Emergency and Abnormal Situations Project

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The Challenge

Emergency and abnormal situations:

- are often time critical, complex, and/or ambiguous
- are high stress, high workload, and a great deal is at stake
- require exceptionally high levels of coordination inside and outside of the airplane

Emergency and abnormal procedures:

- are generally focused on aircraft systems rather than on the situation as a whole
- are practiced seldom (twice a year or less) and used rarely
- are often highly dependent on fragile cognitive processes
- when needed, are crucial and must be performed correctly

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Industry Contacts and Consultants

Manufacturers:	Boeing, Airbus Industries, BAE Systems
Regulatory Agencies:	FAA, CAA (UK), ICAO
Unions and Trade Groups:	ALPA, APA, SWAPA, ATA
Accident Investigation Bodies:	NTSB, TSB of Canada
Airlines:	Southwest Airlines, United Airlines, Continental Airlines, American Airlines, Fed Ex, Aloha Airlines, Hawaiian Airlines, Air Canada, Cathay Pacific, Airborne Express, UPS, US Airways, TWA (prior to merger)

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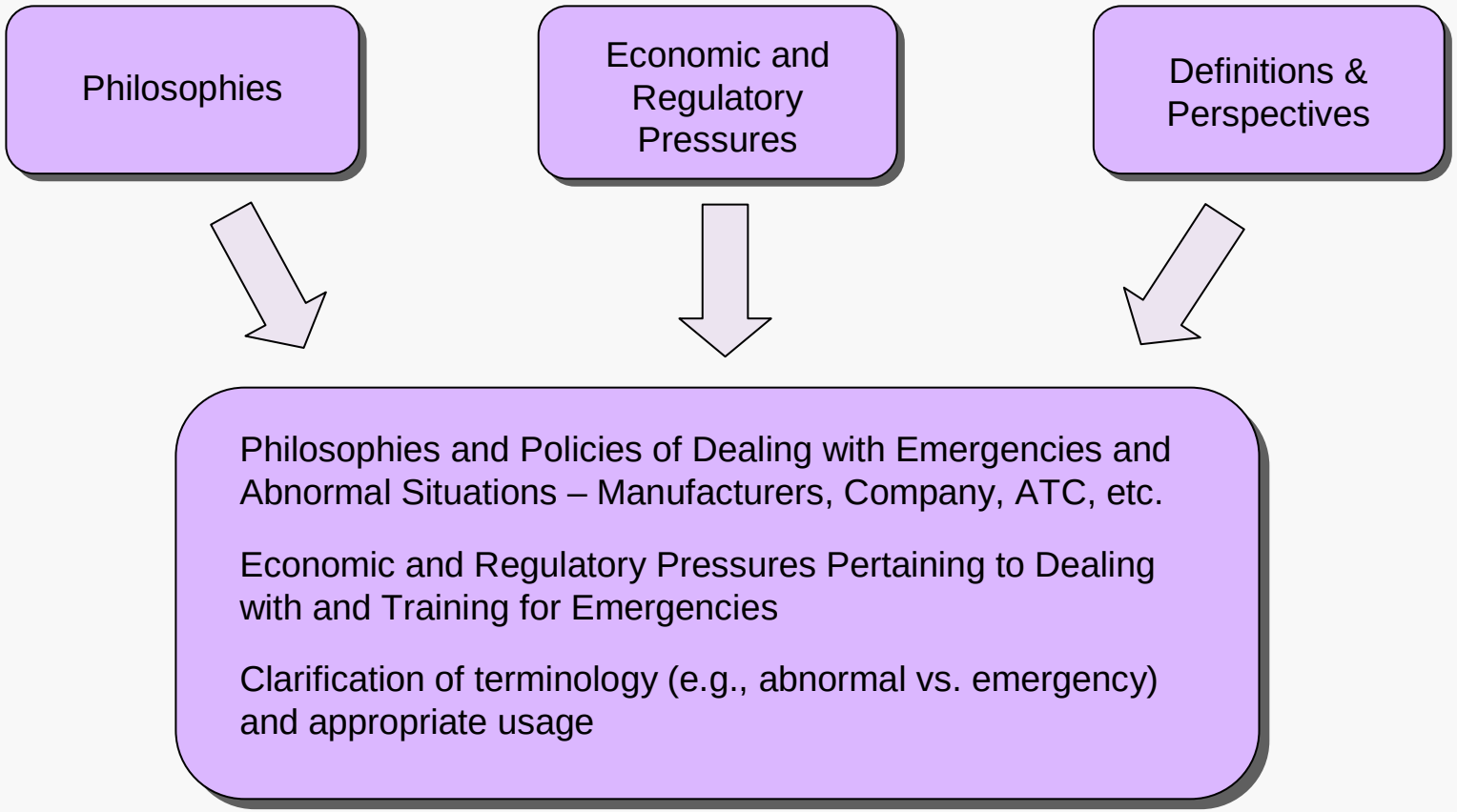
15 Different Categories of Issues:

- Broad, Over-arching Issues (3)
- Issues Related to Checklists and Procedures (3)
- Issues Related to Humans (5)
- Issues Related to the Aircraft (2)
- Issues Related to Training (1)
- Selected Emergency Equipment and Evacuation Issues (1)

Broad, Over-arching Issues



15 Different Categories of Issues:

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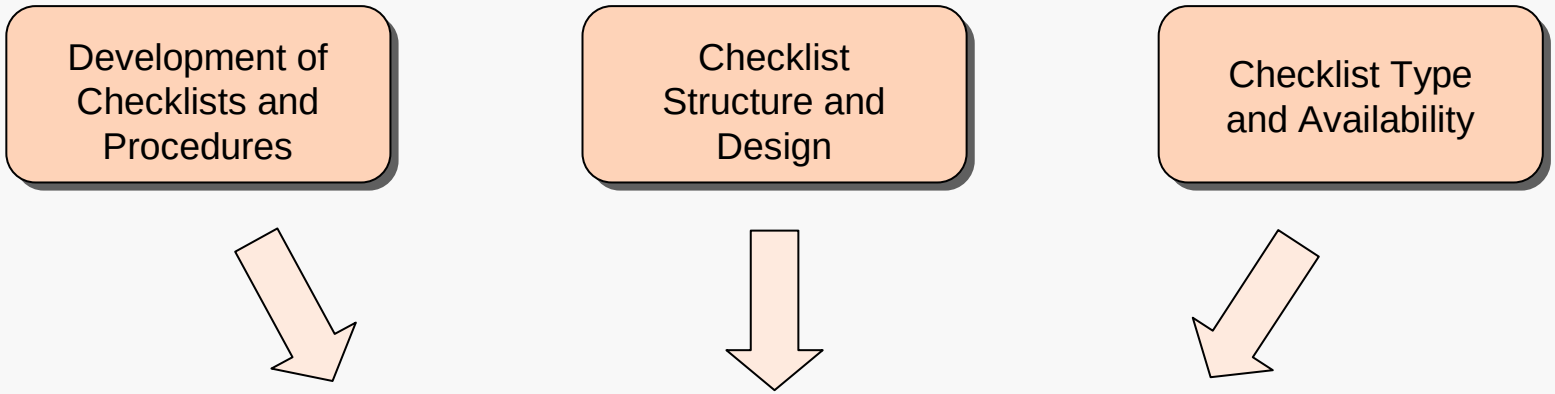
Checklist and Procedures Issues



Development of Checklists and Procedures – When? By whom? How certified? Are they standardized? Etc.

Checklist Structure and Design – Items, memory items, navigation, locating correct checklist, nomenclature, format, etc.

Checklist Type and Availability – Paper, mechanical, electronic (integrated with aircraft and in electronic flight bags), etc.

DC-9 Hard Landing – Nashville, Tennessee – January 7, 1996

- Difficulty raising gear after takeoff from Atlanta
- Crew used UNABLE TO RAISE GEAR LEVER procedure in the QRH
- While still climbing, crew realized cabin pressurization and takeoff warning systems were still in the ground mode
- Crew pulled the ground control relay circuit breakers, as directed by same QRH checklist, to place systems in flight mode
- Later portion of the checklist directed the crew to reset the circuit breakers which they did on final approach approximately 100 feet (30.5 meters) above the ground
- Ground spoilers deployed, aircraft hit the ground very hard, nose wheel separated from the aircraft

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QRH

UNABLE TO RAISE GEAR LEVER

NOSE STEERING WHEEL ..... OPERATE (C)

If steering wheel does NOT turn and centering indices are aligned:

Indicates a malfunction of the anti–retraction mechanism.

If desired, retract landing gear:

GEAR HANDLE RELEASE BUTTON ..... PUSH (PNF)

GEAR LEVER ..... UP (PNF)

If steering wheel turns:

DO NOT RETRACT THE GEAR

Indicates ground shift mechanism is still in the ground mode.

No auto–pressurization, and takeoff warning horn will sound when flaps/slats are retracted.

The ground control relay electrical circuits can be placed in the flight mode by pulling the Ground Control Relay circuit breakers (H20 and J20).

Do not exceed VLE (300 kts/M.70).

Approach and landing:

If landing gear was not retracted prior to landing, ground spoilers must be operated manually.

AIRPLANE ..... DEPRESSURIZE (PNF)

ANTI–SKID SWITCH (before 30 kts) ..... OFF (PNF)

GROUND CONTROL RELAY C/Bs (if pulled)
(H20 and J20) ..... RESET (C or FO)

AOM

UNABLE TO RAISE GEAR LEVER

NOTE

Indicates possible malfunction of ground shift.

Approach and landing:

If landing gear was not retracted prior to landing, ground spoilers must be operated manually.

AIRPLANE ..... DEPRESSURIZE (PNF)
– Ensure airplane is depressurized prior to landing.

ANTI–SKID SWITCH (before 30 kts) ..... OFF (PNF)
– During landing rollout and prior to 30 kts, momentarily release brakes and place Anti–skid switch to OFF.

GROUND CONTROL RELAY C/Bs (if pulled)
(H20 and J20) ..... RESET (C or FO)
– Reset Ground Control Relay circuit breakers during taxi and verify that circuits are in the ground mode.

Philosophy of Response to Emergencies

Evident in Checklist Design

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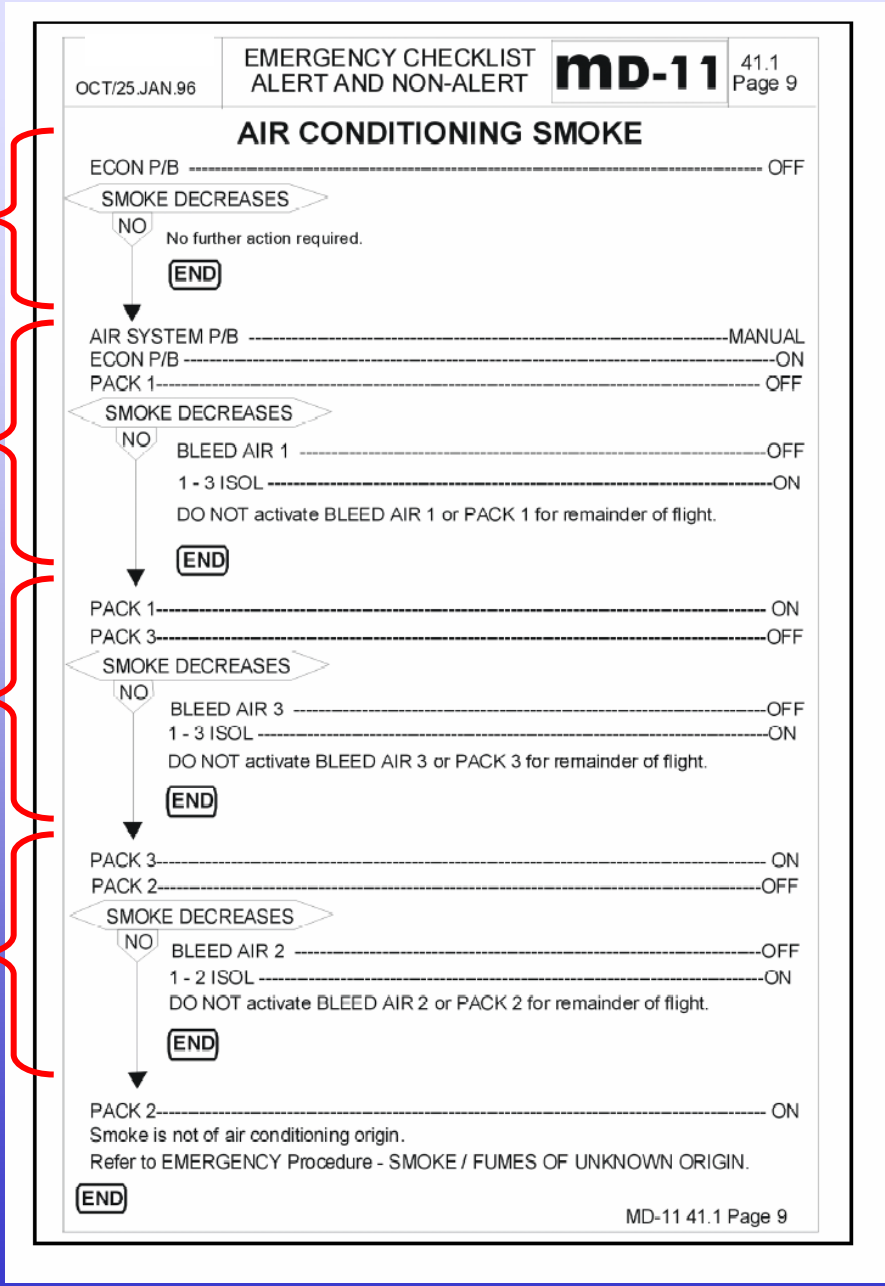
MD-11 In-flight Fire
Nova Scotia, Canada
September 2, 1998



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AIR CONDITIONING SMOKE

ECON P/B ---------- OFF

SMOKE DECREASES

NO

No further action required.

END

AIR SYSTEM P/B ---------- MANUAL
ECON P/B ---------- ON
PACK 1 ---------- OFF

SMOKE DECREASES

NO

BLEED AIR 1 ---------- OFF
1 - 3 ISOL ---------- ON
DO NOT activate BLEED AIR 1 or PACK 1 for remainder of flight.

END

PACK 1 ---------- ON
PACK 3 ---------- OFF

SMOKE DECREASES

NO

BLEED AIR 3 ---------- OFF
1 - 3 ISOL ---------- ON
DO NOT activate BLEED AIR 3 or PACK 3 for remainder of flight.

END

PACK 3 ---------- ON
PACK 2 ---------- OFF

SMOKE DECREASES

NO

BLEED AIR 2 ---------- OFF
1 - 2 ISOL ---------- ON
DO NOT activate BLEED AIR 2 or PACK 2 for remainder of flight.

END

PACK 2 ---------- ON
Smoke is not of air conditioning origin.
Refer to EMERGENCY Procedure - SMOKE / FUMES OF UNKNOWN ORIGIN.

END

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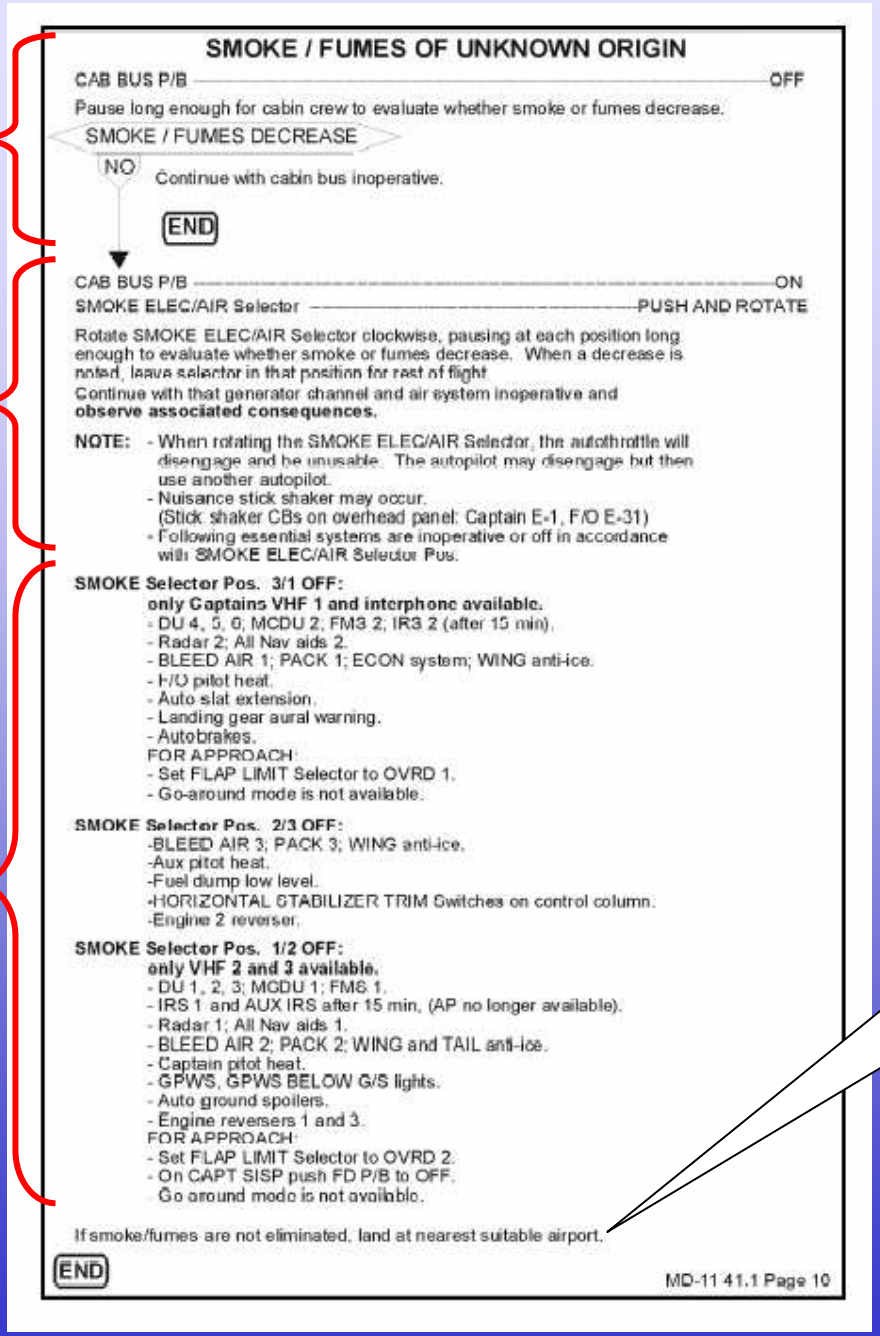

SMOKE / FUMES OF UNKNOWN ORIGIN

CAB BUS P/B ——— OFF

Pause long enough for cabin crew to evaluate whether smoke or fumes decrease.

SMOKE / FUMES DECREASE

NO — Continue with cabin bus inoperative.

END

CAB BUS P/B ——— ON

SMOKE ELEC/AIR Selector ——— PUSH AND ROTATE

Rotate SMOKE ELEC/AIR Selector clockwise, pausing at each position long enough to evaluate whether smoke or fumes decrease. When a decrease is noted, leave selector in that position for rest of flight.

Continue with that generator channel and air system inoperative and **observe associated consequences.**

NOTE:
- When rotating the SMOKE ELEC/AIR Selector, the autothrottle will disengage and be unusable. The autopilot may disengage but then use another autopilot.
- Nuisance stick shaker may occur. (Stick shaker CBs on overhead panel: Captain E-1, F/O E-31)
- Following essential systems are inoperative or off in accordance with SMOKE ELEC/AIR Selector Pos.

SMOKE Selector Pos. 3/1 OFF:
only Captains VHF 1 and interphone available.
- DU 4, 5, 6; MCDU 2; FM3 2; IR3 2 (after 15 min).
- Radar 2; All Nav aids 2.
- BLEED AIR 1; PACK 1; ECON system; WING anti-ice.
- F/O pitot heat.
- Auto slat extension.
- Landing gear aural warning.
- Autobrakes.

FOR APPROACH:
- Set FLAP LIMIT Selector to OVRD 1.
- Go-around mode is not available.

SMOKE Selector Pos. 2/3 OFF:
- BLEED AIR 3; PACK 3; WING anti-ice.
- Aux pitot heat.
- Fuel dump low level.
- HORIZONTAL STABILIZER TRIM Switches on control column.
- Engine 2 reverser.

SMOKE Selector Pos. 1/2 OFF:
only VHF 2 and 3 available.
- DU 1, 2, 3; MCDU 1; FM6 1.
- IRS 1 and AUX IRS after 15 min. (AP no longer available).
- Radar 1; All Nav aids 1.
- BLEED AIR 2; PACK 2; WING and TAIL anti-ice.
- Captain pitot heat.
- GPWS, GPWS BELOW G/S lights.
- Auto ground spoilers.
- Engine reversers 1 and 3.

FOR APPROACH:
- Set FLAP LIMIT Selector to OVRD 2.
- On CAPT SISP push FD P/B to OFF.
- Go around mode is not available.

If smoke/fumes are not eliminated, land at nearest suitable airport.

END

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If smoke/fumes are not eliminated, land at nearest suitable airport

Philosophy of Response to Emergencies – Checklist Design

In a study of 15 in-flight fires that occurred between January 1967 and September 1998, the TSB of Canada determined that the average amount of time between the detection of an on-board fire and when the aircraft ditched, conducted a forced landing, or crashed was 17 minutes.

15 Different Categories of Issues:

- Broad, Over-arching Issues (3)
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- **Issues Related to Humans (5)**
- Issues Related to the Aircraft
- Issues Related to Training
- Selected Emergency Equipment and Evacuation Issues

Issues Related to Humans

- Crew Coordination & Response
- Checklist Use
- Human Performance
- Personnel Issues
- Roles and Behavior of Others

Distribution and prioritization of workload and tasks, distractions, etc.

Errors made when completing checklists, non-compliance, not accessing checklists at all, etc.

Effects of stress, time pressure, and workload on cognitive performance, memory, creative problem solving, etc.

Emotional / affective responses to stress

Influence of crew backgrounds, experience levels, company mergers, etc.

Role of cabin crew, ATC, dispatch, maintenance, ARFF, MedLink, etc. and the degree to which their procedures are consistent / complementary

B727 Rapid Decompression – Indianapolis, Indiana – May 12, 1996

- Right before reaching cruise altitude at FL330 (10058.4 meters), cabin altitude warning sounded
- CA helped FE to find the button to turn it off and noticed that the second pack was off
- As per the CA's instructions, FE said he turned the right pack on and then "went to manual AC and closed the outflow valve"
- In actuality, it appears the FE opened the outflow valve and the aircraft rapidly lost pressurization
- The CA, FE, and lead flight attendant each lost consciousness for a brief time during the event

B727 Rapid Decompression – Indianapolis, Indiana – May 12, 1996

- The FE did not use a checklist for re-instating the second pack

PACK REINSTATEMENT FOLLOWING AUTO PACK TRIP

ELECTRONIC PRESSURIZATION

After 1000 Feet AFL:

Both Pack Switches ..... OFF
Pack Reset Button ..... PUSH
Auto Pack Trip Switch ..... CUT OUT

If in AUTO mode:

One Pack Switch ..... ON

Do not reinstate second pack unless flaps are retracted.

When ready to reinstate second pack:
Second Pack Switch ..... ON

If in STANDBY mode:

– Cabin ALT Selector ..... SET 2000 FEET ABOVE *AIRPLANE'S* ALTITUDE
– Cabin Rate Switch ..... FULL INCREASE
– One Pack Switch ..... ON
After initial pressure surge and as rate of climb returns to zero:
Cabin ALT Selector ..... SET CRUISE CABIN PRESSURE ALTITUDE
– Cabin Rate Knob ..... SET AT INDEX OR AS REQUIRED
Adjust as required to maintain desired rate of change.

If in MANUAL mode:

– Outflow Valve ..... 1/4 to 1/2 OPEN
– One Pack Switch ..... ON
– Outflow Valve ..... ADJUST TO MAINTAIN DESIRED RATE OF CLIMB

When ready to reinstate second pack:
Cargo Heat Outflow Switch ..... CLOSE
Second Pack Switch ..... ON
When rate of climb stabilizes:
Cargo Heat Outflow Switch ..... NORMAL

B727 Rapid Decompression – Indianapolis, Indiana – May 12, 1996

- The FE did not use a checklist for re-instating the second pack
- The CA did not call for and the crew did not complete any emergency checklists including the decompression checklist and emergency descent checklist
- The CA did not put his oxygen mask on immediately when the altitude warning sounded as required by procedures

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DC-10 In-flight Fire – Newburgh, New York – September 5, 1996

- During cruise at 33,000 ft (10058.4 meters) cabin/cargo smoke warning light illuminated – the FO was the PF
- FE announced the memory items and then began to complete the printed SMOKE AND FIRE checklist
- The FE, without input from the CA, completed the checklist branch for “If Descent is NOT Required”

FIRE & SMOKE

1. **Oxygen Mask & Smoke Goggles (As Required)** ..... ON, 100%

2. **Crew & Courier Communications** ..... 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.

or

4. **If Descent is required** ..... PROCEED TO STEP 6

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 350 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)

DC-10 In-flight Fire – Newburgh, New York – September 5, 1996

- CA requested a descent and diversion 3 ½ minutes after the warning light illuminated

- The FE skipped two steps on the second checklist he completed: CABIN/CARGO SMOKE LIGHT ILLUMINATED

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 O_2 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)

DC-10 In-flight Fire – Newburgh, New York – September 5, 1996

- The emergency descent checklist was not called for or completed
- Upon landing, the aircraft was still partially pressurized and the crew's evacuation of the aircraft was impeded and delayed
- The crew did not complete the Evacuation Checklist

DC-10 In-flight Fire – Newburgh, New York – September 5, 1996

- The CA was very busy:
  - Monitoring the spread of the fire
  - Communicating with ATC
  - Trying to coordinate their diversion and emergency descent
  - Monitoring the flying pilot (FO)
  - Concerned with testing the fire detection system
  - Interactions with the FE

Ø The CA showed signs of being overloaded:

  - Emergency descent was delayed
  - Never called for any checklists to be completed
  - Did not adequately monitor the FE's completion of checklists
  - Mistakenly transmitted his remarks to the crew over the ATC frequency

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DC-10 In-flight Fire – Newburgh, New York – September 5, 1996

- The FE was very busy:
  - Selecting and completing emergency checklists and procedures
  - Trying to determine data and Vref speeds needed for landing
  - Completing normal approach and landing checklists
  - Monitoring the progress of the fire
  - Working with the CA to test the fire detection system

Ø The FE showed signs of being overloaded:

  - Missed items on checklists
  - Five times over the span of almost six minutes, he asked for the 3-letter identifier of the airport they were diverting to
  - Did not adequately monitor the status of the aircraft pressurization

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- **Issues Related to the Aircraft (2)**
- Issues Related to Training
- Selected Emergency Equipment and Evacuation Issues

Issues Related to the Aircraft

Critical Aircraft Systems

Automation Issues

Systems within flight protection envelopes, automated systems, etc.

Warnings, warning systems, and “warning overload”

What kinds of automation should be used and under what circumstances and when should automation not be used?

Issues in reverting to manual flying, degradation in hand flying skills, etc.

MD-81 Dual Engine Failure – Gottrora, Sweden – December 27, 1991

- 25 seconds after departing Stockholm the right engine surged
- The left engine surged 39 seconds later
- 77 seconds into the flight both engines lost power
- Grey smoke filled the cockpit and the crew attempted an emergency landing using only back-up instruments as the EFIS screens were blank
- Despite the aircraft breaking into 3 pieces on landing, all 129 on board survived

MD-81 Dual Engine Failure – Gottrora, Sweden – December 27, 1991

- On liftoff, clear ice was broken off the wings and ingested by the engines, damaging the fan stages. This damage lead to the engines surging

- Without the crew noticing, engine power was increased automatically through the effect of Automatic Thrust Restoration (ATR) which caused an increase in the intensity of the surging and contributed to the failure of the engines

- The airline company had no knowledge of ATR

B757 Loss of Control – Puerto Plata, Dominican Republic – February 2, 1996

- During the takeoff roll the CA indicated that his airspeed indicator was not working
- It appeared to start working properly once the aircraft began to climb but significant discrepancies existed between the CA's, FO's, and alternate airspeed indicators
- A few seconds later two advisory messages appeared on the EICAS display: RUDDER RATIO
  MACH/SPD TRIM
- The overspeed warning clacker sounded

B757 Loss of Control – Puerto Plata, Dominican Republic – February 2, 1996

- The center autopilot commanded an 18 degree nose up attitude and the autothrottles were at a very low power setting in response to very high airspeeds as indicated on the CA's PFD
- The autopilot and autothrottles disengaged
- The stall warning "stick shaker" was activated
- Great confusion reigned; power was applied and then removed more than once
- The FO selected Altitude Hold in an attempt to level off and give them time to sort out what was going on.
- However, the throttles were at too low of a power setting to maintain altitude

B757 Loss of Control – Puerto Plata, Dominican Republic – February 2, 1996

- Investigators determined that a pitot tube that provided information to the left Air Data Computer (ADC) was most likely completely blocked
- The left ADC provided information to the CA's airspeed indicator and the center autopilot
- There was no specific airspeed discrepancy warning on the B757
- The crew did not attempt to clarify the RUDDER RATIO or MACH/SPD TRIM advisories but it is unlikely that any related checklists would have proved useful

B757 Loss of Control – Puerto Plata, Dominican Republic – February 2, 1996

- Although the crew agreed that the alternate airspeed indicator was correct they continued to try to use (and be confused by) airspeed information on the PFDs
- The contradictory warnings and indicators were confusing
- The center autopilot and autothrottles contributed greatly to their problems at least initially
- The crew did not attempt to fly the aircraft manually and continued to try use automation that did not help them (i.e., Altitude Hold)

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Issues Related to Training

Training

Relevant training technologies and approaches

Initial vs. recurrent training in dealing with these situations

Skill acquisition and retention of procedures that are unpracticed or seldom practiced

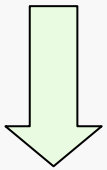
Training for "textbook" vs. "nonstandard" situations

Training for handling single vs. multiple problems

Joint training of flight and cabin crews

Selected Equipment and Evacuation Issues

Equipment and Evacuation Issues



Equipment that is problematic to use in an emergency (e.g., smoke goggles that do not fit over eyeglasses)

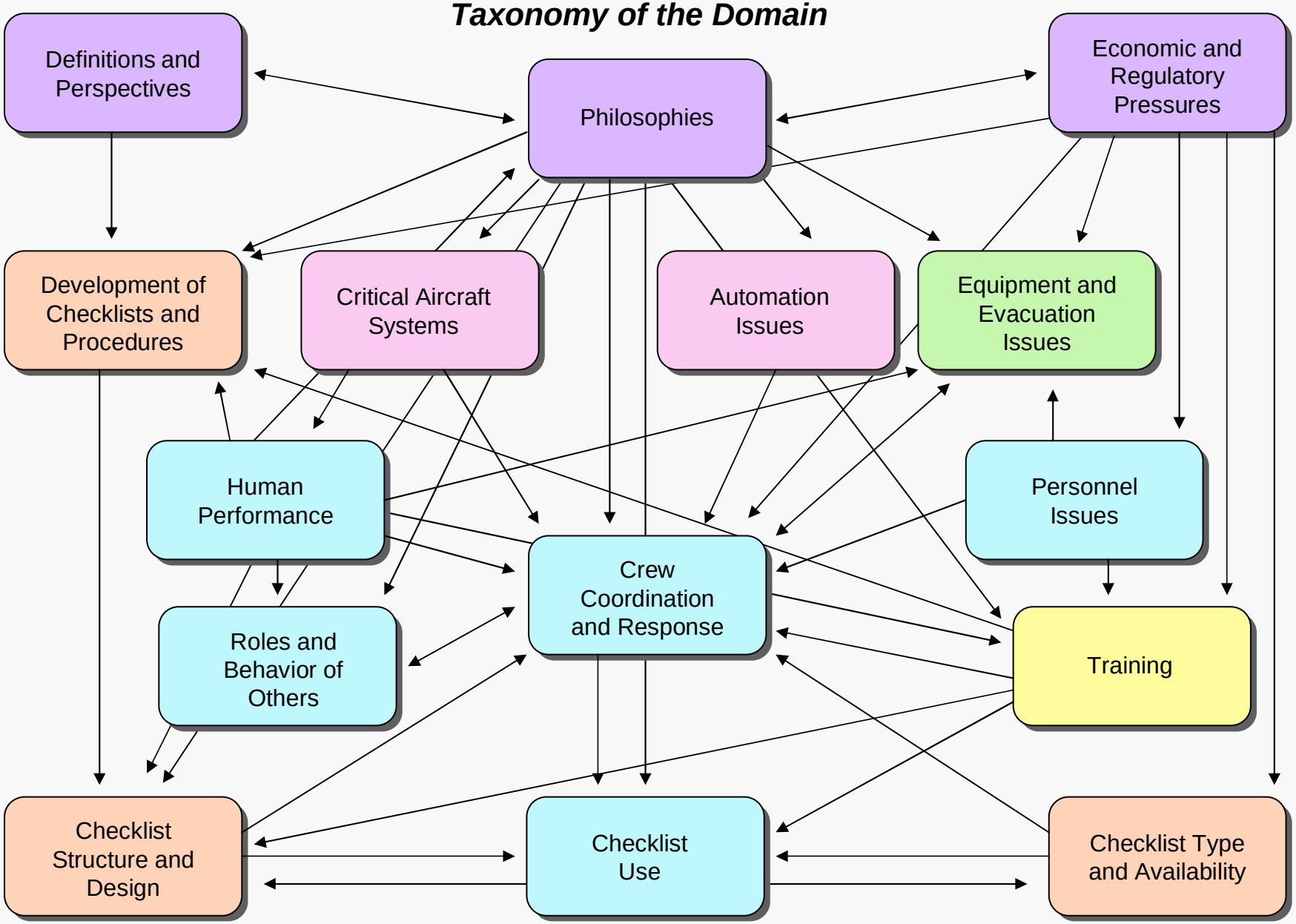
Inadequate training in the use of emergency equipment

Negative transfer (interference) of equipment usage across different aircraft types

Confusion or problems regarding the initiation of evacuations

Emergency and Abnormal Situations Project

Taxonomy of the Domain



Goal

Develop guidance for procedure development and certification, training, crew coordination, and situation management based on knowledge of the operational environment, human performance limitations, and cognitive vulnerabilities in real-world situations.

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Products and Deliverables

Intermediate Products:

Reports, Articles, Papers, Presentations

End Products:

Field Guides for

- Training Entities and Instructors
- Operators
- Manufacturers
- Regulatory Agencies (Certification, POIs)

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