Many factors affect crew effectiveness in handling emergency or abnormal situations

A major research effort is required to find solutions for many of the dilemmas faced by flight crews when an emergency or abnormal situation arises, and to lay a foundation for best practices that help prevent accidents.

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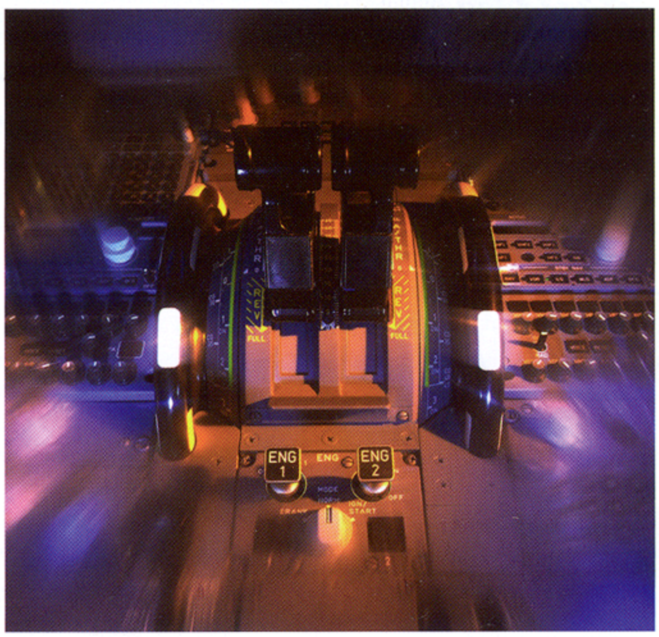
EMERGENCY and abnormal situations occur aboard aircraft every day. The seriousness of these daily occurrences ranges from life-threatening and highly time-critical to mundane and relatively trivial. Fortunately, emergency and abnormal situations aboard aircraft rarely result in accidents. Yet even when the aircraft lands safely, shortcomings are often evident in checklists, procedures, training, crew coordination, and the way the situations are managed.

What influences the manner in which an emergency or abnormal situation will be handled? To answer this question fully, it is necessary to first examine pertinent issues within six interrelated areas:

- specific aspects of emergency or abnormal situations;
- training for emergency and abnormal situations;
- economic and regulatory pressures in aviation;
- human performance capabilities and limitations under high workload and stress;
- aircraft systems and automation; and
- philosophies and policies within the aviation industry.

The issues in each of these areas must then be explored as they relate to the design of procedures and checklists and ultimately to crew response, coordination, and management of emergency and abnormal situations in aviation.

Specific aspects of abnormal situations. Emergency and abnormal situations vary along several dimensions. Determining the degree of time criticality and level of threat — two of these dimensions — is crucial and can be especially difficult when the cues presented to the crew are contradictory or ambiguous. Is the odd smell an indication of a fire or merely commonplace output from the air conditioning system? The crew of Swissair Flight 111 was unable to tell initially.


Airbus S.A.S.

Human performance under high stress and workload needs to be taken into account when developing procedures and checklists to be followed in an emergency or abnormal situation.

The complexity, amount of increased workload, and degree to which a situation is novel or familiar, are other dimensions along which these situations may vary. Many non-normal situations involve a single, well-isolated malfunction. However, even these situations often go beyond the scope of published procedures and checklists.

It is important to keep in mind that some situations may be so time-critical or may unfold so quickly that all energy and attention must be given to controlling and landing the aeroplane with few resources to spare for even consulting a checklist. Such was the case in 1988, when an 18-foot section of fuselage separated from a Boeing 737-200 that was levelling off at 24,000 feet. The flight crew estimated that they completed — largely from memory — all or significant parts of 17 different checklists in the 13 minutes it took for them to complete an emergency descent and landing.

Training for abnormal situations. Training is another important factor that significantly affects how an emergency or abnormal situation is handled. In the United States, training is generally driven by the need to complete Federal Aviation Administration (FAA) mandated manoeuvres described in FAR Part 121. Training under the Advanced Qualification Programme (AQP) allows more flexibility but here, too, time constraints and cost tend to restrict the range and depth of training for emergencies.

Under both AQP and FAR Part 121 crews rarely, if ever, face a situation in the simulator for which there is no checklist or procedure, even though this can be the case in actual emergencies. Likewise, they rarely encounter an event for which the checklist procedures do not work as expected — the light on the overhead panel goes out, the crossfeed opens, the engine fire is contained.[1] It is typically only in line-oriented flight training (LOFT) or line operational evaluation (LOE) simulator sessions, if even then, that crews might be required to avoid other traffic or deal with deteriorating weather conditions while responding to an emergency. Thus the degree to which training truly reflects real-life emergency and abnormal situations with all of their real-world demands, especially with regard to communicating and coordinating a response with others, is often limited.

Despite these drawbacks, however, flight crews do benefit from the training for emergency and abnormal events they currently receive. In a review of 107 reports involving emergency or abnormal situations filed with the U.S. Aviation Safety Reporting System (ASRS), researchers found 25 described situations that appear to have been handled quite well.[2]

Nineteen of these 25 reports involved what might be called "textbook" abnormal or emergency situations — those situations that generally involve only a single system malfunction (as opposed to multiple problems), are highly trained and practiced in a simulator, and for which good checklists exist. As one ASRS reporter remarked, "Our simulator training really paid off. This was my first engine shutdown in 20 years of flying, and it felt like I had done it a thousand times before!"

Thus, most textbook emergencies were handled smoothly and as planned. Most of the ASRS reports which were reviewed, however, described events that were not textbook emergencies (85 in all), and the vast majority of these (93 percent) involved a problem with the way in which the flight crew or others responded to the situation, and/or with the materials and resources they were to use (see accompanying table).

Economic and regulatory pressures. As mentioned above, regulatory and economic pressures significantly affect training for emergencies. To a large degree, regulatory requirements dictate what is trained and, in a vicious circle, economic pressures then dictate that what is not required by regulation is not trained. The latter occurs because the time devoted to various types of training is regarded by most airlines as being fixed at a certain number of days per year. Pulling crews off the line to participate in training has tremendous economic impact on an airline and adding to the training "footprint" is avoided if at all possible.

Crew response	Textbook Emergency	Non-Textbook Emergency	Totals
Handled Well	19	6	25
Not Handled Well	3	79	82
Totals	22	85	107

Crew performance in handling emergencies
(based on study of 107 ASRS reports)

Economic pressures can affect the handling of emergency or abnormal situations in other ways as well. For example, flight crews may also feel some reluctance to divert to an alternate airport or may divert to one where maintenance or other services are available rather than one that is closer. Pilots' fears of reporting requirements or regulatory action may affect their decisions whether or not to declare an emergency with Air Traffic Control, and real or perceived pressures from companies can also have profound implications for how situations are handled. In one safety report, for instance, a pilot admitted: "Had there been an actual engine fire, the fear of being punished by my employer for causing a customer delay may have raised safety concerns because of my reluctance to perform the required engine shutdown."

Human performance. Most emergency and abnormal situations increase the workload on the flight deck. Sometimes this increase is transitory and limited, but at other times it is great and continues for the remainder of the flight. In high workload situations, crew errors and less-than-optimal responses often can be linked directly to inherent limitations in human cognitive processes. These are limitations all humans experience when faced with threat, or when under stress or overloaded with essential tasks.

Studies reveal that cognitive performance is significantly compromised under stress. When experiencing stress, human attention narrows — a phenomenon referred to as tunnelling. Tunnelling restricts scanning the full range of environmental cues, causing the individual to focus narrowly on what are perceived to be the most salient or threatening cues. Thus, under stress pilots may focus on a single cockpit indicator and not notice other indications also relevant to their situation.

Additionally, working memory capacity and the length of time information can be held in working memory decrease under stress. Working memory is the crucial resource that allows individuals to hold and manipulate information cognitively. When working memory capacity is exceeded, individuals' ability to analyse situations and devise solutions is drastically impaired.

Therefore, when experiencing stress and high workload, crews are vulnerable to missing important cues related to their situation and can experience difficulty making sense of information, especially when it is incomplete, ambiguous, or contradictory. Pilots' problem-solving abilities may be impaired, and they will generally have difficulty performing complex mental calculations, such as figuring landing distances on a wet runway with reduced flaps.

Stress-induced limitations on human performance capabilities are often overlooked when considering how crews respond to emergency and abnormal situations. Researchers at NASA recently conducted an in-depth analysis of several airline accidents and determined that normal cognitive limitations experienced by all humans when dealing with

The Boeing Co.

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stress, concurrent task demands, and time pressure, underlie those errors made by the accident crews. As is discussed below, human performance limitations have implications for appropriate checklist design.

Aircraft systems and automation. Various automated aircraft and warning systems can also affect the handling of emergency and abnormal situations. For example, in 1991, while an MD-81's engines were surging, the automatic thrust restoration (ATR) feature on the aircraft increased the engine power without the pilots' knowledge. This increased the intensity of surging, which contributed to the failure of both engines. During the investigation of this accident it was discovered that the pilots and the air carrier were unaware that the ATR feature even existed on the aircraft.

The numbers and types of warnings and warning systems aboard modern aircraft have greatly increased in recent years. The large number of warnings can result in information overload as crews attempt to make sense of the various alerts and respond properly. This is especially true when multiple or contradictory warnings are presented in close succession or at the same time.

These issues were involved in 1996, when erroneous information was sent to a Boeing 757 captain's airspeed indicator by the left air data computer because of a blocked pitot tube. Although the crew agreed that the back-up airspeed indicator was correct, they never attempted to fly the aircraft manually by reference to it. Instead, the first officer selected Altitude Hold but the power setting was too low to maintain altitude and the aircraft crashed soon afterward.

It can be difficult for flight crews to determine the most appropriate level of automation to use during emergency and abnormal situations. In some cases automation can help reduce crew workload, but attempting to use some aspects of automation can also impair a crew's ability to respond appropriately.

Additionally, pilots may become so accustomed to using automation to fly the aircraft that they may have trouble reverting to manual flying when required by an emergency. As stated in one ASRS report, "We were both very absorbed in flying the aircraft by hand, as it's something we don't often do."

Finally, crews have difficulty determining the correct response when they receive a warning that has a long-standing history of being unreliable, as foreseen in this ASRS excerpt: "The cargo compartment smoke alarm system has a maintenance history of false warnings. The frequency of these reports is going to lead some crews to ignore the warnings."

Indeed, between 1994 and 1999, the ratio of false cargo smoke alarms to real cargo smoke alarms was 200 to 1. Making an unnecessary diversion and emergency landing when an alarm is false can have tremendous costs and safety implications. However, not diverting when there is a fire can have even greater costs and safety ramifications.

Philosophies, policies and practices. Almost everyone in the industry — from manufacturers to instructors to directors of flight operations to line pilots — has ideas about how emergency and abnormal situations should be managed. These ideas derive from individual experiences, beliefs and perspectives related to various cost-benefit trade-offs. Often, these ideas are not explicitly expressed in a written document but are evident in choices made throughout the aviation industry, choices such as: (1) the directions and information given to crews in checklists; (2) the types of scenarios emphasized during training; (3) the degree

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1. Restrictions in simulator design may limit the types of problems that can be presented to flight crews. For example, it may not be possible to program some simulators so that a light on the panel remains illuminated after a crew has correctly completed the pertinent checklist procedures.

2. ASRS reports are filed voluntarily; therefore the numbers presented in this article related to these reports cannot be considered representative. They only indicate frequencies within the set of reports used in the study, not the rates of occurrence in aviation operations.

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