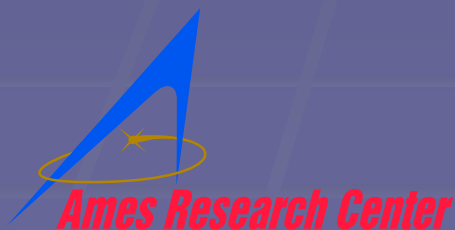


The Issues in Depth: Analysis of an Accident

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Federal Express Flight 1406

- § September 5, 1996
- § Early morning, before dawn
- § Memphis-Boston
- § DC-10
- § Captain, first officer, flight engineer; two jumpseat riders in cabin
- § Normal flight through cruise at 33,000



In a nutshell...

- § Cargo on fire
- § Safe emergency landing in Newburgh, New York
- § Trouble evacuating
- § Airplane consumed by fire
- § NTSB did not cite the crew



The crew's challenge

- § Once-in-a lifetime threat
- § No warning
- § Demands proficiency, no recent practice
- § Aircraft normally reliable so surprise when they're not
- § “Us” versus “Them”

1. “Cabin/cargo smoke” light

- § Crew noticed cabin/cargo smoke warning
- § Crew executed Fire and Smoke checklist

Fire and Smoke Checklist

00:00 Since Onset<>Until Landing **18:00**

0536:23

CAM-1 what the hell's that?

0536:25

CAM-2,3 cabin cargo smoke.

0536:27

CAM-1 you see that .. we got cabin cargo smoke ... cabin cargo smoke.

0536:31

CAM-3 cabin cargo smoke, oxygen masks on.

0536:36

CAM-3 slash courier communication established.

0536:38

CAM-1 alright we got it.

0536:40

CAM-3 okay it's number nine smoke detector.

FIRE & SMOKE

1. **Supervisor Mask & Smoke Detector (If Equipped)** **ON**
2. **ECU/AC Power Control Switches** **ESTABLISH**
Check Mike switches set to MASK, place cockpit speaker ON, place MIC SEL switch to FLT INT, and establish crew communication.
3. Cockpit Door & Smoke Screen **CLOSED**
Close the cockpit door & smoke screen to exclude heavy concentrations of smoke. Leave door closed unless opening it is dictated by a greater emergency, and then at Captain's discretion.
4. If Descent is required **PROCEED TO STEP 8**
5. If Descent is NOT Required **PROCEED TO STEP 14**

WARNING

Should structural damage be suspected, limit airspeed. Gear and / or Speed Brakes may be used depending on type of damage.

6. Autopilot **AS REQUIRED**
7. Throttles **IDLE**
8. Speed Brake **FULL**
9. Airspeed **MACH .82 TO .85 (320 TO 360 KIAS)**

NOTE

If structural damage is known or suspected, use appropriate turbulence penetration speed.

10. ATC **NOTIFY**
11. Transponder (if no contact with ATC) **7700**
12. Tank Pumps **ALL ON**
13. Altimeter **SET**
14. Type Of Smoke Or Fire **DETERMINE & PROCEED TO APPROPRIATE PROCEDURE, THIS CHAPTER**

- A. **ELECTRICAL FIRE & SMOKE** : Can best be determined by smell or visible smoke from electrical components (e.g., circuit breaker, radio)
- B. **AIRCONDITIONING SMOKE** : Can best be recognized by smoke emanating from overhead air conditioning outlets.
- C. **CABIN CARGO SMOKE** : Can best be recognized by checking smoke detectors on the Second Officers panel, or by observing smoke or fire in the main deck cargo area.

(End of Procedure)

Great beginnings

- § Crew had no difficulty noticing the problem and identifying the correct procedure
- § Light-driven procedure design worked
- § Crew performed memory items well
- § Flight engineer initiated the checklist

Fire and Smoke Checklist

02:00 Since Onset <> Until Landing **16:00**

0537:48
INT-1 let's find out what we've got going here.

0537:56
INT-1 okay it's moving forward whatever it is .. it's up to seven.

0538:06
INT-3 okay fire and smoke .. oxygen mask and smoke goggles as required on one hundred percent .. crew and courier communication established .. that completes the phase ones.

0538:14
INT-1 roger.

0538:17
INT-3 cockpit door and smoke screen closed.

FIRE & SMOKE

1. **Oxygen Mask & Smoke Goggles** **ON**

2. **Crew & Courier Communication** **ESTABLISH**

Check Mike switches set to MASK, place cockpit speaker ON, place MIC SEL switch to R.T INT, and establish crew communication.

3. **Cockpit Door & Smoke Screen** **CLOSED**

Close the cockpit door & smoke screen to exclude heavy concentrations of smoke. Leave door closed unless opening it is dictated by a greater emergency, and then at Captain's discretion.

Fire and Smoke Checklist cont'd

02:00 Since Onset <> Until Landing **16:00**



4. If Descent is required PROCEED TO STEP 8
5. If Descent is NOT Required PROCEED TO STEP 14

Result: delayed descent

- § Crew began a discussion about fire location, spread, fire detector test
- § Descent did not begin for an additional 2:40
- § Did not affect outcome, but nearly did
- § Captain not explicitly included in this step of the checklist

What was the captain doing?

- § We don't know what the captain was looking at, listening to, thinking about at the descent decision point
- § Monitoring spread of the fire
- § Communicating with ATC (routine)
- § Monitoring the flying pilot (first officer)
- § Concerned with testing the fire detection system

The ideal for a 3-person crew

- § First officer continued flying
- § Flight engineer ran procedures
- § Captain coordinated crew response
- § Captain did not explicitly make these assignments, but he maintained them

2. Emergency Descent and Cabin/Cargo Smoke Light Illuminated Checklist

04:00 Since Onset<>Until Landing **14:00**

0539:55

INT-3

ready to run the cabin cargo smoke light illuminated.

0539:57

INT-1

go ahead.

0540:01

INT-3

okay it says pack function selectors two off .. two are off.

0540:07

INT-1

we've definitely got smoke guys .. we need to get down right now let's go.

Busy captain

- § Interrupted flight engineer and checklist
- § Discussed diversion with air traffic control
- § Mistakenly transmitted his remarks to the crew over the ATC frequency

0540:18

RDO-1

okay what's the closest field I wonder .. here let me talk to them here.

0540:22

RDO-1

center fedex fourteen zero six.

0540:24

BCNTR

- saying something about the closest field I'll get back to that in a second but one hundred heading seven thousand expect straight in runway six.

0540:30

RDO-1

let's run it, let's get this thing depressurized .. let's get it down.

CABIN CARGO SMOKE LIGHT ILLUMINATED

1. Pack Function Control Selectors TWO PACKS OFF

NOTE

Operate the No. 1 Pack only, if available.

2. Cockpit Air Outlets OPEN

3. Courier Masks & Goggles VERIFY ON/100%

4. Airplane Altitude CAPTAIN'S DISCRETION

A. Land as soon as possible.

OR

B. If above FL 270, consider descent to FL 270. Manually raise cabin altitude to 25,000 ft.

OR

C. If below FL 270, and an immediate landing is not possible, climb to FL 270. Manually raise cabin altitude to 25,000 ft. using the MANUAL CAB ALT control wheel.

5. If unable To Extinguish Fire/Smoke MANUALLY RAISE CABIN ALTITUDE TO 25,000 FEET

6. Cabin Air Shutoff T-Handle PULL

7. Maintain 0.5 PSI Diff Pressure Below FL 270, Or 25,000 Ft. Cabin Altitude Above FL 270.

8. Fire CHECK EXTINGUISHED

NOTE

Restricted articles container is designed to be "relatively" air tight so that any fire which may start inside will quickly consume all available oxygen. Depressurizing airplane will further deny oxygen to fire and should result in adequate fire control.

CAUTION

No crewmember should leave the cockpit to fight a fire except when it is determined that the fire is accessible and then only when measures already taken have not been effective. In addition, do not open restricted articles container during flight when a fire within is known or suspected.

9. If It Is Necessary To Leave The Cockpit To Fight A Fire:

A. Protective Breathing Equipment DON/ACTIVATE

NOTE

The PBE is located in a container in the coat closet and should be worn when fighting an actual fire. The walk-around O₂ bottle is also available in the cockpit.

B. Fire extinguisher OBTAIN

C. Fire or smoke source EXTINGUISH

10. Land At Nearest Suitable Airport.

(End of Procedure)

Cabin/Cargo Smoke Light Illuminated Checklist

05:00 Since Onset <> Until Landing **13:00**

0541:41
INT-3 okay courier mask and goggles verify on one hundred percent .. cockpit air outlets open ... they are open ... it says ah land as soon as possible ... and we are descending now ... if unable to extinguish fire and smoke manually raise cabin altitude to twenty-five thousand .. while you're in a descent to eleven?

0542:03
INT-1 roger, go ahead and start raising it.

0542:07
INT-3 okay continue the descent.

0542:21
INT-3 and we now have just detectors eight, nine and ten .. we've lost detector seven .. it's gone out.

0542:28
INT-1 roger.

0542:30
INT-3 okay what's that ah .. stand by.

2. Cockpit Air Outlets OPEN
3. Courier Masks & Goggles VERIFY ON 100%
4. Airplane Altitude CAPTAIN'S DISCRETION
 - A. Land as soon as possible.
 - OF B. If above FL 270, consider descent to FL 270. Manually raise cabin altitude to 25,000 ft.
 - OF C. If below FL 270, and an immediate landing is not possible, climb to FL 270. Manually raise cabin altitude to 25,000 ft. using the MANUAL CAB ALT control wheel.
5. If unable To Extinguish Fire/Smoke MANUALLY RAISE CABIN ALTITUDE TO 25,000 FEET

Cabin/Cargo Smoke Light Illuminated Checklist

07:00 Since Onset<>Until Landing **11:00**

0543:02

INT-3

and I'm manually raising the cabin altitude .. there is smoke in the ah cabin area.

0543:03

CAM

[sound of overspeed warning alert]

0543:06

INT-1

roger.

0543:12

INT-2

okay .. okay you have an approach plate for us?

0543:25

CAM-?

*.

0543:22

INT-3

what's the three letter identifier for stewart.

Cabin/Cargo Smoke Light Illuminated Checklist

10:00 Since Onset<>Until Landing 8:00

0546:31
INT-3 okay we are depressurized.

0546:34
INT-1 alright.

0546:52
INT-3 okay, it says fire .. check extinguished .. the lights are off ..
 it's still smoky out there.

5. If unable To Extinguish Fire/SmokeMANUALLY RAISE CABIN ALTITUDE TO 25,000 FEET
6. Cabin Air Shutoff T-Handle PULL
7. Maintain 0.5 PSI Diff Pressure Below FL 270, Or 25,000 Ft. Cabin Altitude Above FL 270.
8. FireCHECK EXTINGUISHED

Overloaded flight engineer

- § Flight engineer recalled feeling overloaded
- § Humans have limitations to our cognitive capabilities, such as the limits on our ability to retrieve and apply little-used or little-practiced skills from memory, limits on reallocating our attention among concurrent tasks, and limits in our ability to process ambiguous information
- § Flight engineer may have reached these limits
- § Possible affective aspects: threat to life, fear, performance anxiety



Emergencies are messy

- § Illustrates the tradeoffs required to manage concurrent tasks in emergency situations
- § Interruptions made it difficult for the flight engineer to manage his own workload, and the descent increased his workload by adding the demands of normal preparations for landing
- § The captain had to divide attention among overseeing the flight engineer and the emergency checklists, monitoring the first officer's flying the emergency descent and diversion to the nearest airport, and communicating with ATC
- § These concurrent task demands required the flight engineer and captain to jump back and forth among these active tasks and to attempt to remember where they were in each interrupted task when it was resumed

Emergencies are messy, cont'd

- § Not just the number of tasks that must be performed concurrently, but also that the crew cannot control the timing of task demands (Loukopoulos, Dismukes, Barshi research on normal procedures)
- § In emergency crews are frequently interrupted by radio calls and other crew members, and often they must suspend one task while waiting for information from some other person or for a system to react
- § There are cognitive limits in our ability to reliably swap tasks, recall tasks we temporarily leave aside, and recall intentions, especially under stress.
- § These disruptions and distractions make any crew more vulnerable to characteristic errors

Monitoring somebody else may be unreliable

- § Captain was supposed to assist the flight engineer and monitor him, but he was overloaded, too
- § Humans are poor monitors when multi-tasking
 - § Monitoring drops out when under own workload
- § Captain may not be able to see or hear what a flight engineer, seated behind the captain, is doing
- § Generally, monitoring may be more difficult and less reliable for a two-person crew, in which the flying pilot is monitoring the actions of the non-flying pilot
- § Pilots may not be able to reliably detect and correct checklist errors made by another unless they are explicitly drawn into the checklist

Monitoring and leading

- § Unsurprising that the captain did not detect and correct the flight engineer's checklist errors
- § Ideally the captain would have noted the flight engineer's overload and prioritized his tasks
- § Both monitoring and leadership require mental resources that can be pre-empted by the workload demands of an emergency

3. Successful landing, trouble evacuating

18:00 Since Onset<>Until Landing **0::00**

- § Excellent crew performance on approach and landing
- § Could not open doors when attempting to evacuate
- § Flight engineer then depressurized cabin, crew and passengers exited through partially open doors

Successful landing, trouble evacuating

18:00 Since Onset <> Until Landing **0::00**

- § Crew did not run the emergency evacuation checklist
- § Captain recalled thinking that he had accomplished most of the items
- § Result: passengers not briefed, cockpit door lock breaker not tripped, cabin not depressurized

0555:07

RDO-1

we need to get the hell out of here.

Successful landing, trouble evacuating, cont'd

18:00 Since Onset <> Until Landing **0::00**

- § Emergency evacuation checklist supposed to be run during descent
- § Possible name confusion
- § Checklist not integrated with other descent checklists

DC-10 EMERGENCY EVACUATION (LAND)	
INFLIGHT PREPARATION (IF REQUIRED)	
1. Crew & Couriers (Flight Attendants and Passengers, if on board)	NOTIFY
A. On passenger flights, time permitting:	
(1) Summon the Senior Flight Attendant to brief:	
(a) Nature of emergency.	
(b) Time remaining to prepare.	
(c) Cockpit commands "Brace For Landing."	
(d) Cockpit commands "Evacuate."	
(e) Special instructions.	
(2) Brief passengers:	
(a) Nature of emergency.	
(b) Plan of action.	
(c) Follow Flight Attendant directions.	
B. On cargo aircraft the S/O briefs the jumpseaters.	
2. ATC & Company	NOTIFY
3. Cockpit Doorlock CB (LM E-2)	TRIP
4. Fuel	DUMP, AS REQUIRED
5. Pressurization	DEPRESSURIZE BEFORE LANDING
A. Cabin Pressure Auto/Man selector	
MAN	
B. Manual Cabin Altitude control	
OPEN	
6. Cockpit Loose Items	SECURED
THIRTY SECONDS PRIOR TO TOUCHDOWN	
7. Announce	"BRACE FOR LANDING"
GROUND EVACUATION AFTER STOPPED	
8. Parking Brake	SET
9. Tower/Ground	NOTIFIED
10. Emergency Power Switch	ON
11. Start Levers	OFF

(CONTINUED)

Successful landing, trouble evacuating, cont'd

18:00 Since Onset <> Until Landing **0::00**

§ Crew's training for planned evacuations is unknown, but they must have received some

§ Crews do not have the opportunity to practice emergency procedures such as evacuation frequently enough for their actions to become automatic and fluid.

DC-10 EMERGENCY EVACUATION (LAND)

(CONTINUED)

AS SOON AS POSSIBLE

12. Thunderstorm Light ON

13. Evacuation INITIATE

A. Command "Evacuate" with Passenger Address system.

B. Direct cabin crew to specific exits considering:

- (1) High wind effects on escape slides.
- (2) Irregular ground conditions.
- (3) Structural damage or fire.

14. Engine Fire Handles DOWN

15. Engine Fire Bottles DISCHARGE, IF REQUIRED

16. Cockpit Voice Recorder C/B (AV B-5) TRIP

17. Emergency Power Switch OFF

18. Battery Switch OFF

19. Crew Evacuation Duties ACCOMPLISH

NOTE

Check visually for fire or obstructions before opening an exit.

Captain:

- Direct & assist to ensure all occupants have evacuated.
- On passenger aircraft, exit (or designate a representative) through door L4.

First Officer:

- Obtain first aid kit, exit aircraft & assist from outside.
- On passenger aircraft ensure Zones A and B are evacuated then exit through door R1.

Second Officer:

- Assist the Captain as necessary to ensure all occupants have evacuated.
- On passenger aircraft ensure the airplane is evacuated then exit through door R4.

(End of Procedure)

Conclusion: Errors are expected

- § This crew did many things excellently and brought the flight in safely
- § Errors made by an otherwise high-performing crew point to the difficulty of handling an emergency under stress, high workload, and extreme time pressure



Conclusion: Procedures can help---and hurt

- § Results also suggest that procedures--both emergency and normal--might have been more helpful
- § Procedure design added to concurrent task demand, and crew may have reached cognitive limits



Conclusion: Training--partial solution?

- § Training to perform a complex, rare procedure very reliably is problematic
- § Crews may receive little or no training or realistic experience in managing the demands of concurrent tasks, interruptions, distractions, and stress

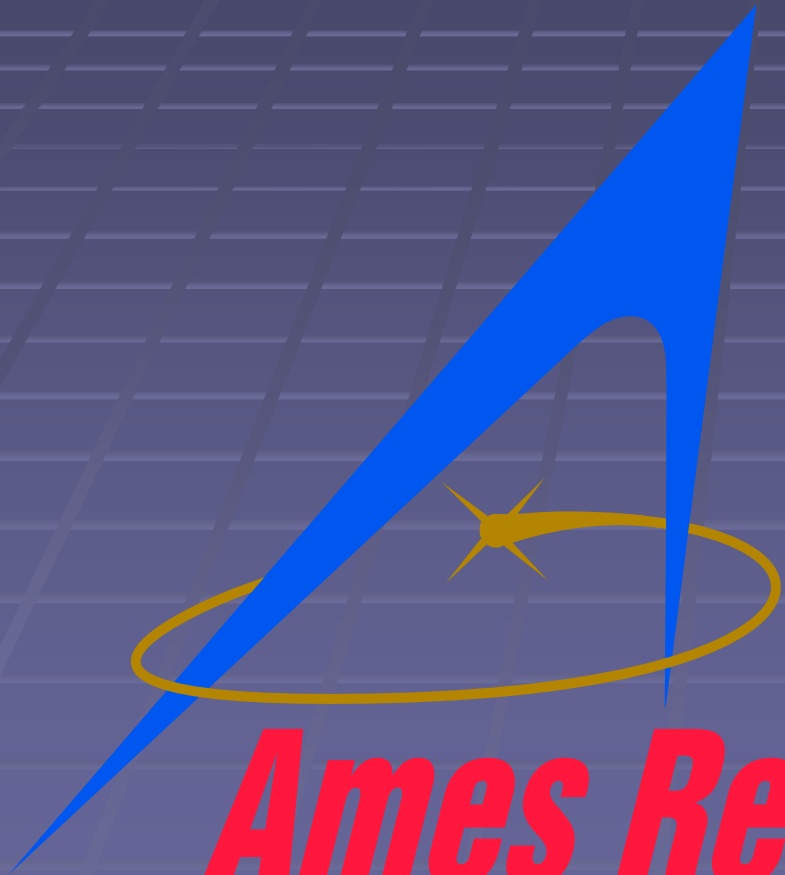


Conclusion: No easy fixes

- § Not helpful to blame the crew
- § Performance demands collide with real human cognitive limitations and vulnerabilities
- § Monitoring is difficult, especially when not built into procedures
- § Tradeoffs among training, procedures design, system/display design



Thanks!!



Ames Research Center

