

Emergency and Abnormal Situations Project

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NASA Ames Research Center



Human Factors
research and technology



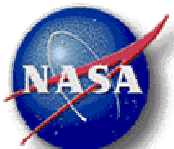
The Challenge

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,
Bombardier

Regulatory and
Governmental Agencies: FAA, CAA (UK), JAA, ICAO, Eurocontrol

Unions and
Trade Groups: ALPA, APA, SWAPA, ATA, ADF







Accident Investigation
Bodies: NTSB, TSB of Canada, ISASI

Airlines: Airborne Express, Air Canada, Alaska,
Aloha, American, Atlantic Southeast,
Cathay Pacific, Continental, Delta, Fed
Ex, Frontier, Hawaiian, Horizon,
JetBlue, Southwest, United, UPS,
US Airways, TWA (prior to merger)



Emergency and Abnormal Situations Project *Taxonomy of the Domain*

15 Different Categories of Issues:

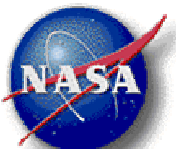
-  Broad, Over-arching Issues (3)
-  Issues Related to Checklists and Procedures (3)
-  Issues Related to Humans (5)
-  Issues Related to the Aircraft (2)
-  Issues Related to Training (1)
-  Selected Emergency Equipment and Evacuation Issues (1)



Emergency and Abnormal Situations Project *Taxonomy of the Domain*

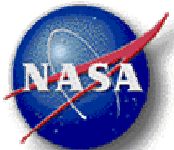
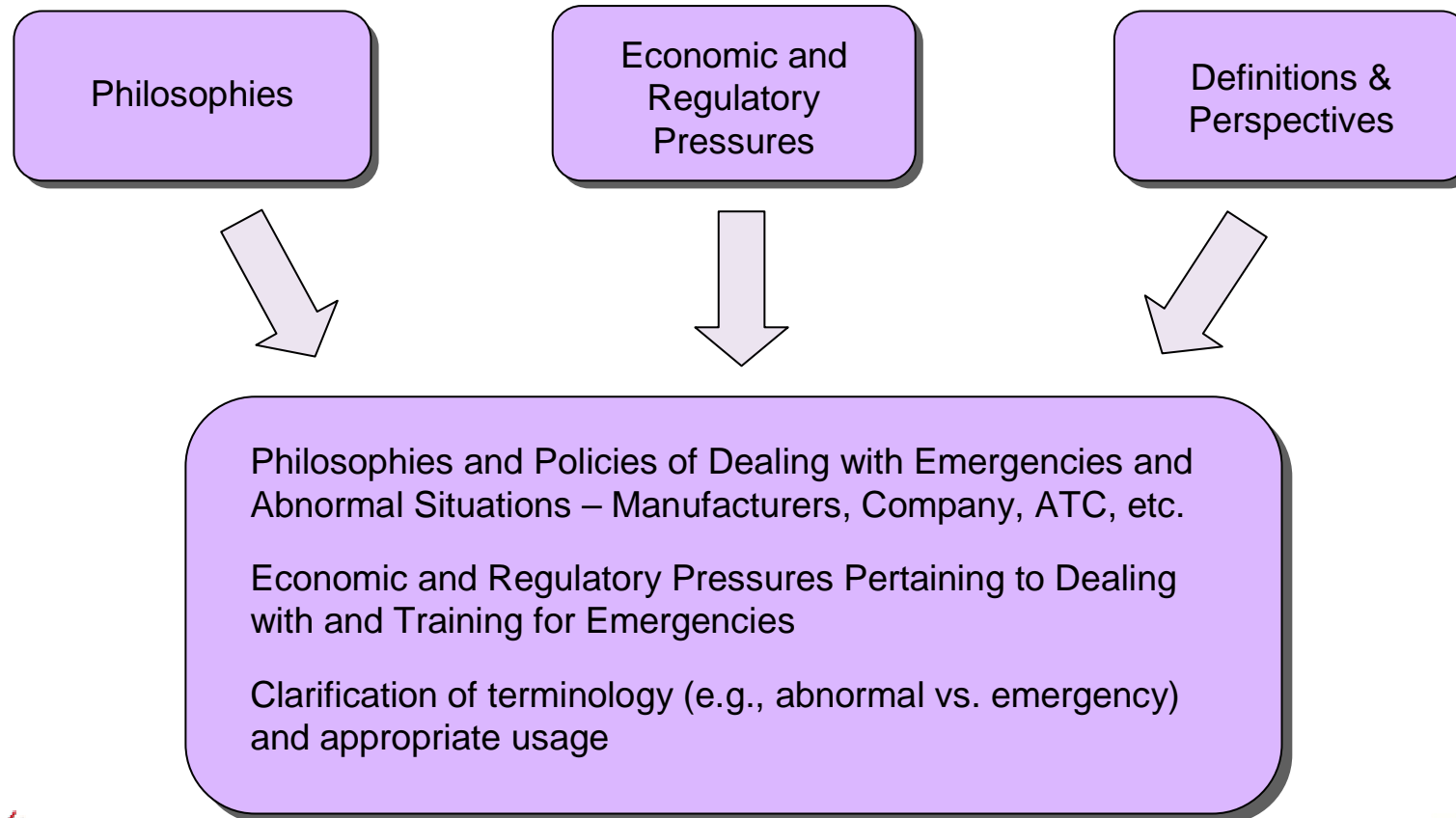
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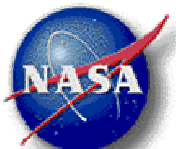
Emergency and Abnormal Situations Project Taxonomy of the Domain

Broad, Over-arching Issues



Philosophy of Response to Emergencies

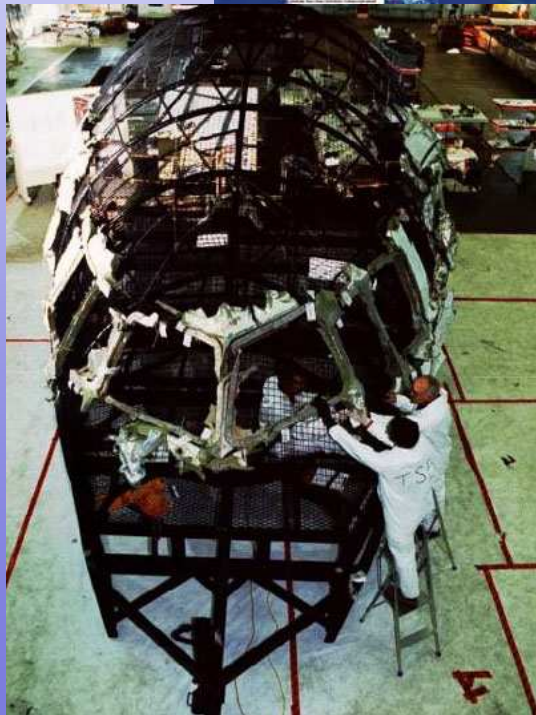
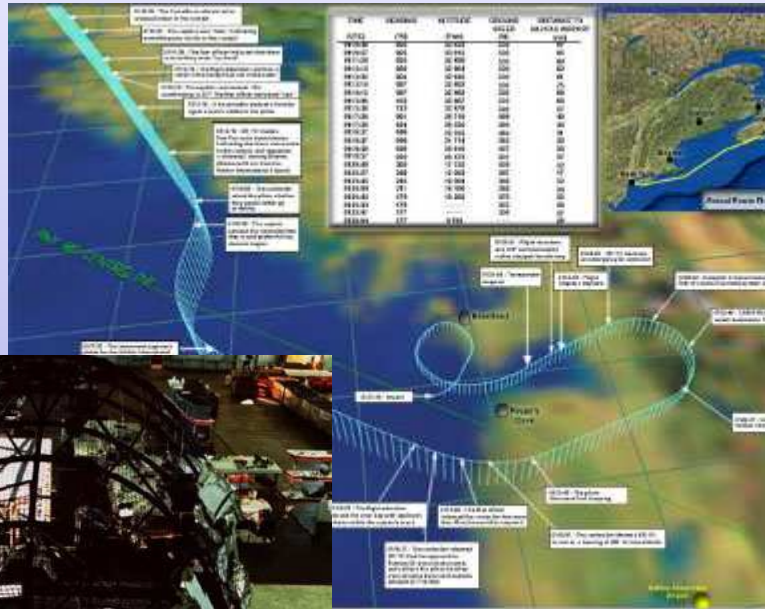
Evident in Checklist Design



Human Factors
research and technology



Swissair 111 - In-flight Fire Nova Scotia, Canada September 2, 1998



EMERGENCY CHECKLIST **md-11** 41.1
ALERT AND NON-ALERT 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

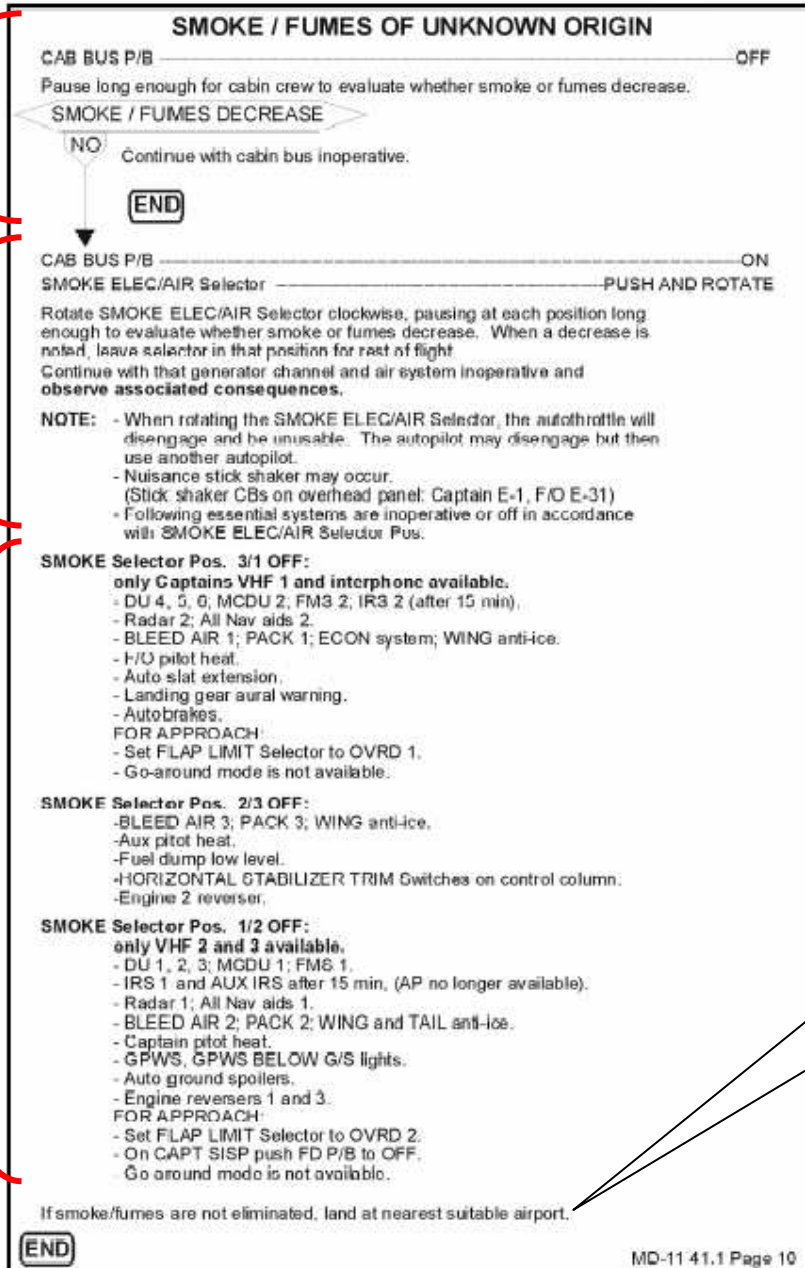
PACK 2 ----- ON

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

END

MD-11 41.1 Page 9

Swissair 111 - In-flight Fire Nova Scotia, Canada September 2, 1998



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

ValueJet 592 - In-flight Fire, Florida Everglades, May 11, 1996



ELECTRICAL SMOKE OR FIRE

OXYGEN MASKS AND SMOKE GOGGLES	ON/100%
RADIO RACK Switch	VENTURI
CABIN PRESSURE Control	MANUAL
EMER PWR Switch	ON
GEN Control and APU Bus Switches	OFF

NOTE: Wait a reasonable time to determine whether to follow step A or B below.

A If smoke continues:

AC and DC BUS X TIE Switches	OPEN
R & L GEN or APU BUS Switches	ON
F/O FLT INSTRUMENTS	CHECK
EMER PWR Switch	OFF
AC EMERG FEED C/B's (K10 & L11)	PULL

NOTE: If smoke disappears, fault is on AC emergency bus. If smoke continues:

AC EMERG FEED C/B's (K10 & L11)	RESET
DC EMERG FEED C/B (M36)	PULL

[930, 960 Series A/C (N37)]

NOTE: If smoke disappears, fault is on DC emergency bus. If smoke continues:

DC EMERG FEED C/B (M36)	RESET
-------------------------	-------

[930, 960 Series A/C (N37)]

BATT Switch OFF

NOTE: If smoke disappears, fault is on battery bus. If smoke continues:

BATT Switch	ON
BATT DIRECT BUS C/B's(Overhead)	PULL

NOTE: If smoke continues:

BATT DIRECT BUS C/B's(Overhead)	RESET
DC TRANSFER BUS FEED C/B(M35)	PULL

[930, 960 Series A/C (N37)]

[A/C #960 (M36)]

B If smoke stops or decreases, at Captain's discretion:

AC & DC X-TIE Switches	OPEN
LEFT GEN Switch	ON

NOTE: If smoke reappears, fault is on left gen bus, left AC bus, left DC bus, or AC X-tie is shorted:

L GEN Switch	OFF
R GEN Switch	ON

F/O FLT INSTRUMENTS	CHECK
EMGNCY POWER Switch	OFF

NOTE: If smoke reappears, fault is on right gen bus, right AC bus, right DC bus, ground service AC bus, battery charger, or AC X-tie is shorted:

[END]







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.



Emergency and Abnormal Situations Project *Taxonomy of the Domain*

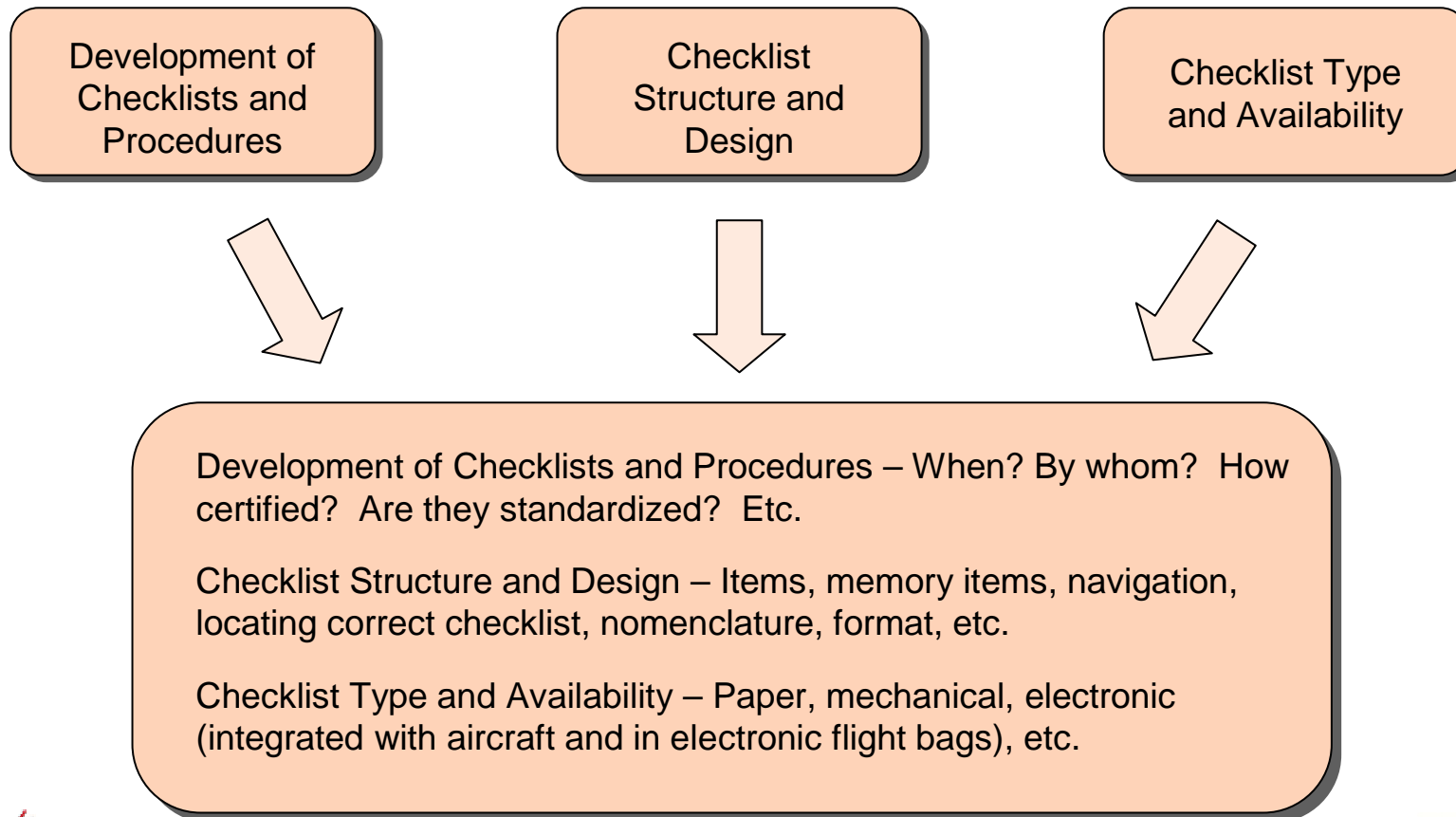
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Emergency and Abnormal Situations Project Taxonomy of the Domain

Checklist and Procedures Issues



Valujet 558 - DC-9 Hard Landing – Nashville, Tenn., Jan. 7, 1996

The crew followed QRH procedures that were incomplete. This caused the aircraft to fall from 100 ft agl on final approach. The nosewheel separated from the aircraft.



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)

The missing information was included in the AOM expanded checklists but was never transferred to the QRH checklists.

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.**

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 Δ P 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:

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

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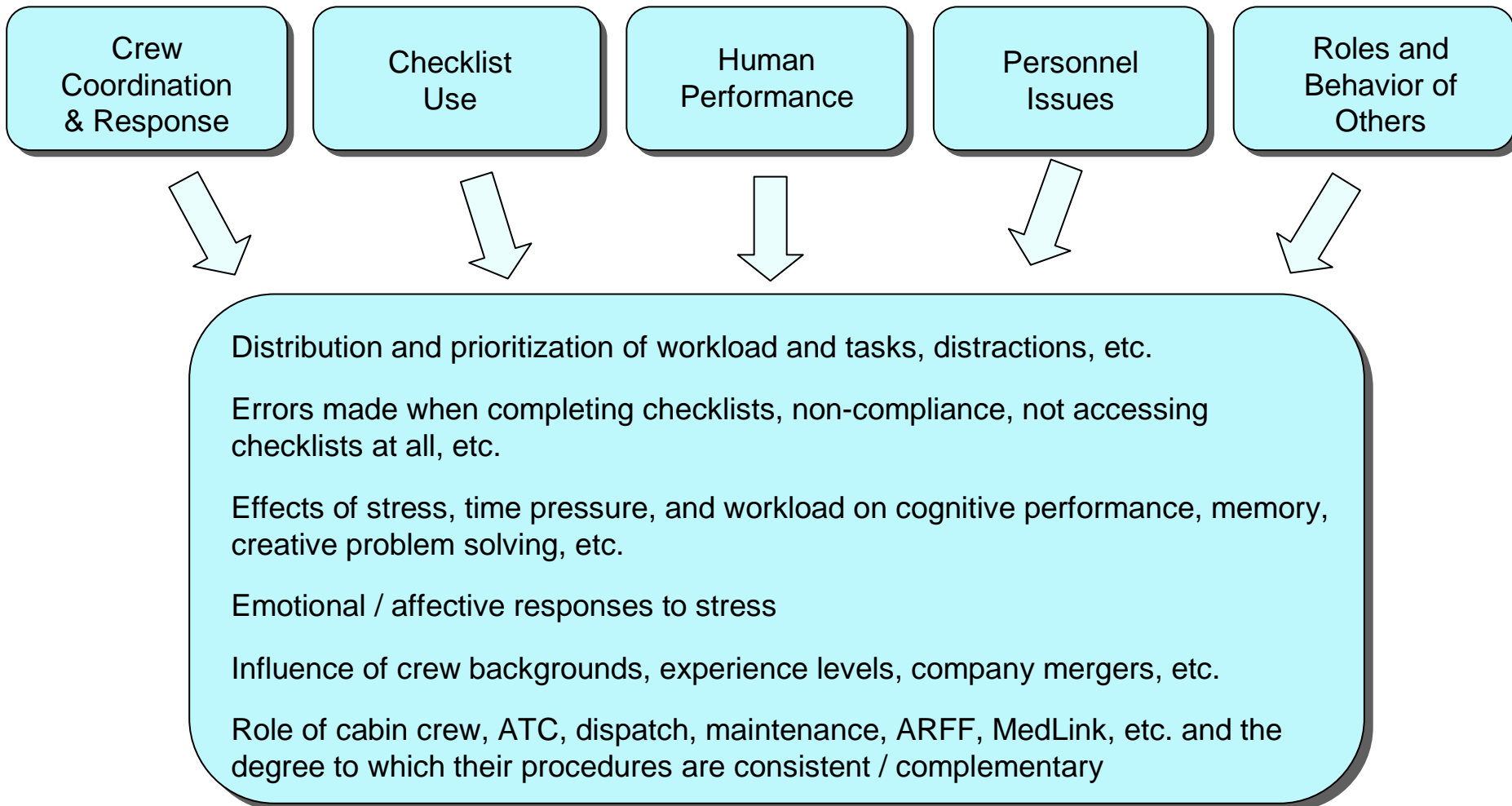
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Issues Related to Humans



*ATA 406
B727 Rapid
Decompression –
Indianapolis, Indiana
May 12, 1996*

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
Reinstate second pack:	
Second Pack Switch	CLOSE
One Pack Switch	ON
Stabilizes:	
Stabilizer Switch	NORMAL

Without referring to a checklist to reinstate a pack that had automatically tripped off, the flight engineer opened the outflow valve by mistake (instead of closing it) and caused the aircraft to rapidly decompress.

The captain, flight engineer, and a flight attendant, who had been on the flight deck, each lost consciousness during the event.





FedEx 1406, DC-10 In-flight Fire – Newburgh, New York September 5, 1996

In a rapidly deteriorating situation under high stress and workload, some checklist steps were missed which resulted in the aircraft being partially pressurized after making an emergency landing.

The crew and two passengers barely escaped the burning aircraft.

DC-10 FLIGHT MANUAL

FIRE & SMOKE

- Oxygen Mask & Smoke Goggles (As Required) ON, 1
- 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.
- Cockpit Door & Smoke Screen CLOSE
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.
- If Descent is required PROCEED TO STE
- If Descent is NOT Required PROCEED TO STE

WARNING

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

- Autopilot AS REQUIRED
- Throttles I
- Speed Brake F
- Airspeed
- If structure
- ATC ...
- Transp
- Tank P
- Altimeter
- Type O

A. OK
B. ABOVE
C. STOP

20 March 1994

DC-10 FLIGHT MANUAL

CABIN CARGO SMOKE LIGHT ILLUMINATED

- Pack Function Control Selectors TWO PACKS OFF
NOTE
Operate the No. 1 Pack only, if available.
- Cockpit Air Outlets OPEN
- Courier Masks & Goggles VERIFY ON/100%
- 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.
- If unable to Extinguish Fire/Smoke MANUALLY RAISE CABIN ALTITUDE TO 25,000 FEET
- Cabin Air Shutoff T-Handle PULL
- Maintain 0.5 PSI Diff Pressure Below FL 270, Or 25,000 Ft. Cabin Altitude Above FL 270.
- 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



Air Canada 797 - DC-9 In-flight Fire, Covington, Kentucky June 2, 1983

Initial actions taken by cabin crew to assess and deal with fire were inadequate

Captain was told the smoke was lessening – 5 ½ minute delay in starting emergency descent

After poor handoff, ATC identified the wrong radar target as the emergency flight









First officer turned the airconditioning and pressurization packs off

Toxic fumes and gases built up, a flash fire occurred soon after landing and 23 passengers died.

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Issues Related to the Aircraft

Critical Aircraft
Systems

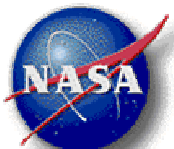
Automation
Issues

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.



SAS 751 - MD-81 Dual Engine Failure – Gottrora, Sweden – December 27, 1991

On takeoff, ice was ingested into the engines which damaged the fan stages and caused the engines to surge – all power was lost 77 seconds later.



During the event engine power was increased automatically by the Automatic Thrust Restoration (ATR) feature, which increased the intensity of the surging and contributed to the failure of the engines.

Neither the crew nor the company knew that the ATR feature existed on the airplane.

Birgenair ALW 301 - B757 Loss of Control – Puerto Plata, Dominican Republic – February 2, 1996

Erroneous information was sent to the captain's airspeed indicator and center autopilot by the left air data computer because a pitot tube was blocked.

The crew members were tremendously confused by contradictory warnings (overspeed and stall warnings) and conflicting airspeed indications on the three displays.









The center autopilot and autothrottles contributed to their problems. The crew did not attempt to fly the aircraft manually and tried to use automation in a way that did not help them.

The aircraft crashed into the ocean. All onboard perished.

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Emergency and Abnormal Situations Project Taxonomy of the Domain

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



British Midlands, Loss of Engine Kegworth, Leicestershire, England January 8, 1989

The flight crew mistakenly thought there was a problem with their right engine and shut it down.

Cabin crew and passengers could see flames coming from the left engine but this information was not given to the flight crew







48 passengers died as a result of the crash landing

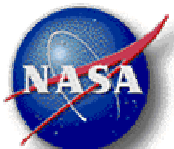
Joint emergency training for flight and cabin crews was recommended by the Air Accidents Investigation Branch of the Ministry of Transport (UK)



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Taxonomy of the Domain

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



Airtran 356 - 717-200 – Flushing, New York – March 26, 2003
NTSB Preliminary Report



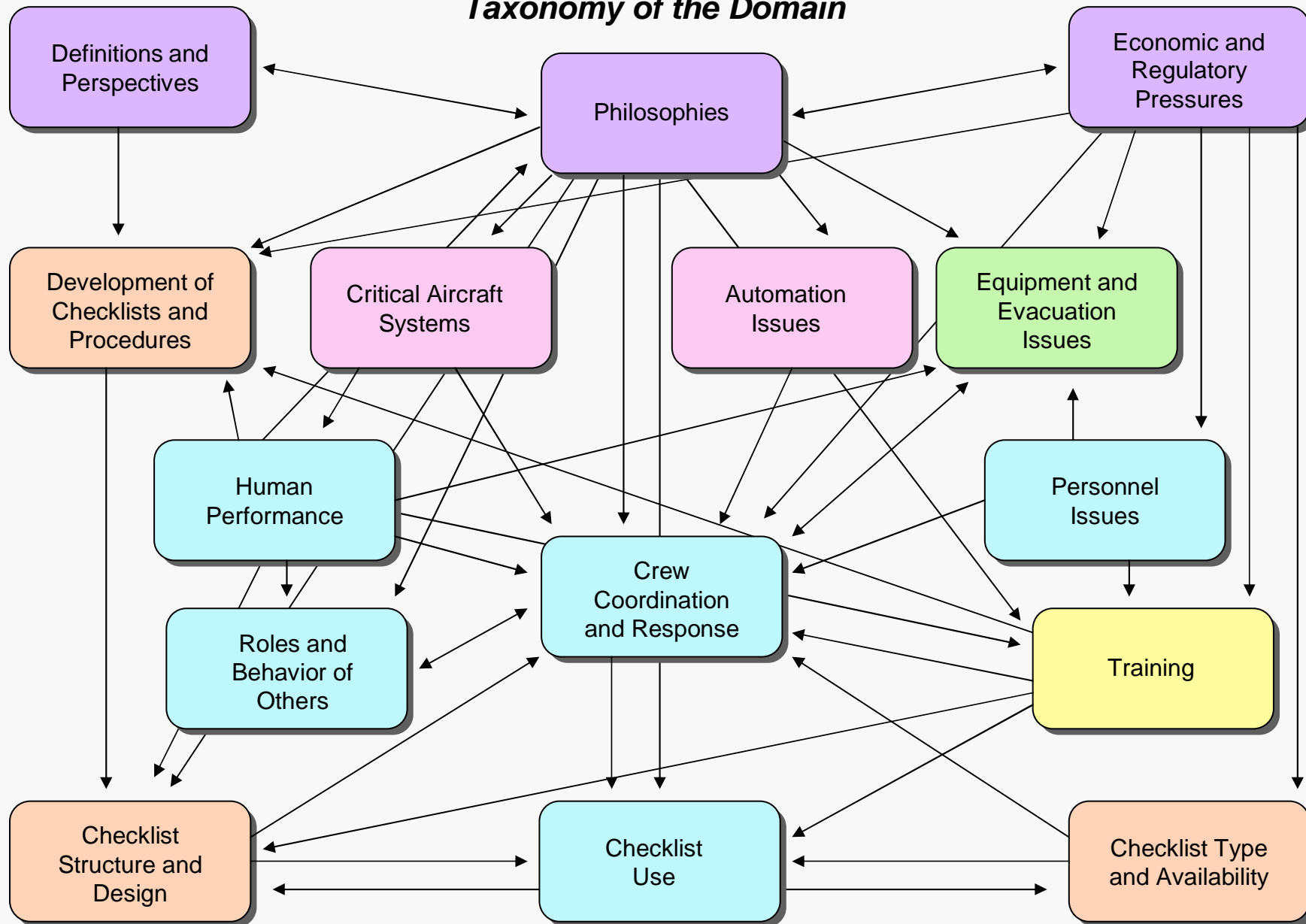
While on final approach the forward flight attendant noticed a burning smell and discovered that the handset to call the cockpit was not working.

After landing she pounded on the cockpit door and yelled to get the flight crew's attention.

The flight crew never heard the flight attendant pounding or yelling.



Emergency and Abnormal Situations Project Taxonomy of the Domain



Overall Goal of the EAS Project

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)



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