Emergency and Abnormal Situations: Aviation and Process Control Industries

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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

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<td>Manufacturers:</td>
<td>Boeing, Airbus Industries, BAE Systems</td>
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<td>Airlines:</td>
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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)
15 Different Categories of Issues:

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- Issues Related to Training
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Emergency and Abnormal Situations Project

Taxonomy of the Domain

Broad, Over-arching Issues

- Philosophies
- Economic and Regulatory Pressures
- Definitions & Perspectives

Philosophies and Policies of Dealing with Emergencies and Abnormal Situations – Manufacturers, Company, ATC, etc.

Economic and Regulatory Pressures Pertaining to Dealing with and Training for Emergencies

Clarification of terminology (e.g., abnormal vs. emergency) and appropriate usage

NASA
Human Factors
research and technology
Philosophy of Response to Emergencies

Evident in Checklist Design
MD-11 In-flight Fire
Nova Scotia, Canada
September 2, 1998
If smoke/fumes are not eliminated, land at nearest suitable airport.
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)]

[AC #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]
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.
Emergency and Abnormal Situations Project
Taxonomy of the Domain

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Checklist and Procedures Issues

- Development of Checklists and Procedures

- 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.

• 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
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 (PFN)
GEAR LEVER ................................ UP (PFN)

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/gears are retracted.

The ground control relay electrical circuits can be placed
in the flight mode by pulling the Ground Control Relay
switch 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 (PFN)
ANTI-SKID SWITCH (before 30 kts) ............ OFF (PFN)

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

EPR 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
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.
Briefing message—stabilizer trim red box. This message has appeared on MD80 flight plans for at least 5 months, if not 6 months. This is supposedly a critical emergency procedure that is to be committed to memory, yet there has been no change whatsoever to the MD80 operating manual on the subject. No revisions. No change bulletin. Nothing.

During the last 6 months, there have been several bulletins issued, yet nothing on this critical red box change. Is the caution text supposed to be memorized? Is the note at the bottom supposed to be memorized? The lack of consistent publication of this red box item is only bound to cause problems for the airline and crews if there is an actual problem.
During the flight and unknown to the crew, the right standby fuel pump continued to operate uncommanded after engine start because of two bonded contacts on the fuel-control panel.

This prevented fuel from being transferred to the right wing during normal transfer procedures - caused a severe fuel imbalance.

Control was lost of the aircraft while maneuvering for an emergency landing – all eight individuals on board perished.
➢ The flight manual did not contain a checklist for correcting a fuel imbalance that occurs during the transfer of fuel

➢ Such a checklist was available from the manufacturer but the operator did not contract for flight manual updates from the manufacturer
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Emergency and Abnormal Situations Project
Taxonomy of the Domain

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
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
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
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”
DC-10 FLIGHT MANUAL

FIRE & SMOKE

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

2. Crew & Courier Communications
   ESTABLISH
   Check Mike switches 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. 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.

20 March 1994
2-8-1
• 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
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 CN/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 ............................................................. FULL

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)
20 March 1994
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
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
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
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.
During approach...the gear failed to come down...after notifying the tower we had a ‘Gear Indication Problem’...

The QRH procedure...requires cycling the gear handle...after 4 or 5 attempts the landing gear came down...
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.
Emergency and Abnormal Situations Project
Taxonomy of the Domain

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- **Issues Related to the Aircraft**
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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.
MD-81 Dual Engine Failure – Gottorera, 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
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.
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
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.
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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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
• 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

• No attempt was made to feather the propeller, secure the engine, or complete any abnormal or emergency checklists or procedures

• 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.

Company records did not provide enough evidence that training performance was properly monitored and managed.
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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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
• 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.
Approach

Review: all existing guidelines, handbooks, bulletins, reports, recommendations, documents, and pertinent literature

Analyze: ASRS reports, NTSB and FAA accident reports

Study: philosophies, policies, practices, and procedures currently in use by manufacturers and air carriers

Observe: normal air carrier operations, initial and recurrent emergency and abnormal training for flight crews

Interview: manufacturer procedure developers, procedure certifiers, POIs, air carrier management, instructors, pilots, cabin crew, dispatchers, maintenance personnel, air traffic controllers, etc.

Conduct: surveys, field studies, simulator studies, experimental lab studies
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)
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