# Overview of the 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

# *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) |

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)

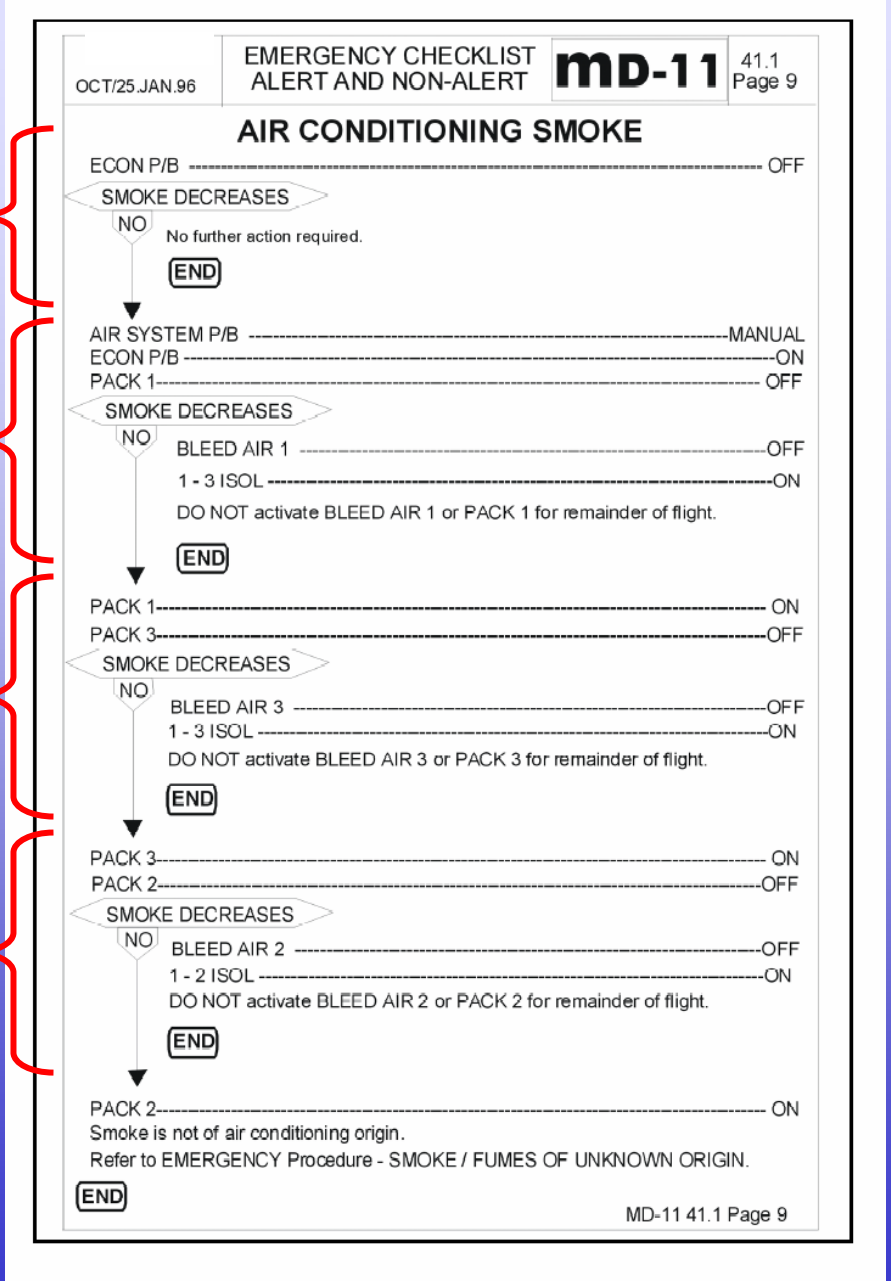
# Broad, Over-arching Issues

- Philosophies
- Economic and Regulatory Pressures
- Definitions & Perspectives

# Philosophy of Response to Emergencies

## Evident in Checklist Design

*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



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.

# Response to Emergencies:

## Job Responsibilities Influence Perspectives and Behavior

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

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.

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

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

15 Different Categories of Issues:

- Broad, Over-arching Issues
- **Issues Related to Checklists and Procedures**
- Issues Related to Humans
- Issues Related to the Aircraft
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# Checklist and Procedures Issues

- Development of Checklists and Procedures
- Checklist Structure and Design
- Checklist Type and Availability

# *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

# 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.

## 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

EAR 1.97

* **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

# AIR PACK FAULT

**If pack not supplied:**

**If in single pack operation:**

REMAINING PACK ..... ON

PACK (Affected) ..... OFF

**If pack overheat:**

**If in single pack operation:**

REMAINING PACK ..... ON

PACK (Affected) ..... OFF

PACK MODE SEL (Affected) ..... MAN/COLD

**When turb temp below limit:**

PACK (Affected) ..... ON

PACK (Affected) ..... MAN CTL

**If both packs inoperative:**

MAX ALTITUDE ..... 10,000 FT/MEA

**WHEN ΔP BELOW 1 PSI:**

RAM AIR ..... ON

**PROC:** AIR PACK FAULT

**If Pack Fault due to low bleed air supply, a bleed leak does not exist, and if WING ANTI-ICE not required:**

BLEED VALVE (Affected sided) ..... OFF

AIR X FEED ..... MAN/IN LINE

PACK (Affected) ..... ON

**If above FL370:**

ECON FLOW ..... ON

**END OF PROCEDURE**

**If Pack Fault due to low bleed air supply, a bleed leak does not exist, and if WING ANTI-ICE not required:**

# *ASRS Report – Accession Number 437817*

Hydraulic caution light illuminated while taxiing….I..completed the QRH checklist…We rolled to a stop in the grass…A very poorly written QRH emergency checklist, I believe should be modified and improved.

CALLBACK: …The checklist is for use in-flight, not on the ground…no changes to the checklist have been made in the 2 months since the incident occurred.

15 Different Categories of Issues:

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- **Issues Related to Humans**
- Issues Related to the Aircraft
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- Selected Emergency Equipment and Evacuation Issues

# Issues Related to Humans

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

# *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.

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

or

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

➢ 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

# *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

➢ 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

# *ASRS Report – Accession Number 437830*

The…events took place over a time span of less than 4 minutes during a critical phase of flight…the events occurred simultaneously with radio transmissions, configuration changes, airspeed changes and constantly changing altitude…

What we learned from this event is that running the emergency checklists may not be a classical situation where one has plenty of time for analysis and application of curative measures.

# *ASRS Report – Accession Number 433902*

We were told to execute a left 360 degree turn. We questioned this with the controller, but he said it was necessary for separation. We reluctantly complied since we did not have a need to land immediately. I felt that this was not acceptable, as we were an emergency.

15 Different Categories of Issues:

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# Issues Related to the Aircraft

Critical Aircraft Systems

Automation Issues

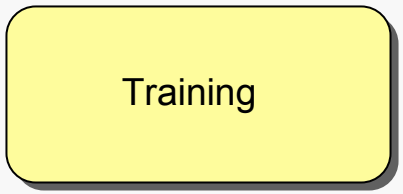
- During the takeoff roll the CA indicated that his airspeed indicator was not working
- It appeared to start working properly once the aircraft began to climb but significant discrepancies existed between the CA's, FO's, and alternate airspeed indicators
- A few seconds later two advisory messages appeared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

- 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

- Investigators determined that a pitot tube that provided information to the left Air Data Computer (ADC) had most likely been 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

- 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)

# Issues Related to Training



# *BAe Jetstream 32 Loss of Control – Morrisville, NC – December 13, 1994*

- Crew intercepted localizer ILS approach to runway 5L at Raleigh Durham – CA was the PF
- At final approach fix descending through 2,100 ft (640 meters) an illuminated ignition light led the CA to believe the left engine had flamed out
- During a missed approach procedure, the CA lost control of the aircraft and it struck terrain – three passengers survived the accident

- The illuminated ignition light was actually a minor transient anomaly. Both engines functioned normally throughout the flight until impact
- Company provided incorrect training by associating the ignition light with an engine failure
- Training did not adequately address recognition of an engine failure at low power

# *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.

# Selected Equipment and Evacuation Issues

Equipment and Evacuation Issues

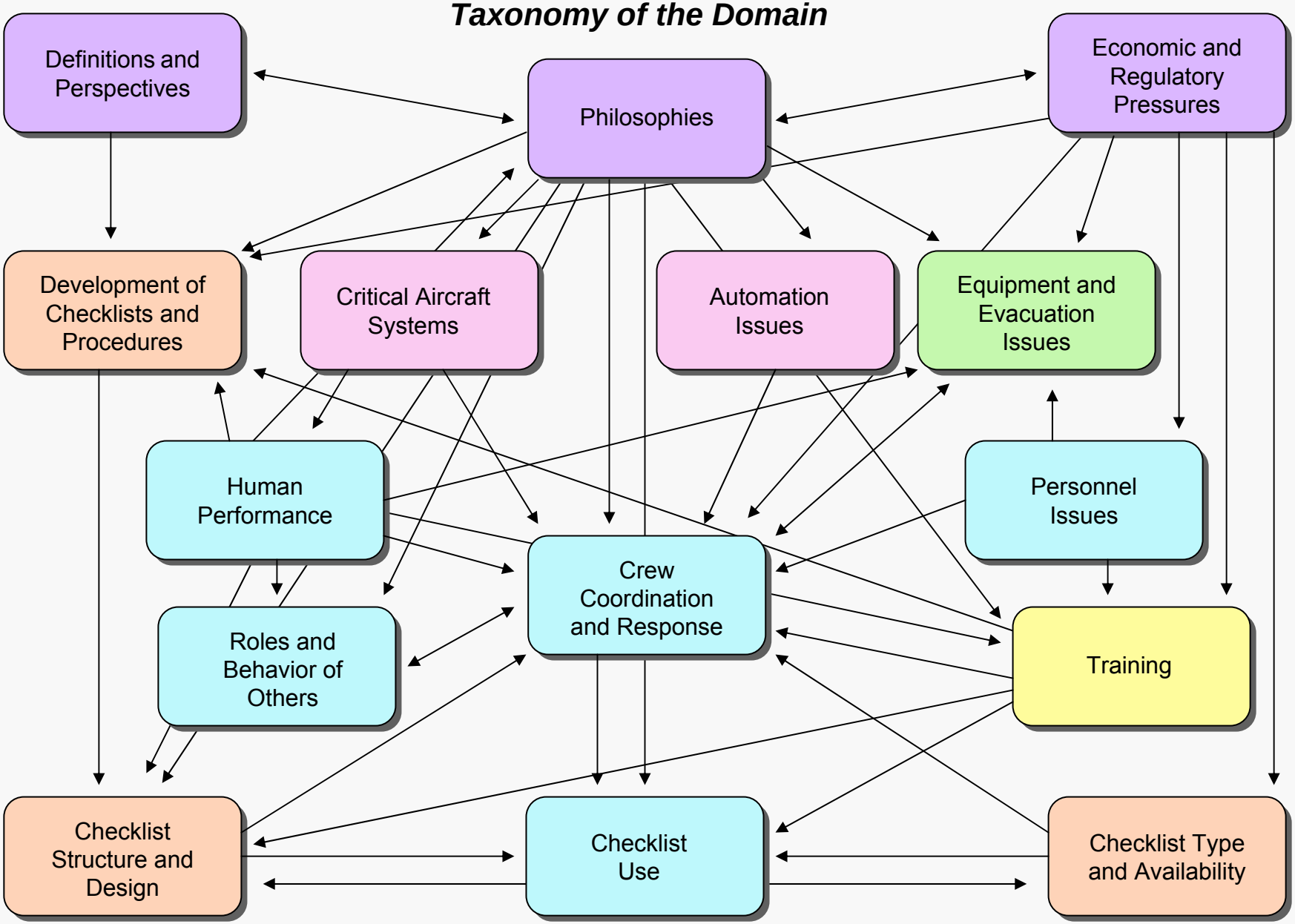
# *717-200 – Flushing, New York – March 26, 2003 – Preliminary Report*

- 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

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

# *Emergency and Abnormal Situations Project*

## ***Taxonomy of the Domain***



# *A Few Current and Recently Completed Studies*

- Current Practices in Emergency and Abnormal Training for Flight Crews
- Boeing Checklist Development Process, Design, and Philosophy: B777 ECL and QRH, B737 QRH
- Non-normal Checklists: Issues in Philosophy, Design, and Use
- Stress and Cognition – A Review of the Scientific Literature
- Pilot Critical Incident Interviews
- Emergency and Abnormal Situations: ASRS Incident and NTSB Accident Reviews
- Sponsored Industry-wide International Symposium on Emergency and Abnormal Situations in Aviation – June 2003

# *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.

# *Products and Deliverables*

## Intermediate Products:

Reports, Articles, Papers, Presentations

## End Products:

*Field Guides* for

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

# *EAS Project Team*

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