
Emergency and Abnormal Situations Project

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Human Factors
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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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Emergency and Abnormal Situations Project

Taxonomy of the Domain

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)



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Taxonomy of the Domain

Broad, Over-arching Issues

Philosophies

Economic and
Regulatory
Pressures

Definitions &
Perspectives



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Philosophy of Response to Emergencies

Evident in Checklist Design



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

OCT/25 JAN.96	EMERGENCY CHECKLIST ALERT AND NON-ALERT	MD-11	41.1 Page 9
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			
MD-11 41.1 Page 9			

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; FMS 2; IR3 2 (after 15 min).
 - Radar 2; All Nav aids 2.
 - BLEED AIR 1; PACK 1; ECON system; WING anti-ice.
 - F/O pilot 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 pilot 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; FMS 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 pilot 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 SISF push FD P/B to OFF.
 - Go-around mode is not available.

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

END

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.



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Response to Emergencies:

Job Responsibilities Influence Perspectives and Behavior



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MD-83 Jammed Stabilizer Trim – Port Hueneme, California – Jan. 31, 2000

DISPATCH: ...If uh you want to land at LA of course for safety reasons we will do that uh wu we'll uh tell you though that if we land in LA uh we'll be looking at probably an hour to an hour and a half we have a major flow program going right now uh that's for ATC back in San Francisco



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MD-83 Jammed Stabilizer Trim – Port Hueneme, California – Jan. 31, 2000

LA-OPS: ok also uh....just be advised uh because you're an international arrival we have to get landing rights. I don't know how long that's gonna take me...but uh I have to clear it all through customs first.



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MD-83 Jammed Stabilizer Trim – Port Hueneme, California – Jan. 31, 2000

MX: yea did you try the suitcase handles and the pickle switches, right?

CA: yea we tried everything together, uh...we've run just about everything...

MX: um yea I just wanted to know if you tried the pickles switches and the suitcase handles to see if it was movin in with any of the uh other switches other than the uh suitcase handles alone or nothing

CA: yea we tried just about every iteration

MX: and alternate's inop too huh?

CA: yup, its just it appears to be jammed the uh the whole thing it spikes out when we use the primary. We got AC load that tells me the motor's tryin to run but the brake won't move it when we use the alternate. Nothing happens



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MD-83 Jammed Stabilizer Trim – Port Hueneme, California – Jan. 31, 2000

Dispatchers – Movement and scheduling of aircraft

Operations Agents – Take care of logistics related to landing

Maintenance Personnel – Fix broken airplanes

All were trying to do their jobs as they normally do them.

Very hard to set aside the mindset for normal mode of operations, recognize and communicate the severity of a situation, and to put all other considerations aside to get the airplane safely on the ground



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Emergency and Abnormal Situations Project

Taxonomy of the Domain

15 Different Categories of Issues:

-  Broad, Over-arching Issues
-  **Issues Related to Checklists and Procedures**
-  Issues Related to Humans
-  Issues Related to the Aircraft
-  Issues Related to Training
-  Selected Emergency Equipment and Evacuation Issues



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Emergency and Abnormal Situations Project

Taxonomy of the Domain

Checklist and Procedures Issues

Development of
Checklists and
Procedures

Checklist
Structure and
Design

Checklist Type
and Availability



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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

QUICK REFERENCE HANDBOOK PILOT MANUAL - DC-9

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

PAGE: A-11-2
DATE: 3/13/95
REVISION: 8

ABNORMAL PROCEDURES AIRCRAFT OPERATING MANUAL - DC-9

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.

SECTION 3-1

ONE ENGINE INOPERATIVE LANDING

- Plan a flaps 15 landing
- Minimum VREF 15 + 5 on final approach

DESCENT - APPROACH

ANTI-ICE..... AS REQUIRED
TCAS MODE SELECTOR T/A ONLY
ENG START SWITCH (Operating ENG)..... ON
ALTIMETER & INST SET & CHECKED
*EPR & IAS BUGS CHECKED & SET, VREF 15

* **NOTE** If additional Go-Around thrust is desired
accomplish the following below 10,000 ft:

ISOLATION VALVE..... CLOSE
NO 1 ENG BLD AIR SW..... OFF
APU BLD AIR SW ON

CAUTION Do not open the APU bleed
valve if the ENG FIRE LIGHT
remains illuminated:

NO 2 ENG BLEED AIR SW..... OFF
(Add .03 to Go-Around EPR)

GROUND PROX INHIBIT
FUEL..... BALANCE

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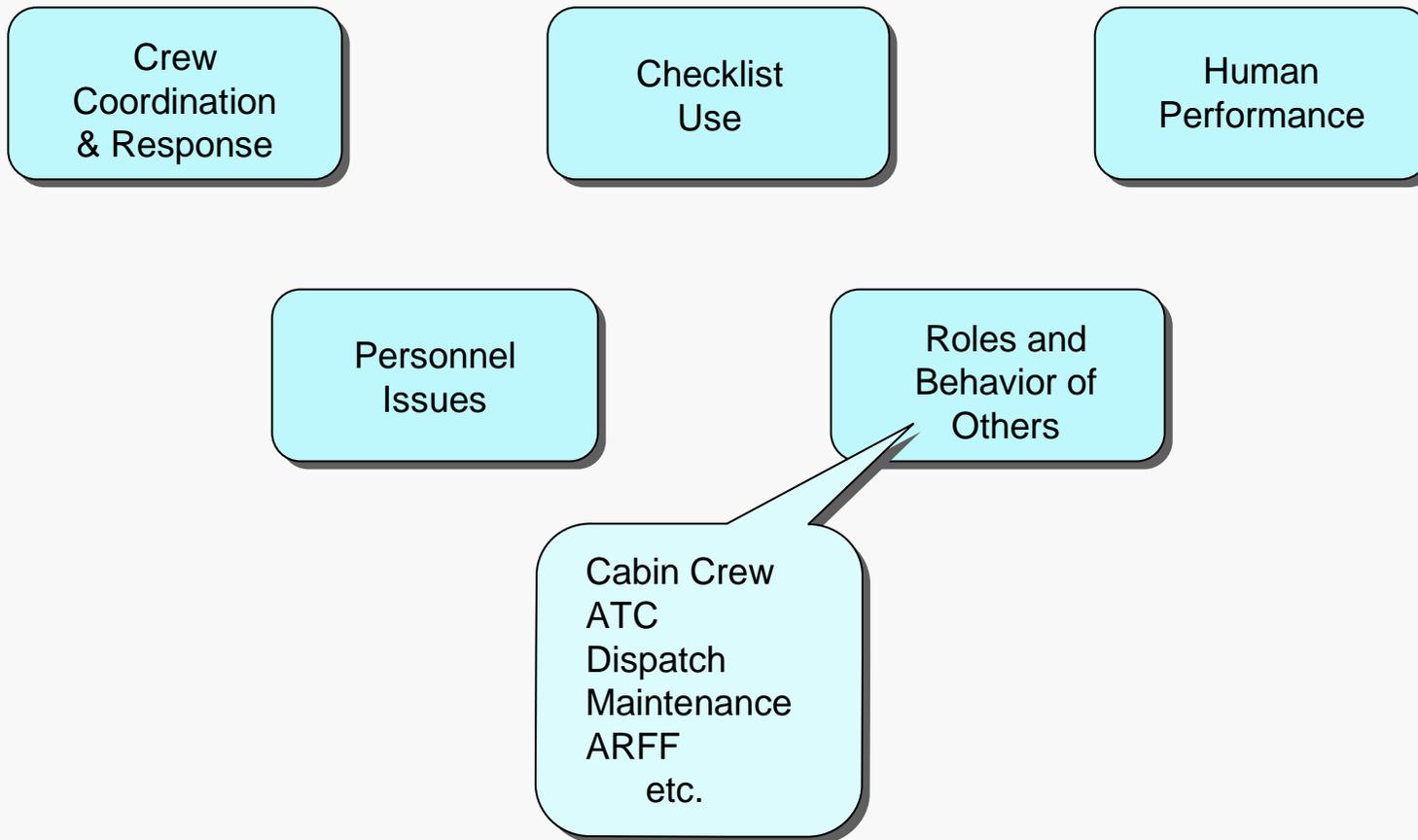
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Taxonomy of the Domain

Issues Related to Humans



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”



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DC-10 FLIGHT MANUAL

FIRE & SMOKE

1. Oxygen Mask & Smoke Goggles (As Required) ON, 100% ESTABLISH
2. Crew & Courier Communications
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 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. **AIRCRAFT CONDITIONING 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.

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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



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DC-10 FLIGHT MANUAL

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

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



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

- ∅ 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

- 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



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

∅ 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

• 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



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Taxonomy of the Domain

Issues Related to the Aircraft

Critical Aircraft
Systems

Automation
Issues



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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



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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



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Taxonomy of the Domain

Issues Related to Training

Training



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ASRS Report – Accession Number 463186

Procedures and checklists worked well, but we did not don goggles (and ended up not needing them). The thing about goggles is they must be donned first – before the mask!

But procedures training and habit all result in donning the mask first. Then if the goggles are required, the mask has to be removed. 'Smoke Procedures' should call for goggles first without analysis for need.



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Taxonomy of the Domain

Selected Equipment and Evacuation Issues

Equipment and
Evacuation Issues



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717-200 – Flushing, New York – March 26, 2003 – Preliminary Report

- Nearing the final approach fix the engine and alert display (EAD) indicated that the left generator had failed
- The display units (DU) and standby instruments went dark and then began flashing off and on
- The crew then noticed a burning smell in the cockpit
- The forward flight attendants also noticed a burning smell in the cabin and determined the handset used to make announcements and contact the cockpit was inoperative
- After landing the lead flight attendant tried banging on the cockpit door and speaking loudly to get the attention of the flight crew



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717-200 – Flushing, New York – March 26, 2003 – Preliminary Report

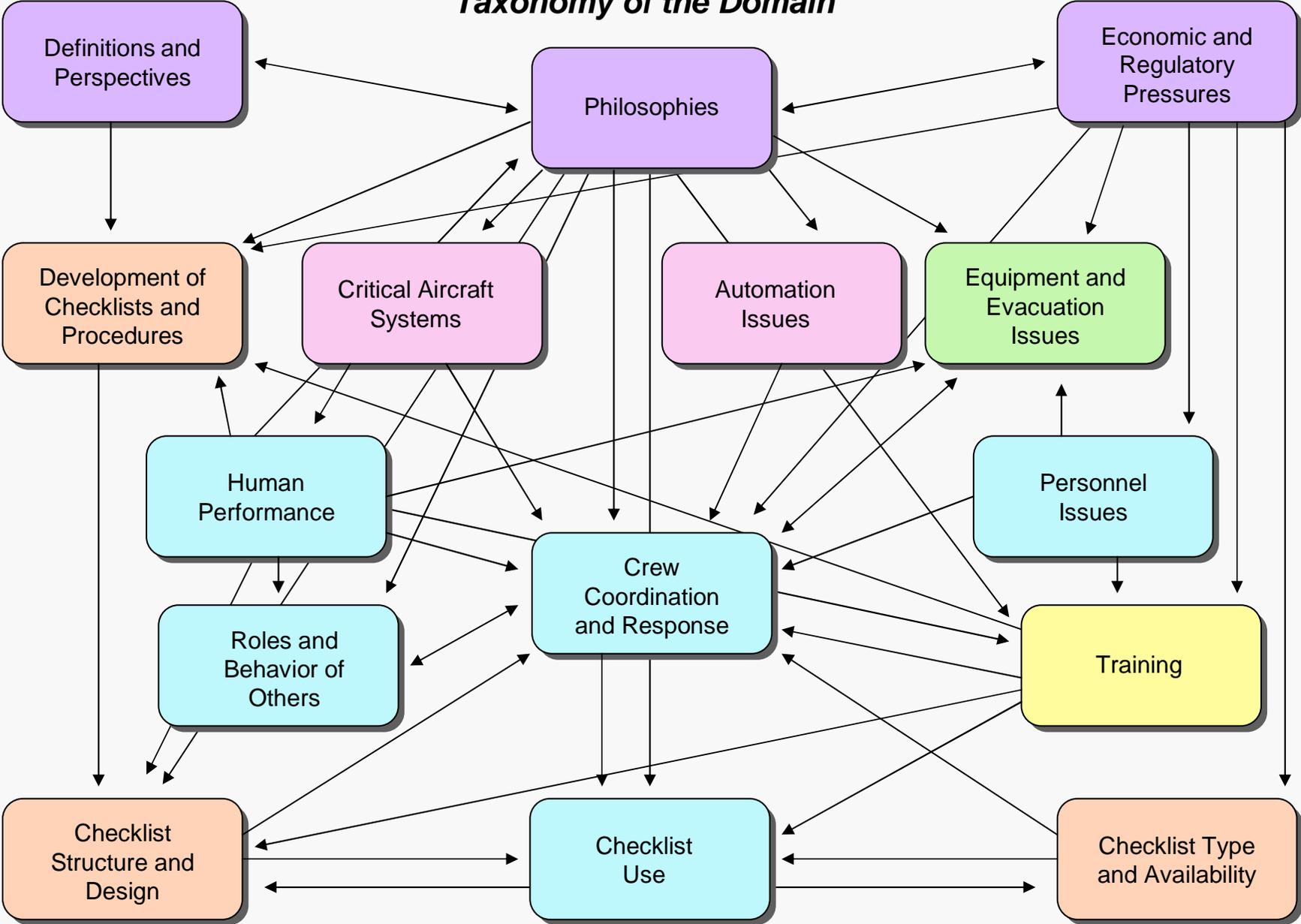
- ∅ The flight crew did not hear the flight attendant banging on the door or speaking loudly



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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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What Are We Missing?

How Can We Learn from You and Your Experiences?

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