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## **The Emergency and Abnormal Situations Project**

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This paper reviews the objectives, goals, and issues being addressed in the Emergency and Abnormal Situations (EAS) project currently underway in the Human Factors Research and Technology Division of the NASA Ames Research Center.<sup>1</sup> Examples of various issues being covered in the project that are evident in recent aviation accidents are provided.

### Introduction and Overview

Emergency and abnormal situations represent unique challenges in air carrier operations. They are often time critical and complex, and the nature of the underlying problem is sometimes ambiguous. Almost by definition they involve high stress and high workload conditions that require exceptionally high levels of coordination inside and outside of the airplane. Executing emergency and abnormal procedures depends on cognitive processes that are fragile under the combination of high workload, time pressure, and stress. Some procedures are confusing or difficult to complete, and many procedures focus on responding to malfunctioning aircraft systems rather than guiding crews to manage the situation as a whole. Although these procedures must be executed correctly and efficiently when needed in line operations, crews have infrequent opportunity to practice them.

The aviation industry lacks substantive human performance guidelines for designing, validating, certifying, and training procedures for emergency and abnormal situations. It is tremendously challenging to design procedures that are robust in the face of real-world ambiguities, workload demands, and time constraints and that are well matched to human cognitive processes and limitations. Pilot initial and recurrent training currently provides limited opportunity to practice emergency and abnormal procedures in the context of real-world demands (e.g., coordinating with ATC, dispatch, maintenance, and cabin crew; avoiding other traffic; responding to emergencies in deteriorating weather conditions).

The Emergency and Abnormal Situations (EAS) project was undertaken to address these and related concerns, which are discussed in greater detail below. Our overriding goal for this project is to develop guidance for procedure and checklist development and certification, training, crew coordination, and situation management based on knowledge of the operational environment, human performance limitations and capabilities, and cognitive vulnerabilities in real-world emergency and abnormal situations.

We are working toward this goal through several focused studies in close collaboration and consultation with partners from the aviation community. Ultimately we will produce a series of field guides that will summarize what we learn and provide guidelines for best practices targeted to the specific needs of various populations within the aviation industry. Although the project is largely oriented around the flight crew, to understand the issues affecting crews' ability to manage non-normal situations we must also consider their interaction with other players in the aviation system who help manage these situations, especially cabin crew, controllers, dispatchers, and mechanics.<sup>2</sup> We are also concerned with the roles of manufacturers, regulatory agencies, and air carriers in developing equipment, procedures, checklists, written guidance, and training for use in non-normal situations.

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Table 1

### EAS Project Taxonomy of the Domain

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#### Broad Over Arching Issues

- Philosophies, Policies, and Practices of Dealing with Emergencies and Abnormal Situations
- Economic and Regulatory Pressures
- Definitions and Perspectives

#### Issues Related to Checklists and Procedures

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

#### Issues Related to Humans

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

#### Issues Related to Training

- Flight and Cabin Crew Emergency Training

#### Issues Related to the Aircraft

- Critical Aircraft Systems
- Automation Issues

#### Emergency Equipment and Evacuations

- Selected Emergency Equipment and Evacuation Issues
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## EAS Project – Taxonomy of the Domain

This project addresses many diverse issues and concerns. We have sorted these into 15 categories, grouped in six larger areas, which we refer to as the “Taxonomy of the Domain” (Table 1). This taxonomy helps guide our work in the focused studies. In this paper, organized around our taxonomy, we sketch out the issues and illustrate them with examples from airline accidents.<sup>3</sup>

### Broad, Over-arching Issues

Three categories in the taxonomy relate to rather broad, overarching issues. The first involves **Philosophies, Policies, and Practices of Dealing with Emergencies and Abnormal Situations**. Here, we are concerned with how the philosophies, policies, and practices of manufacturers, regulatory agencies, and air carriers shape the materials and guidance they provide flight and cabin crews, air traffic controllers and others who must directly respond to emergency and abnormal situations. We are also interested in how the perceptions, attitudes, and practices of those directly involved in these situations influence their performance. For example, checklists from different organizations vary in the degree to which they focus on troubleshooting a problem versus simply isolating the problem to allow continued flight in a non-normal condition. The extent of explanatory or annotated information included in checklists also varies. Both of these issues are driven by checklist designers’ philosophies regarding the desired role of flight crews when responding to non-normal situations and the degree of knowledge that crews are expected to have, and be able to readily retrieve from memory, during situations that often challenge human information processing capabilities.

We are also interested in the ways that **Economic and Regulatory Pressures** influence how the various players involved in non-normal situations respond to the demands of those situations. Several issues revolve around **Definitions and Perspectives**, which is a third category in our taxonomy. For example, what is the difference between an emergency and an abnormal situation? Does such a distinction matter, and if so, when, or under what circumstances? How do procedures and checklists differ? And, what are the objectives and goals of emergency and abnormal checklists and the steps that comprise them? The answers to these questions have great relevance for checklist and procedure development and design and for the best ways to manage non-normal situations.

### *Examples from Recent Accidents*

Following the in-flight fire and subsequent crash of a MD-11 off the coast of Nova Scotia, Canada on September 2, 1998, the Transportation Safety Board (TSB) of Canada studied 15 in-flight fires that occurred over 31 years (TSB, 2003). The Board determined that the average amount of time between the detection of an on-board fire and the point at which the aircraft ditched, conducted a forced landing, or crashed was 17 minutes. Seventeen minutes is not a lot of time to complete a diversion from cruise altitude, and half of these flights had less than that amount of time.

Examination of the smoke-related checklists available to the crew of this MD-11 reveals a series of checklist steps designed to isolate the origin of the smoke, followed by a list of system limitations and consequences related to the identified inoperative system (TSB, 2003). The final step at the bottom of the second checklist the crew would have likely accessed states: “If smoke/fumes are not eliminated, land at nearest suitable airport.” The ELECTRICAL SMOKE OR FIRE checklist available to the crew of a DC-9 that crashed in the Florida Everglades on May 11, 1996 (National Transportation Safety Board (NTSB), 1997) also contains numerous steps designed to isolate the source of the smoke. Unlike the second MD-11 checklist however, this checklist contained no item regarding diverting to a nearby airport. In these two accidents, because of the speed with which the fires on-board spread, it is unlikely that the crashes could have been avoided even if the crews had diverted to make emergency landings as soon as the fires were discovered (TSB, 2003; NTSB, 1997). However, in other accidents a prompt decision to conduct an emergency descent and landing might mean the difference between life and death. Thus, it is important to evaluate the underlying philosophies illustrated by the design of these checklists.

When are crews to consider that their problem may be so serious that a diversion is required? Only after attempts at isolation have failed? If the isolation or elimination of smoke is not attempted, will the crews become so incapacitated that a diversion is not possible? How often are crews able to successfully isolate and eliminate smoke or extinguish a fire and continue their flights to their planned destinations? If this happens in the vast majority of these situations, then, perhaps, placing a checklist step related to diverting at the end of a checklist would not seem unreasonable. Conversely, however, if even one catastrophic accident might be averted by a crew making a diversion at the first sign of trouble, then perhaps “Divert to the nearest airport” should be at or near the top of a smoke or fire checklist, even if it means that many flights are diverted unnecessarily. This of course is a policy decision involving cost-benefit tradeoffs. This clearly illustrates how philosophy and economic issues may influence checklist design.

Another accident illustrates the ways different job responsibilities of individuals involved in managing in-flight emergencies can influence their perspectives and actions. Below are four excerpts from the cockpit voice recorder (CVR) transcript of an MD-83 that crashed off the coast of California on January 31, 2000 (NTSB, 2002). This first was an exchange between the captain (CA) and a company dispatcher (DIS) over the radio:

DIS: ...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  
CA: Well uh yu you eh huh... boy you put me in a spot here um...  
CA: I really didn't want to hear about the flow being the reason you're calling us cause I'm concerned about overflying suitable airports  
DIS: Well we wanna do what's safe so if that's what you feel is uh safe we just wanna make sure you have all of the uh...all the info.  
CA: Yea we we kinda assumed that we had...what's the uh the wind again there in San Francisco?

Soon after this exchange, the captain was recorded saying to someone on the flight deck (most likely a flight attendant):

CA: ...just...drives me nuts...not that I wanna go on about it you know, I it just blows me away they think we're gonna land, they're gonna fix it, now they're worried about the flow. I'm sorry this airplane's idn't gonna go anywhere for a while...

The dispatcher was concerned about the movement of aircraft and adherence to a schedule - central aspects of a dispatcher's job. It is not clear from this transcript that the dispatcher was aware how serious the problem faced by the captain was. However, the captain by this time was clearly aware that their situation was serious, based upon the other recorded comment and his concern in the first exchange about over-flying airports suitable for an emergency landing. (His concern about "overflying suitable airports" may have also been motivated by a desire to not violate legal requirements included in the Federal Aviation Regulations.)

The captain decided to continue toward San Francisco until landing data could be obtained at which time they would turn back and begin their decent for a landing at Los Angeles International Airport (LAX). Soon thereafter, in a conversation with an operations agent (OPS) in Los Angeles, the following exchange was recorded:

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.

CA: ok I unders...I remember this is complicated. Yea well. Better start that now cause we're comin to you.

Following this exchange, the captain talked with an individual from maintenance (MX. It appears that the crew had also consulted with maintenance prior to the beginning of the CVR transcript):

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

In the conversation with the operations agent, the captain was frustrated. He knew he had a serious problem on his hands but the operations agent was concerned with making sure all logistics were in order. The maintenance technician was trying to help the crew troubleshoot their problem. Taking care of logistics and fixing things that are broken on airplanes is what operations agents and maintenance personnel do. Both were trying to do their jobs as they normally do them. It can be very difficult for individuals to set aside the mindset for their normal mode of operation--be it scheduling airplanes, taking care of landing logistics, troubleshooting systems problems, or flying an aircraft from point A to B-- to recognize and communicate the severity of a situation and to put all other considerations aside in order to get the airplane safely on the ground. Cognitive research has demonstrated that individuals are slow to revise an established mindset even when aware of circumstances that should compel revision. (Klein, 1998).

## Issues Related to Checklists and Procedures

The issues grouped in the next three categories in the EAS project taxonomy of the domain pertain to the checklists and procedures used in emergency and abnormal situations. In the **Development of Checklists and Procedures** category, we are concerned with what checklists and procedures are developed and by whom. What types of situations warrant the development of a checklist? When and how are changes to checklists made and recorded? How is regulatory approval obtained for checklists and procedures? What guidance exists for developers and regulatory agencies regarding checklist development and design? How well do checklists and procedures reflect the realities of the operational environment and to what degree, if any, can they be standardized across different aircraft fleets?

The **Checklist Structure and Design** category includes many important issues that influence the degree to which checklists are useful to the crews, including which items are placed on checklists and where, missing or incorrect items, the length of time required to complete a checklist, and the inclusion (or exclusion) of memory or recall items. We are concerned with how well crews are able to navigate within a checklist (to find the actions appropriate for their specific situation) and what features help crews locate the proper checklist in the first place (e.g., organization, indexing, nomenclature, etc.). We are interested in whether or not normal checklist steps are integrated with non-normal checklists and the consistency of the checklists and procedures used by the flight crews with those used by cabin crews, with the MELs, and with other material the flight crews may reference. Of course, we are also interested in style guide, formatting, and layout considerations.

In the **Checklist Type and Availability** category, we are concerned with issues related to the modality used for the presentation of checklists (i.e., paper, mechanical, integrated electronic, non-integrated electronic, etc.) and the ways that crews must physically access the checklists. Issues related to computerized prioritization schemes that determine which integrated electronic checklists are displayed first are also considered under this category.

### *Examples from Recent Accidents*

On January 7, 1996, the crew of a DC-9 had difficulty raising the landing gear on their departure climb-out (NTSB, 1996). They used the UNABLE TO RAISE GEAR LEVER procedure that was included in their quick reference handbook (QRH). Although this allowed them to resolve their gear problem, a few minutes later they realized that the cabin pressurization and takeoff warning systems were still in the ground mode. As directed by the same checklist, the crew pulled the ground control relay circuit breakers to place the systems in the flight mode.

In a later portion of the UNABLE TO RAISE GEAR LEVER checklist, under a heading entitled "Approach and landing," was a checklist step directing the crews to reset the circuit breakers. The crew did this while on final approach into Nashville, approximately 100 feet (30.5 meters) above the ground. Upon doing this, however, related systems immediately went into the ground mode causing the ground spoilers to deploy. The aircraft lost lift, hit the ground very hard and the nose wheel separated from the aircraft. The aircraft bounced into the air and the crew were able to complete a successful go-around procedure and landed on a different runway.

Other than including the item instructing the crew to reset the ground control relay circuit breakers in an “Approach and landing” section of the QRH checklist, no further guidance was given to the crew about specifically when or how this step was to be completed. However, in the expanded or annotated checklists that appear in the aircraft operating manual (AOM), such guidance was given: “Reset Ground Control Relay circuit breakers during taxi and verify that circuits are in the ground mode.” Yet according to interviews with the accident flight crew and other pilots employed by the same air carrier, they were trained to refer only to the QRH when handling an emergency or abnormal situation. Some people may argue that the accident crew should have been able to reason out that these circuit breakers should only be reset once on the ground. We believe that crews should have all information necessary for the proper completion of checklist steps in the primary resource referenced (in this case, the QRH) so that such reasoning is not required when time may be limited and workload and stress may be high.

Another example of a checklist or procedure related issue can be found in the accident of a C21A (a US military version of a Learjet 35A) that occurred in Alexander City, Alabama on April 17, 1995 (Fuel Imbalance Cited, 2000). During the flight, 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 fuel transfer procedures and resulted in a severe fuel imbalance as fuel was pumped from the right to the left wing tank. The crew incorrectly believed that the fuel in the left wing had become “trapped” and that both engines were using fuel from the right wing. Fearing an imminent dual engine flameout, the crew attempted an emergency landing but lost control and all eight individuals on board perished.

The crew’s 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 at the time of the accident, however, but the operator did not contract for flight manual updates from the manufacturer after purchasing the aircraft.

### Issues Related to Humans

Until the day that commercial transport category aircraft fly without pilots, cabin crew, dispatchers, and air traffic controllers, the human element will continue to be crucial in the response to emergency and abnormal situations. In the EAS project, issues specifically related to humans in these situations comprise five taxonomy categories.

Issues such as the distribution of workload and tasks, decision making, prioritization of tasks, and accurate assessment of the nature of the threat and the degree of risk are considered under the **Crew Coordination and Response** category. Issues related to communication, coordination, and crew resource management (CRM) within and between flight and cabin crews are also considered. We are also concerned with the ways in which vulnerability to confusion, fixation, distraction, and overload may affect how well crews are able to manage non-normal situations.

Under **Checklist Use** we are interested in errors made by crews such as inadvertently skipping checklist items, misunderstanding directions, or completing the wrong conditional branch for the specific situation. We are examining situations in which checklists or procedures were not used at all or in which they were accessed but not complied with. We are also considering the amount of “blind faith” crews place in checklists or procedures for dealing with emergency or abnormal situations.

As research psychologists, we are particularly interested in **Human Performance** under high stress and high workload conditions. We are examining the effects of stress and time pressure on attention, retrieval from memory, and problem solving. We are interested in the conditions, factors, and cues that affect pilots’ ability to recall procedural and declarative knowledge under stress and heavy workload. Flight crews’ emotional or affective response to stress is also being considered within this category.

Under the **Personnel Issues** category we are examining the influence that background, previous experiences, initial training, and experience levels may have on pilots’ response to non-normal situations. We are interested in the effect that flight crew size (2-person crews, 3-person crews) and cabin crew size has on situation response and the influence that company mergers can have on working relations, communication, and how non-normal situations are handled.

We are not just considering the response of flight and cabin crews to these situations but also the **Roles of Others** involved in the situations. Air traffic controllers, dispatchers, maintenance personnel, airport rescue and fire fighting personnel, MedLink, and even passengers each play important parts in how these situations are resolved. A high degree of communication and coordination between these various groups is essential for the successful outcome of emergency and abnormal situations. The degree to which the procedures and checklists of different parties are consistent with and compliment each other is particularly important.

### *Examples from Recent Accidents*

On May 12, 1996, a B727 experienced a rapid decompression and performed an emergency landing at Indianapolis, Indiana (NTSB, 1998a). While showing the flight engineer how to silence a cabin altitude warning that sounded right before reaching their cruise altitude of 33,000 ft. (10058.4 meters), the captain noticed that the second pack was off. The captain instructed the flight engineer to reinstate it. The flight engineer stated that he turned the right pack on and then “went to manual AC and closed the outflow valve.” When taking these actions the flight engineer did not refer to the PACK REINSTATEMENT FOLLOWING AUTO PACK TRIP checklist, which is fairly lengthy. Also, instead of closing the outflow valve, the flight engineer actually opened it and the aircraft rapidly lost pressurization.

During this event, the captain, flight engineer, and lead flight attendant, who had been on the flight deck at the time, briefly lost consciousness. The first officer, who was the pilot flying and was still on his initial operating experience in the B727, performed an emergency descent and they landed without further incident. However, the captain did not call for and the crew did not complete any emergency checklists, including the decompression checklist or the emergency descent checklist. The captain did not put his oxygen mask on immediately when the altitude

warning sounded, as required by procedures—fortunately, the first officer did immediately don his mask.

An accident involving a DC-10 near Newburgh, New York on September 5, 1996 (NTSB, 1998b), provides several good examples of issues related to human performance under stress. During cruise at 33,000 ft. (10058.4 meters) the cabin/cargo smoke warning light illuminated and the crew very quickly realized that they had a real fire on their hands. The flight engineer announced, and the crew completed, the memory items from the SMOKE AND FIRE checklist and then the flight engineer accessed the printed checklist and continued to execute it. However, without input from the captain, the flight engineer chose to complete the conditional branch on the checklist for “If Descent is NOT Required.” The captain did command an emergency descent and diversion to the closest airport but only somewhat later – three and one half minutes after the warning light had first illuminated. Prior to this he was preoccupied with the warning indicators, testing the fire detection system, and other cockpit duties.

The flight engineer missed two steps on the CABIN/CARGO SMOKE LIGHT ILLUMINATED checklist, which was the next checklist he conducted. The captain was busy monitoring the progress of the fire and coordinating the diversion with ATC and the first officer, who remained the pilot flying throughout the flight. The captain did not notice the flight engineer’s errors and did not call for any checklists, although required by company procedures to do so. The emergency descent checklist and the evacuation checklists were never accessed or completed. While the flight engineer was attempting to complete the two emergency checklists he did access, he was also trying to complete the normal approach and landing checklists and obtain data needed for figuring the landing speeds. Upon landing, the missed checklist items and uncompleted checklists resulted in the aircraft remaining partially pressurized, which impeded and delayed the crew’s evacuation.

This was a very serious emergency, and the crew and two jumpseat riders barely escaped the burning aircraft. The influence of the great stress and overload the crew was experiencing was evident in many ways. The captain delayed making the decision to divert and land and never called for any checklists to be completed. He did not adequately monitor the flight engineer’s completion of the checklists and mistakenly transmitted his remarks to the crew over the ATC frequency on several occasions. The flight engineer missed checklist items, did not adequately monitor the status of the aircraft pressurization on descent, and five times over the span of six minutes, he asked for the 3-letter identifier of the airport they were diverting to so he could obtain landing data from an on-board computer. Although he was told the identifier at least twice, he apparently never heard it. During an interview following the incident, the flight engineer reported that he had felt very overloaded.

### Issues Related to Training

The **Training** that flight and cabin crews receive regarding emergency and abnormal situations is also an important area we are examining. We are looking at various training technologies and approaches used for dealing with these situations during both initial and recurrent training. We are interested in issues related to skill acquisition and retention, especially of procedures that are rarely practiced or even discussed. We are particularly interested in training to help prepare

crews to deal with “non-standard” or ambiguous problems and how to respond to situations in which multiple problems occur concurrently

### *Examples from Recent Accidents*

A particularly tragic example of some of these training issues can be found in the crash of a BAe Jetstream 32 that lost control on approach to the airport at Raleigh Durham, North Carolina on December 13, 1994 (Commuter Captain, 1996). At the final approach fix descending through 2,100 ft. (640 meters), with the power levers at flight idle, an illuminated ignition light led the captain to believe that the left engine had flamed out. The captain, who was the pilot flying, did not feather the propeller, secure the engine, or undertake any abnormal or emergency procedures associated with an engine failure. During a missed approach procedure, the captain lost control of the aircraft and it struck terrain. Three passengers survived the accident.

The illuminated ignition light was actually a “minor transient anomaly” (Commuter Captain, 1996, p. 8) and it was later determined that both engines had functioned normally throughout the flight until impact. However, in the accident investigation it was discovered that the company had incorrectly trained their flight crews to always associate an illuminated ignition light with an engine failure. During the accident investigation it was also determined that training provided by the company did not adequately address the recognition of an engine failure at low power and company records did not provide enough evidence that training performance was properly monitored and managed.

### Issues Related to the Aircraft

We are also looking at issues related to the aircraft that influence the outcome of non-normal situations. In a category we have named **Critical Aircraft Systems**, we are interested in the role that systems with flight protection envelopes might play in how these situations are handled. We are also interested in how cockpit warnings and warning systems may facilitate or impede a crew’s response.

**Automation Issues** are also important to consider in these situations. We are interested in learning what level and types of automation are most appropriate to use and under what conditions. We are exploring the degree to which uncritical acceptance of automation may lead crews to misdiagnose or respond incorrectly to a non-normal situation. We are also interested in comparing procedures for emergency and abnormal situations between highly automated aircraft and less automated aircraft. Issues involving reverting to manual flying and degradation of hand-flying skills are also being considered.

### *Examples from Recent Accidents*

Two recent accidents provide examples of how aircraft and automation issues factor in the resolution of emergency and abnormal situations. One accident occurred on December 27, 1991 at Gottrora, Sweden and involved a MD-81 that experienced a dual engine failure shortly after departure from Stockholm (Martensson, 1995). The day was snowy and windy, with temperatures hovering around freezing. On lift-off, clear ice broke off the wings and was

ingested by the engines, damaging the fan stages. This damage caused the engines to surge – the right one began to surge 25 seconds after lift off, the left one 39 seconds later. At 3,194 ft. (973.5 meters) both engines lost power. Grey smoke filled the cockpit and the electronic flight instrument system (EFIS) went blank, forcing the crew to attempt an emergency landing using only back-up instruments. Despite the aircraft breaking into three pieces on landing, all 129 on board survived.

On climbout the crew did not notice that engine power was increased automatically by the automatic thrust restoration (ATR) feature. This increase in engine power increased the intensity of the surging and contributed to the failure of the engines. During the accident investigation it was discovered that the airline company had no knowledge of the ATR feature.

Issues related to automation and warning systems are illustrated by an accident involving a B757 that lost control off the coast of the Dominican Republic on February 2, 1996 (Walters & Sumwalt, 2000). During the takeoff roll the captain indicated that his airspeed indicator was not working. It appeared to start working once the aircraft began to climb but significant discrepancies appeared between the captain's, first officer's, and alternate airspeed indicators. A few seconds later two advisory messages appeared on the engine indicating and crew alerting system (EICAS) display: RUDDER RATIO and MACH/SPD TRIM.

By this time, the captain's airspeed indicator showed a very high speed and the overspeed warning clacker sounded. Additionally, the center autopilot commanded an 18 degree nose-up attitude and the autothrottles moved to a very low power setting in an attempt to bring the speed down. Adding to the crew's bewilderment, the stall warning "stick shaker" activated and the autopilot and autothrottles automatically disengaged. As the crew tried to sort out the true nature of their problem, they applied power and then removed it more than once. The first officer selected Altitude Hold on the mode control panel in an attempt to level off and to stabilize the aircraft. However, the throttles were at too low of a power setting to maintain altitude so the selection of Altitude Hold was ineffectual. The aircraft crashed into the ocean a short time later and all lives on board were lost.

Investigators later determined that the pitot tube providing information to the left Air Data Computer (ADC) had most likely been completely blocked and consequently the information provided by the left ADC to the captain's airspeed indicator and the center autopilot was erroneous. The crew did not attempt to clarify the RUDDER RATIO or MACH/SPD TRIM advisories, however, it is unlikely that they had time to do so or that the related checklists would have proved useful to them. The relation of these two particular messages to the difference in the captain's and first officer's indicated airspeeds is far from intuitive and is not information generally included in checklists related to these messages. There was no specific airspeed discrepancy warning on the B757.

Although the crew agreed that the alternate airspeed indicator was displaying correct airspeed information, they were distracted by and continued to try to use (and be confused by) airspeed information on the primary flight displays. The contradictory warnings and indicators were greatly confusing to the crew and the center autopilot and autothrottles contributed greatly to their problems, at least initially. Additionally, the crew did not try to fly the aircraft manually;

they continued to try use automation (i.e., Altitude Hold) in a ways that did not help them. During normal operations the use of automation can be confusing for crews; under non-normal conditions, these problems are likely exacerbated.

### Selected Issues Related to Emergency Equipment and Evacuations

Finally, the EAS project is addressing a selected sub-set of issues involving **Emergency Equipment and Evacuations**. Some equipment provided to flight and cabin crews for emergency or abnormal situations can be problematic to use, for example, smoke goggles that do not fit over eyeglasses. Another issue is whether crews receive adequate training and practice to be proficient in use of emergency equipment. We are also interested in whether differences in emergency equipment among different aircraft configurations and types create vulnerability to confusion and error by flight attendants. Although the EAS project is not addressing the full range of evacuation issues we are concerned with issues such as the decision whether to evacuate and communication between the cabin and the cockpit.

#### *Examples from Recent Accidents*

There have been many accidents in which problems with emergency equipment impeded a flight or cabin crew's response to an emergency. One such accident occurred in Maui, Hawaii on April 28, 1988, when an 18 ft. section of fuselage separated from a B727-200 as it was leveling out at a cruise altitude of 24,000 ft (7315.2 meters), causing an explosive decompression (NTSB, 1989). Although the crew was able to land at Maui 13 minutes after the event occurred, the first officer had to hold the oxygen mask on her head and to her face because it was so large that it kept sliding around and communication was very difficult through the oxygen mask microphone.

Problems with communication between the cabin and flight crews likely influenced the evacuation of a flight on March 26, 2003 in Flushing, New York (NTSB, 2003; preliminary report). Nearing the final approach fix the engine and alert display (EAD) of a B717-200 indicated that the left generator had failed. The display units and standby instruments went dark and then began flashing randomly. The flight crew noticed a burning smell in the cockpit. The forward flight attendants also noticed a burning smell in the cabin and determined that the handset used to make announcements and contact the cockpit was inoperative. After landing, the lead flight attendant tried to get the attention of the flight crew by banging on the cockpit door and speaking loudly. The flight crew reported that they heard neither the banging nor the loud talking through the door. This incident is currently under investigation so it is still unknown if the flight crew did not hear the flight attendant because they were preoccupied with other duties or if the reinforced security door precluded communication.

### Conclusion

Fortunately, serious accidents, such as the ones we have reviewed, are infrequent in airline operations. However, emergency and abnormal situations occur on flights across the world everyday. These situations are inherently challenging and require highly skilled performance by flight crews and close coordination among all those assisting them. Many issues are involved in this large domain, more than can be answered definitely by any one project. By identifying

latent vulnerabilities and delineating issues, the EAS project will lay a foundation for establishing best practices. In this way, we hope to help prevent emergency and abnormal situations from becoming accidents.

#### Footnotes

<sup>1</sup> The Emergency and Abnormal Situations project is funded through the Training Element of NASA's Aviation Safety and Security Program.

<sup>2</sup> For simplicity, the term "non-normal situations" will occasionally be used to refer to both emergency and abnormal situations.

<sup>3</sup> All accident-related information included in this paper has been taken from the reports of the investigative bodies involved.

#### References

Commuter Captain Fails to Follow Emergency Procedures After Suspected Engine Failure, Loses Control of the Aircraft During Instrument Approach. (1996). *Flight Safety Foundation - Accident Prevention*, 53(4).

Fuel Imbalance Cited in Learjet 35A Control Loss. (2000). *Flight Safety Foundation - Accident Prevention*, 57(2).

Klein, G. A. (1998). *Sources of power: How people make decisions*. Cambridge, MA: MIT Press.

Martensson, L. (1995). The Aircraft Crash at Gottrora: Experiences of the Cockpit Crew. *The International Journal of Aviation Psychology*, 5(3) 305-326.

National Transportation Safety Board. (1989). *Aloha Airlines Flight 243, Boeing 737-200, N73711, Near Maui, Hawaii, April 28, 1988*. Washington, DC: Author (NTIS No. PB89-910404).

National Transportation Safety Board. (1996). *Ground Spoiler Activation in Flight/Hard Landing, ValuJet Airlines Flight 558, Douglas DC-9-32, N922W, Nashville, Tennessee, January 7, 1996*. Washington, DC: Author (NTIS No. PB96-910407).

National Transportation Safety Board. (1997). *In-flight Fire and Impact with Terrain, ValuJet Airlines, Flight 592, Douglas DC-9-32, N904VJ, Everglades, Near Miami Florida, May 11, 1996*. Washington, DC: Author (NTIS No. PB97-910406).

National Transportation Safety Board. (1998a). *American Trans Air Flight 406, Boeing 727-290, N775AT, Indianapolis, IN, May 12, 1996 (NTSB ID No. CHI96IA157)*. Abstract Retrieved July 16, 2003, from [http://www.nts.gov/ntsb/brief.asp?ev\\_id=20001208X05709&key=1](http://www.nts.gov/ntsb/brief.asp?ev_id=20001208X05709&key=1)

National Transportation Safety Board. (1998b). *In-Flight Fire/Emergency Landing, Federal Express Flight 1406, Douglas DC-10-10, N68055, Newburgh, New York, September 5, 1996*. Washington, DC: Author (NTIS No. PB98-910403).

National Transportation Safety Board. (2002). *Loss of Control and Impact with Pacific Ocean, Alaska Airlines Flight 261, McDonnell Douglas MD-83, N963AS, About 2.7 Miles North of Anacapa Island, California, January 31, 2000*. Washington, DC: Author. (NTIS No. PB-2002-910401).

National Transportation Safety Board. (2003). *Air Tran Airways Flight 356, B717-200, N957AT, Flushing, NY, March 26, 2003 (NTSB ID No. NYC03FA067)*. Preliminary Report Retrieved July 16, 2003 from [http://www.nts.gov/ntsb/brief.asp?ev\\_id=20030409X00464&key=1](http://www.nts.gov/ntsb/brief.asp?ev_id=20030409X00464&key=1)

Transportation Safety Board of Canada. (2003). *In-Flight Fire Leading to Collision with Water. Swissair Transport Limited, McDonnell Douglas MD-11 HB-IWF, Peggy's Cove, Nova Scotia 5 nm SW, 2 September 1998 (TSB Report No. A98H0003)*. Gatineau, Quebec: Author.

Walters, J.M., & Sumwalt, R.L., III. (2000). *Aircraft Accident Analysis: Final Reports*. Chap. 4, pp. 75-87. New York: McGraw-Hill.

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