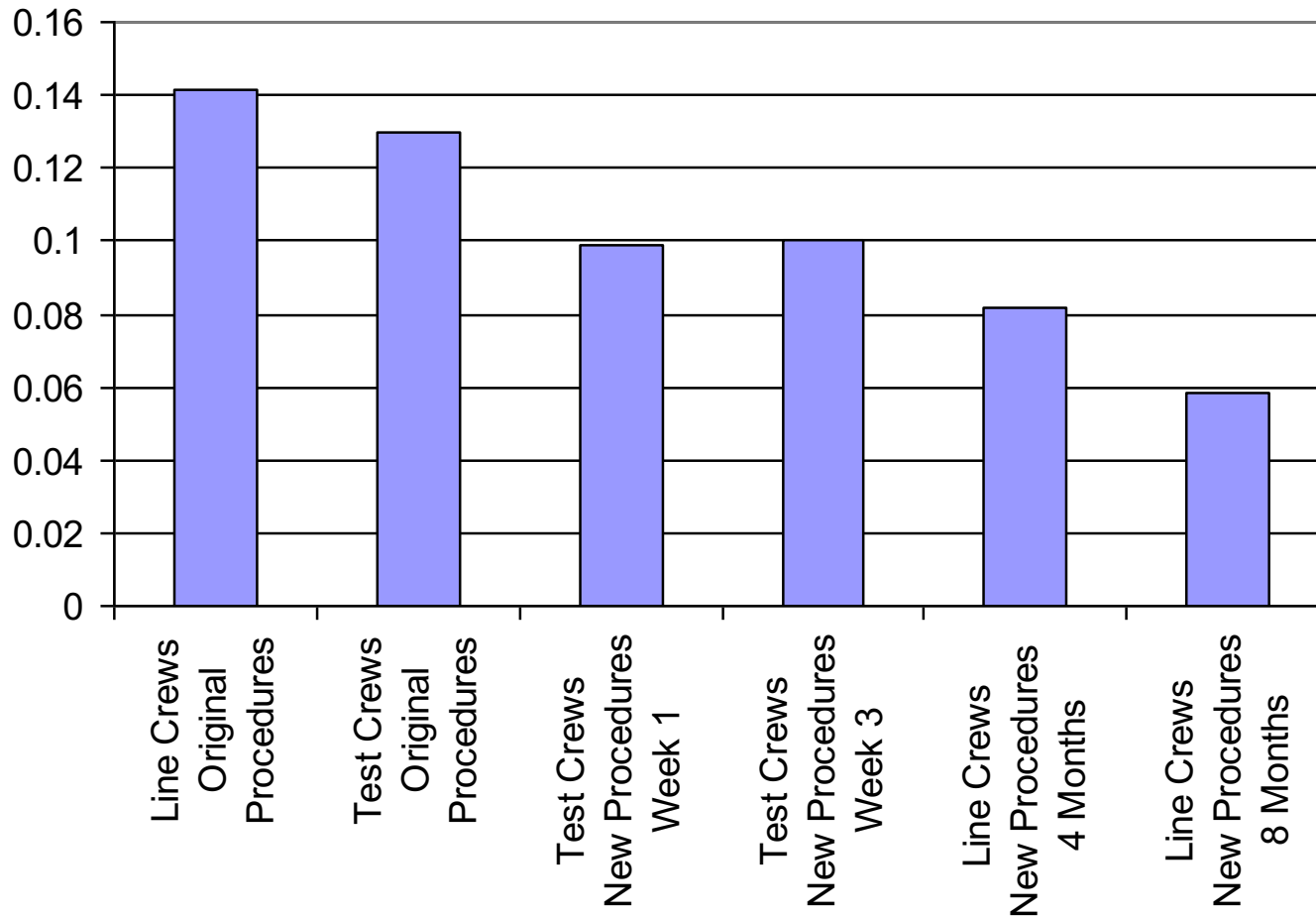


Figure 3. Problems on Target Items by Phase of Flight

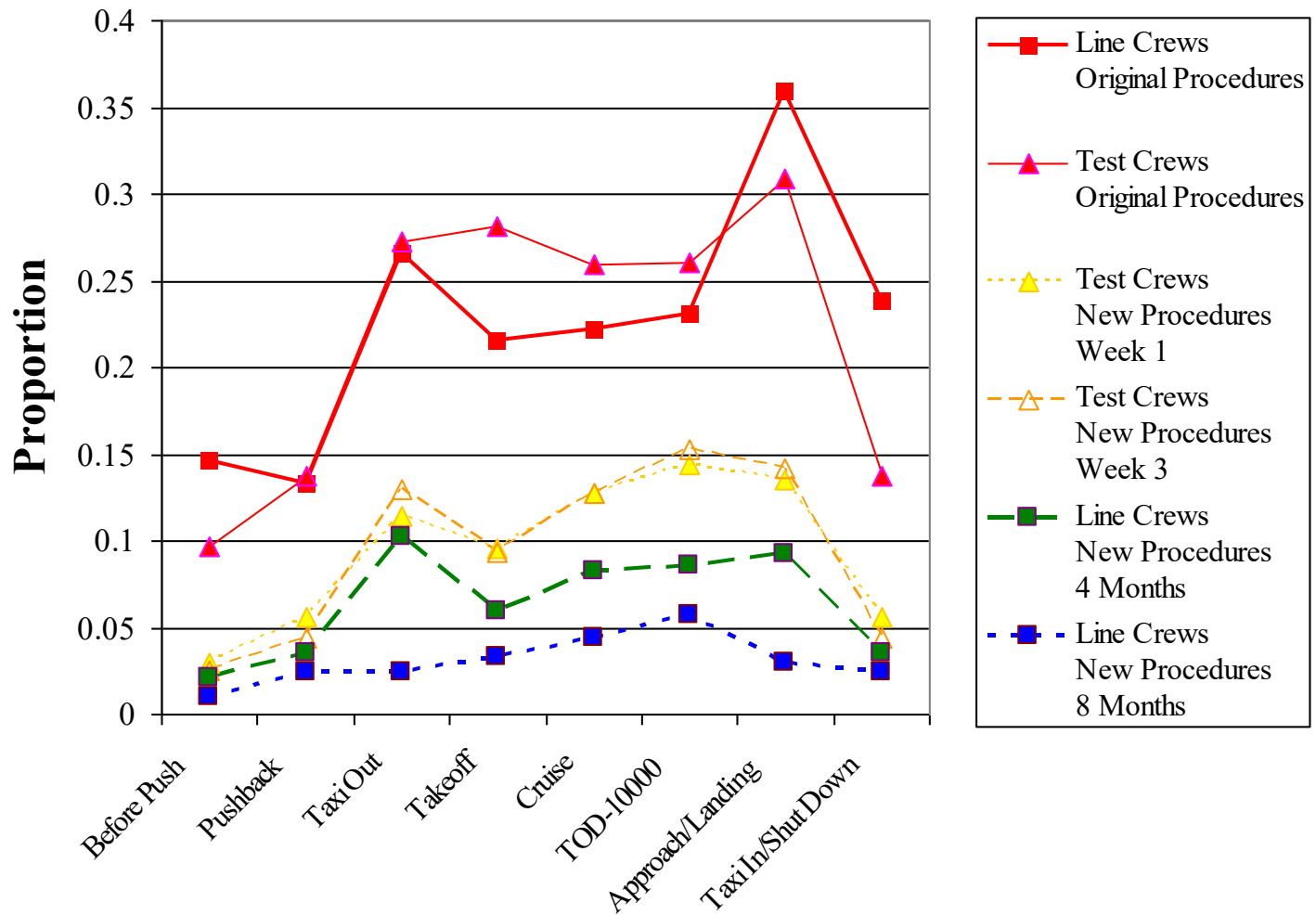
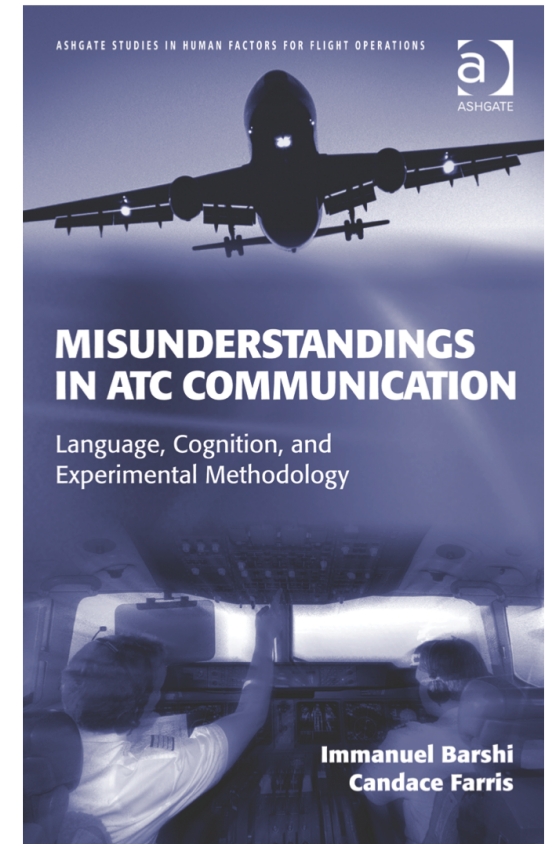
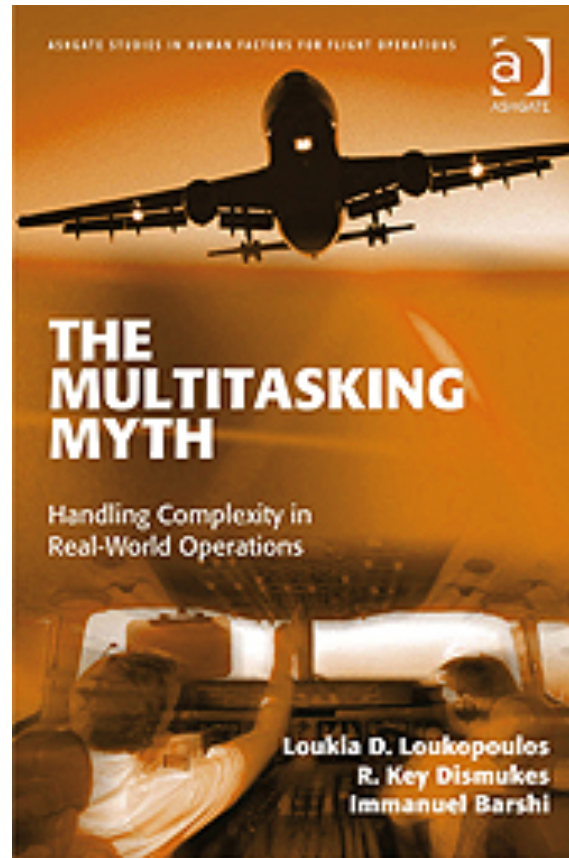


Table 1. Pilots' perceptions of flight under the new procedures as compared to flight under the old procedures 4 and 8 months following adoption of the new procedures.

Question		Response	
Compared to legs flown under the old procedures, on this leg:		Worse	Same or Better
How well did things go overall?	4 Months	10.0 % (12)	90.0% [26.9 (32); 63.1 (75)]
	8 Months	2.2% (2)	97.8% [18.7 (17); 79.1 (72)]
How well did you and the other pilot communicate?	4 Months	3.3 % (4)	96.6% [26.1 (31); 70.5 (84)]
	8 Months	2.2% (2)	97.8% [23.1 (21); 74.7 (68)]
How well did you and the other pilot check / monitor each other?	4 Months	2.5 % (3)	96.6% [22.7 (27); 73.9 (88)]
	8 Months	3.3% (3)	96.7% [17.6 (16); 79.1 (72)]
How well did you and the other pilot check / monitor the aircraft systems?	4 Months	2.5 % (3)	97.6% [38.7 (46); 58.9 (70)]
	8 Months	0.0% (0)	100.0% [31.9 (29); 68.1 (62)]
How tired were you?	4 Months	10.9 % (13)	89.1% [66.4 (79); 22.7 (27)]
	8 Months	4.4% (4)	95.6% [69.2 (63); 26.4 (24)]
How stressed did you feel?	4 Months	12.5 % (15)	87.4% [53.8 (64); 33.6 (40)]
	8 Months	2.2% (2)	97.8% [58.2 (53); 39.6 (36)]
How much effort did you expend?	4 Months	15.0 % (18)	84.8% [44.5 (53); 40.3 (48)]
	8 Months	5.6% (5)	94.4% [42.2 (38); 52.2 (47)]
How rushed were you?	4 Months	13.4 % (16)	86.5% [21.0 (25); 65.5 (78)]
	8 Months	5.5% (5)	94.5% [22.0 (20); 72.5 (66)]

Note. Reported percentages are based on the total number of responses. Numbers in () parentheses are the actual number of responses. Values in [] brackets are: [percent responding "same" (number); percent responding "better" (number)].

Additional Information:



**THANK YOU for
your attention**

Or contact me at: Immanuel.Barshi@nasa.gov