Emergency and Abnormal Situations: In-Flight Smoke, Fires and Fumes

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The Emergency and Abnormal Situations project is funded through the NASA Aviation Safety and Security Program.
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
# Emergency and Abnormal Situations Project

## Industry Contacts and Consultants

<table>
<thead>
<tr>
<th>Manufacturers:</th>
<th>Boeing, Bombardier, Airbus Industries, BAe Systems,</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulatory and Governmental Agencies:</td>
<td>FAA, CAA (UK), JAA, ICAO, Eurocontrol, NavCanada</td>
</tr>
<tr>
<td>Unions and Trade Groups:</td>
<td>ALPA, IFALPA, APA, SWAPA, ATA, IATA, AFA, ADF</td>
</tr>
<tr>
<td>Accident Investigation Bodies:</td>
<td>NTSB, TSB of Canada, ISASI</td>
</tr>
<tr>
<td>Airlines:</td>
<td>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)</td>
</tr>
</tbody>
</table>
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

15 Different Categories of Issues:

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- 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
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, then a bleed leak does not exist, and if WING ANTI-ICE is not required:

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

If Pack Fault due to low bleed air supply, and if WING ANTI-ICE is not required:
Emergency and Abnormal Situations Project
Taxonomy of the Domain

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- Selected Emergency Equipment and Evacuation Issues
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.
15 Different Categories of Issues:

- Broad, Over-arching Issues
- Issues Related to Checklists and Procedures
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- Issues Related to the Aircraft
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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.
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.
Challenges in Emergency and Abnormal Checklist Design

Smoke, Fire, and Fumes
Checklists and Procedures
Smoke, Fire, and Fumes Checklists and Procedures

A Few of the Many Design and Content Issues

- Location of checklists
- Determining / accessing the proper checklist
- Number of SFF checklists available and to choose between
- Length of checklist and amount of time needed to complete procedures
- General checklist design considerations
- Reduced visibility – font size, layout, color of text and background
- Paper vs. electronic checklists
- Various human factors considerations
- Ambiguity of cues / level of certainty about the situation
- Conflicting warnings / cues
- Smoke / fumes of an unknown origin
- Hidden fires / smoke or fire in inaccessible places
Smoke, Fire, and Fumes Checklists and Procedures

A Few of the Many Design and Content Issues, continued

- What memory Items, if any?
- How much time spent on source identification / troubleshooting?
- Initiating a descent / diversion and when
- What type of descent profile?
- Timing of source identification vs. smoke removal vs. descent initiation vs. fighting fire
- High false smoke alarm rate
- EROPS – nearest airport is far away
- Ditching while on fire
- Powering down electrical buses
- Circuit breaker resetting
- If / when to declare an emergency with ATC
- Communicating / coordinating with Cabin Crew
Smoke, Fire, and Fumes Checklists and Procedures

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Smoke, Fire, and Fumes Checklists and Procedures

Methods for Accessing the Correct Checklist (un-alerted / unannunciated events):

- Gateway Checklist
- Several Separate Checklists
- One Integrated Checklist
Accessing the Correct Checklist: Gateway Checklist

1. Oxygen Mask & Smoke Goggles (As Required)
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
   - 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 Pump
    - 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)
Accessing the Correct Checklist: Several Separate Checklists
Accessing the Correct Checklist: One Integrated Checklist

SMOKE, CABIN/COCKPIT
- Oxygen masks and regulators: On, 100%
- Crew and flight attendant communications: Establish
- Cabin fans switch: Off
- Blower switch: Override
- Extract switch: Override
- Galley/galley and cabin switch: Off
- Descent: Initiate
- Cabin signs: On

CONTINUED FROM ORC
If dense smoke at any time, accomplish reverse side.
REFERENCE ACTION:
If electrical, cabin, or galley equipment smoke/fire is suspected:
- Emergency exit light switch: On
If commercial switch installed:
- Commercial switch: Off
If commercial switch is not installed:
- Bus tie switch: Off
- Generator 2 switch: Off
If smoke persists or just before landing gear extension:
- Generator 2 switch: On
- Bus tie switch: Auto

If air conditioning smoke is suspected:
- APU bleed switch: Off
- Blower switch: Auto
- Extract switch: Auto
- Pack 1 switch: Off
If smoke does not decrease:
- Pack 1 switch: On
- Pack 2 switch: Off
- Cargo heat air isolation valve switch: Off
If smoke persists:
- Pack 2 switch: Override
- Extract switch: Override

If avionics smoke is suspected:

DENSE SMOKE
EMERGENCY DESCENT
- FCU altitude (safe altitude/10,000 feet): Set
- FCU expedite switch: Push
- Target speed: Confirm, 30/340KIAS
- Thrust: Confirm, idle
- Speed brakes: Extend
- ATC: Advise

SMOKE REMOVAL
- Pack flow selector: High
- Landing elevation selector: Safe altitude/10,000 feet
When at safe altitude/10,000 feet:
- Pack switches 1 + 2: Off
- Cabin pressure mode selector: Manual
- Manual vertical speed control switch: Full up
When differential pressure is less than 1 PSI:
- Ram air switch: On
If cockpit smoke requires a cockpit window to be opened:
- Maximum speed: 200 KIAS
- Headsets: On
- Cockpit window: Open

EMERGENCY ELECTRICAL CONFIGURATION (if Required)
- Emergency electrical generator 1 line switch: Off
- Emergency electrical power switch: Manual on
When emergency generator available:
- APU generator switch: Off
- Generator 2 switch: Off
Before landing gear extension:
- Generator 2 switch: On
- Emergency electrical generator 1 line switch: On

Courtesy of Captain Richard Gilbert, UAL
Integrated SFF Checklist Template

**SMOKE / FIRE or FUMES**

Condition: Smoke, fire or fumes is identified.

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anticipate Diversion</td>
</tr>
<tr>
<td>2</td>
<td>Oxygen Masks (If required) ON</td>
</tr>
<tr>
<td>3</td>
<td>Smoke Goggles. (If required) ON</td>
</tr>
<tr>
<td>4</td>
<td>Crew &amp; Cabin Communications Establish</td>
</tr>
</tbody>
</table>

Accomplish SMOKE OR FUMES REMOVAL checklist any time smoke or fumes becomes the greatest threat. Page x.x.

5. Source is obvious, accessible and extinguishable:
   - If Yes, Go to Step 6.
   - If No, Go to Step 8.

6. Isolate and extinguish the source.
   [If practical, remove power from affected equipment by switch or circuit breaker on the flight deck or in the cabin.]

7. Source confirmed to be extinguished and the smoke/fumes dissipating:
   - If Yes, Go to Step 19.
   - If No, Go to Step 8.

<table>
<thead>
<tr>
<th>Initial steps.</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Manufacturers step A Accomplish</td>
</tr>
<tr>
<td>9</td>
<td>Manufacturers step B Accomplish</td>
</tr>
<tr>
<td>10</td>
<td>Manufacturers step C Accomplish</td>
</tr>
<tr>
<td>11</td>
<td>Initiate Diversion to the nearest suitable airport while continuing this checklist.</td>
</tr>
</tbody>
</table>
| 12             | Smoke/fire/fumes conditions dissipating:
   - If Yes, Go to Step 17.
   - If No, Go to Step 13. |

<table>
<thead>
<tr>
<th>Smoke/fire/fumes persist after initial steps.</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do not delay landing to accomplish these steps.</td>
<td></td>
</tr>
<tr>
<td>Time and conditions permitting, accomplish these system related steps in order unless a specific system is suspected.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
</table>
| 13   | XXXX system actions Accomplish
   [Further actions to control/extinguish source.]
   - If conditions persist Go to next unaccomplished step.
   - If dissipating Go to Step 17. |
| 14   | YYYY system actions Accomplish
   [Further actions to control/extinguish source.]
   - If conditions persist Go to first unaccomplished step.
   - If dissipating Go to Step 17. |
| 15   | ZZZZ system actions Accomplish
   [Further actions to control/extinguish source.]
   - If conditions persist Go to first unaccomplished step.
   - If dissipating Go to Step 17. |
| 16   | Smoke/fire/fumes persist after all system related steps are accomplished:
   - Land Immediately
   - Go to Step 18. |

<table>
<thead>
<tr>
<th>Follow up items.</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Land at the nearest suitable airport.</td>
</tr>
<tr>
<td>18</td>
<td>See Considerations below</td>
</tr>
<tr>
<td>19</td>
<td>Accomplish Smoke Removal checklist, if required. Page X.X</td>
</tr>
<tr>
<td>20</td>
<td>■ ■ (End of Checklist) ■ ■</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Considerations</th>
</tr>
</thead>
</table>
This area is to list considerations – such as; overweight landing, tailwind landing, etc. are OK in an emergency.
Smoke, Fire, and Fumes Checklists and Procedures

Checklist Design and Content Issues

Three In-flight Smoke, Fire, Fumes Accidents:

- Swissair 111  September 2, 1998
- FedEx 1406   September 5, 1996
- Air Canada 797 June 2, 1983
Smoke, Fire, and Fumes Checklists and Procedures

Swissair 111

- Location of checklists
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  - Conflicting warnings / cues
  - Smoke / fumes of an unknown origin
  - Hidden fires / smoke or fire in inaccessible places
Smoke, Fire, and Fumes Checklists and Procedures

Swissair 111

• What memory Items, if any?
• How much time spent on source identification / troubleshooting?
• Initiating a descent / diversion and when
• What type of descent profile?
• Timing of source identification vs. smoke removal vs. descent initiation vs. fighting fire
• High false smoke alarm rate
• EROPS – nearest airport is far away
• Ditching while on fire
• Powering down electrical buses
• Circuit breaker resetting
• If / when to declare an emergency with ATC
• Communicating / coordinating with Cabin Crew
Swissair 111 - In-flight Fire
Nova Scotia, Canada
September 2, 1998
If smoke/fumes are not eliminated, land at nearest suitable airport.
Smoke, Fire, and Fumes Checklists and Procedures

Emergency Descent and Diversion

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.
Cost of Diversions: fuel, passenger ill-will, operational considerations, aircraft and crew scheduling, possible evacuation injuries, etc.
Smoke, Fire, and Fumes Checklists and Procedures

FedEx 1406

- Location of checklists
- Determining / accessing the proper checklist
- Number of SFF checklists available and to choose between
- Lengths of checklists and amount of time needed to complete procedures
- **General checklist design considerations**
  - Reduced visibility – font size, layout, color of text and background
  - Paper vs. electronic checklists
- **Various human factors considerations**
  - Ambiguity of cues / level of certainty about the situation
  - Conflicting warnings / cues
  - Smoke / fumes of an unknown origin
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In a rapidly deteriorating situation under high stress and workload, some checklist steps were not completed, which resulted in the aircraft being partially pressurized after making an emergency landing.

The crew and two passengers barely escaped the burning aircraft.
**FedEx 1406, DC-10**  
**September 5, 1996**

**Events:**

- FE was confused by step 5
- did not complete step 6
- did not appear to complete step 7

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**CABIN CARGO SMOKE LIGHT ILLUMINATED**

<table>
<thead>
<tr>
<th>Event</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Pack Function Control Selectors</td>
</tr>
<tr>
<td>2.</td>
<td>Cockpit Air Outlets</td>
</tr>
<tr>
<td>3.</td>
<td>Courier Masks &amp; Goggles</td>
</tr>
<tr>
<td>4.</td>
<td>Airplane Altitude</td>
</tr>
<tr>
<td></td>
<td>A.</td>
</tr>
<tr>
<td></td>
<td>B.</td>
</tr>
<tr>
<td></td>
<td>C.</td>
</tr>
<tr>
<td>5.</td>
<td>If unable To Extinguish Fire/Smoke</td>
</tr>
<tr>
<td>6.</td>
<td>Cabin Air Shutoff T-Handle</td>
</tr>
<tr>
<td>7.</td>
<td>Maintain 0.5 PSI Diff Pressure Below FL 270, Or 25,000 Ft. Cabin Altitude Above FL 270.</td>
</tr>
<tr>
<td>8.</td>
<td>Fire</td>
</tr>
<tr>
<td></td>
<td>NOTE</td>
</tr>
<tr>
<td></td>
<td>CAUTION</td>
</tr>
<tr>
<td>9.</td>
<td>If It Is Necessary To Leave The Cockpit To Fight A Fire:</td>
</tr>
<tr>
<td></td>
<td>A.</td>
</tr>
<tr>
<td></td>
<td>B.</td>
</tr>
<tr>
<td></td>
<td>C.</td>
</tr>
<tr>
<td>10.</td>
<td>Land At Nearest Suitable Airport.</td>
</tr>
</tbody>
</table>
FedEx 1406, DC-10
September 5, 1996

Items Pertaining to Adjusting Cabin Altitude or Flight Level

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4.</td>
<td><strong>Airplane Altitude</strong> .................................................. <strong>CAPTAIN'S DISCRETION</strong></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>Land as soon as possible.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>B.</td>
<td>If above FL 270, consider descent to FL 270. Manually raise cabin altitude to 25,000 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>C.</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td><strong>If unable To Extinguish Fire/Smoke ..........MANUALLY RAISE CABIN ALTITUDE TO 25,000 FEET</strong></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td><strong>Cabin Air Shutoff T-Handle</strong> ......................... <strong>PULL</strong></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td><strong>Maintain 0.5 PSI Diff Pressure Below FL 270, Or 25,000 Ft. Cabin Altitude Above FL 270.</strong></td>
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Smoke, Fire, and Fumes Checklists and Procedures

Air Canada 797

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Smoke, Fire, and Fumes Checklists and Procedures

Air Canada 797

- What memory Items, if any?
- **How much time spent on source identification / troubleshooting?**
- Initiating a descent / diversion and when
- What type of descent profile?
- Timing of source identification vs. smoke removal vs. descent initiation vs. fighting fire
- High false smoke alarm rate
- EROPS – nearest airport is far away
- Ditching while on fire
- Powering down electrical buses
- Circuit breaker resetting
- If / when to declare an emergency with ATC
- **Communicating / coordinating with Cabin Crew**
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 decent.

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

First officer turned the air conditioning and pressurization packs off.

Toxic fumes and gases built up, a flash fire occurred soon after landing and 23 passengers died.
Smoke, Fire, and Fumes Checklists: Design and Content Considerations

(Work Currently in Progress)
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Emergency and Abnormal Situations Project
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