Cockpit Smoke Solution

According to Air Safety Week, at least once a day somewhere in North America a plane has to make an unscheduled or emergency landing because of a smoke and in-flight fire event.

Statistics from FAA Service Safety Reports clearly show that in-flight fires, smoke or fumes are one of the most significant causes of unscheduled or emergency landings and account for 3 percent of all runways per day based on 1,589 events during a 10 month period in 1995.

A pilot encountering smoke in the cockpit so thick that the instruments cannot be seen can utilize a relatively simple device, which provides a clear view.

The Emergency Vision Assurance System (EVAS) provides a clear space of air through which a pilot can see flight instruments and out the front windshield for landing. The pilot still relies on the oxygen mask for breathing, smoke goggles for eye protection and employs approved procedures for clearing smoke from the aircraft. When smoke evacuation procedures are not sufficient, EVAS provides emergency backup allowing the pilot to see and fly the aircraft to a safe landing.

EVAS measures 3 x 8.5 x 10 inches when stowed, the approximate space of a Jeppesen navigation manual. When needed, the pilot removes the IVU (Inflatable Vision Unit) from the EVAS case and pulls a tab to activate the system. The IVU inflates with one lobe above and one below the windshield. According to EVAS Worldwide, the manufacturer, the whole process takes 15-20 seconds. The pilot leans forward, placing his smoke goggles in contact with the EVAS clear window giving him an unimpaired view of both vital instruments and the outside world.

After it is activated, EVAS is continually pressurized with filtered cockpit air to maintain volume, and preserve a clear view. The device is independent of aircraft power, relying on a self contained battery power supply, pumps and filters in each storage case. EVAS systems are designed to run for at least two hours, and filter down to .01 microns. The system requires virtually no installation.

While FAA regulations require smoke detectors, fire extinguishers, smoke goggles and oxygen masks, pilots point out that these safeguards and all other systems and equipment for flight safety are useless if the pilots cannot see to control and land the aircraft.

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The Royal Aeronautical Society has 20 Specialist Interest Group Committees, each of which has been set up to represent the Society in all aspects of the aerospace world. These committees vary in size and activity, but all their members contribute an active knowledge and enthusiasm. The Groups meet four or five times a year and their main activities centre around the production of conferences and lectures, with which the Society fulfils a large part of its objectives in education and the dissemination of technical information.

In addition to planning these conferences and lectures, the Groups also act as focal points for the information enquiries and requests received by the Society. The Groups therefore form a vital interface between the Society and the world at large, reflecting every aspect of the Society's diverse and unique membership.

By using the mechanism of the Groups, the Society covers the interests of operators and manufacturers, military and civil aviators, commercial and research organisations, regulatory and administrative bodies, engineers and doctors, designers and distributors, company directors and students, and every other group of professionals who work within aerospace.

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A Guild of the City of London

Founded in 1929, the Guild is a Livery Company of the City of London, receiving its Letters Patent in 1956.

With as Patron His Royal Highness The Prince Philip, Duke of Edinburgh, KG KT and as Grand Master His Royal Highness The Prince Andrew, Duke of York, CVO ADC, the Guild is a charitable organisation that is unique among City Livery Companies in having active regional committees in Australia, Hong Kong and New Zealand.

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- To assist air pilots and air navigators and their dependents with their children's education and those in need through a Benevolent Fund.

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To join the Guild, please contact the Clerk, Guild of Air Pilots and Air Navigators, Cobham House, 9 Warwick Court, Gray's Inn, London WC1R 5DJ - Tel: +44 (0)20 7404 4032. Fax: +44 (0)20 7404 4035. E-mail: gapan@gapan.org & web site: www.gapan.org

This Publication represents the views of the Specialist Flight Operations Group of the Royal Aeronautical Society. It was proof read by some of the Specialist Groups Committee member chairmen but has not been discussed outside the Learned Society Board. As such, it does not necessarily represent the views of the Society or any other specialist Group or Committee.
Reducing the Risk of Smoke, Fire and Fumes in Transport Aircraft

Past History, Current Risk and Recommended Mitigations

By
Captain John M. Cox, FRAeS
President
Safety Operating Systems (USA)

With original Appendices material by the Reviewing team of the RAeS Flight Operations Group (FOG) Committee

The Appendices must be read in conjunction with the Main Paper. They are complementary corollaries and an important part of this Specialist Paper

Published by
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THE AUTHOR

Captain John M. COX, FRAeS

A veteran major airline, corporate and general aviation pilot, Captain Cox has flown over 14,000 hours with over 10,000 in command of jet airliners. Additionally, he has flown as an instructor, check pilot, and test pilot in addition to extensive involvement in global air safety. He holds an Air Line Transport Pilot Certificate with type ratings in the Airbus A320 family, the Boeing 737 family, the Fokker F28 and the Cessna Citation. He is an experienced accident investigator having been involved in six major NTSB investigations (the best known being the US Air 427 accident in Pittsburgh in 1994) and numerous smaller investigations he holds an Air Safety Certificate from the University of Southern California. The International Federation of Airline Pilots Association (IFALPA) certified him as an international accident investigator. For over twenty years he served as an Air Safety Representative for the Air Line Pilots Association rising to the position of Executive Air Safety Chairman, ALPA’s top safety job. ALPA awarded him their highest safety award in 1997. A Fellow of the Royal Aeronautical Society, he was awarded a Master Air Pilot Certificate by the Guild of Air Pilots and Air Navigators in October 2004. In December 2004 he retired from airline flying after twenty five years to found Safety Operating Systems a Washington, DC, based aviation safety consulting firm.
SMOKE, FIRE AND FUMES IN TRANSPORT AIRCRAFT

THE ROYAL AERONAUTICAL SOCIETY FLIGHT OPERATIONS GROUP

The Flight Operations Group committee consists of 30 members from both the civilian airline and military transport & flying training sectors, with Flight Safety and the Quality of Training throughout the Public Transport Industry being its primary objectives. The FOG is a discussion group that focuses on issues which primarily concern civil aviation, although it touches upon aviation safety in the armed forces, specifically where the safety issues could also be applicable to civilian operations. Its membership is highly respected within the civil aviation operations area and brings together a team with many years of experience in the field of aviation.

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The Future Flight Deck (1992 - 93) by Captain Peter Buggé, FRAeS, and Capt John Robinson, FRAeS
British Aviation Training (1998) by Captain G.L. Fretz, FRAeS
Smoke and Fire Drills (1999) by Captain Peter Buggé, FRAeS, Captain Ron Macdonald, FRAeS and SFE Peter Richards, IEng, FRAeS
So You Want to be A Pilot? (2002) by Captain Ralph Kohn, FRAeS
The Human Element in Airline Training (September 2003) by Captain Ralph Kohn, FRAeS
So You Want to be A Pilot? (2006) by Captain Ralph Kohn, FRAeS
Reducing the Risk of Smoke, Fire & Fumes in Transport Aircraft (July 2006) by Captain John M. Cox, FRAeS
The All Weather Operations Guide (to be published in late 2006) by Captain Ralph Kohn, FRAeS

The above listed Papers represent the views of the Specialist Group of the Society and of the Guild committee that were involved with their preparation. They were not discussed outside the Specialist Group Committee or the Guild’s Secretariat. As such, they do not necessarily represent the views of the Society or the Guild as a whole, or any other specialist Group or Committee, or of the National Regulatory Authority (UK CAA).
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I want to thank Dr Kathy Abbott, PhD, FRAeS, of NASA, who is on detachment to the FAA as chief scientific technical advisor in Flight Safety Human Factors, for her assistance with this Specialist Paper.

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John M. Cox, FRAeS
Reducing the Risk of Smoke, Fire and Fumes in Transport Aircraft

Past History, Current Risk and Recommended Mitigations
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EXECUTIVE SUMMARY

From the beginning of aviation history uncontrolled in-flight fire has been a serious issue. Aviation’s first fatal accident occurred as a result of an uncontrolled in-flight fire. In July 1785, Jean-François Pilâtre de Rozier’s hydrogen balloon ignited and burned over the English Channel.\(^1\)

The occurrence of smoke, fire or fumes aboard a commercial aircraft presents a potentially dangerous situation. Accident data show in-flight fire with the fourth highest number of on board fatalities and the seventh highest category of accidents.\(^2\)

In addition, data from recent years indicate the probability of passengers experiencing an in-flight smoke event is greater than one in 10,000. In the United States alone, one aircraft a day is diverted due to smoke.\(^3\)

There have been significant improvements in the safety of transport aircraft. Yet, there remain additional opportunities for improvements in equipment design and airworthiness criteria, protective equipment, maintenance, improved pilot procedures and flight crew training.

Further reducing the risk involves multiple layers of mitigation.

The adoption of the recommendations may provide the needed layers while helping to reduce the risk and severity of future in-flight fires. As in the past, aviation will continue to experience in-flight fires.

The recommendations are intended to help prevent the initiation of fires and reduce the likelihood that any fire that does ignite does not become uncontrollable.

RECOMMENDATIONS TO REDUCE THE SEVERITY & EFFECTS OF IN-FLIGHT FIRES INCLUDE

Equipment Design and Airworthiness

1. Evaluate aircraft for single point failures of wiring and potential effect on systems of the aircraft.

2. Improve the engineering and installation of wires so that the routing does not endanger, by proximity, any critical system wiring. Evaluate modifications using the same approval process for Supplemental Type Certificate modification as for Type Certificates.

3. Install arc fault circuit interrupter technology on new and existing transport aircraft.

4. Conduct continuous smoke testing for flight deck smoke evaluation tests for a type certificate.

5. Install fire access ports or dedicated fire detection and suppression systems in inaccessible areas of aircraft.

6. Review all existing and planned cabin interior materials and insulating materials surrounding the cabin, towards specifications producing less ‘toxic fumes’ when subject to heat.

7. Mark locations of minimal damage for access to inaccessible areas of the aircraft.

8. Increase the number and location of sensors to alert the flight crew of smoke/fire/fumes. These sensors should take advantage of new technology to minimise the false alarm rate.
Protective Equipment

1. Implement vision assurance technology for improved pilot visibility during continuous smoke in the flight deck.

2. Install full-face oxygen masks and provide sufficient flight crew oxygen for descent and landing during a smoke/fire/fume event.

3. Increase size of flight deck and cabin fire extinguishers to five pounds of Halon or an equivalent effective agent.

Maintenance

1. Include in maintenance plans for all transport aircraft regular inspections of thermal acoustic insulation blankets and smoke barriers to insure cleanliness.

2. Modify maintenance procedures to minimise the possibility of contamination of thermal acoustic insulation blankets.

3. Improve wiring inspection maintenance programmes using new technology not relying exclusively on visual inspection of wiring bundles.

Pilot Procedures

1. Implement flight crew procedures for using autoflight systems to reduce pilot workload. There should, however, be provisions in the procedures for the failure or un-serviceability of the autoflight system.

2. Eliminate procedures to open flight deck window to vent of smoke. Improve smoke removal procedures to ensure maximum effectiveness.

3. Redesign all transport aircraft checklists pertaining to smoke/fire/fumes to be consistent with the Flight Safety Foundation smoke/fire/fume checklist template. Consider: memory items, prevention of checklist “bottlenecks,” font size and type, where it should be found (quick reference handbook (QRH) or electronic), smoke removal, number of checklists for smoke/fire/fumes, and the length of the checklists.

Flight Crew Training

1. Assure that flight crew training includes the proper use of a crash axe, the necessity of proper fire extinguisher operation including vertical orientation, the proper accomplishment (or abandonment) of checklist during simulated smoke/fire/fume events, the importance of maintaining a smoke barrier during smoke/fire/fume events and the ineffectiveness of, and potential problems with, opening a flight deck window during realistic line oriented re-current flight training on a recurrent annual basis.

Co-operation of the regulators, manufacturers, air carriers, and professional associations is needed to implement these safety recommendations. Only through execution of a comprehensive mitigation strategy along with developing and implementing a plan to maximise fleet coverage can the risk of in-flight smoke, fire and fumes be reduced to an acceptable level.
Data from recent years indicate the probability of passengers experiencing an in-flight smoke event is greater than one in 10,000. In the United States alone, one aircraft a day is diverted due to smoke. Fortunately, it is rare for a smoke event to become an uncontrolled in-flight fire. However, data collected by the International Air Transport Association (IATA) estimates that more than 1,000 in-flight smoke events occur annually, resulting in more than 350 unscheduled or precautionary landings. In-flight smoke events are estimated at a rate of one in 5,000 flights while in-flight smoke diversions are estimated to occur on one in 15,000 flights.

Over 36 months (from January 2002 to December 2004), IATA conducted a study of Air Safety Reports (ASR) filed in their safety trend analysis, evaluation and data exchange system (STEADES) database from 50 commercial operators. Over the three years 2,596 smoke events were recorded. The study revealed that 1,701 of the 2,596 events were in-flight occurrences of smoke. The highest number of these events occurred within the cruise phase of flight and resulted in an operational impact on the flight (e.g. a diversion and unscheduled landing). The fleet analysis illustrated that both Boeing and Airbus aircraft are equally affected by smoke events. The origination of smoke/fume events occurred most often (in order): cabin, lavatory, flight deck, cargo hold and the galley.

Reviewing the statistics from 1987 to 2004, the four leading categories (out of 17 listed) of commercial jet aircraft fatalities were loss of control (LOC), controlled flight into terrain (CFIT), specific component failure (non-powerplant) and in-flight fire. These four causes accounted for the largest number of fatalities. Of the 226 accidents included in the study there were 10 in-flight fires. This was the seventh most common type of accidents tied with the accident type of undershoot/overshoots.

Advisory Circular (AC) 25-1309-1a contains useful definitions for identifying the severity of potential events and relating them to the frequency of occurrence. Using these definitions, an in-flight fire can be characterised as a catastrophic event because it has the potential to be a “condition that would prevent continued safe flight and landing.”

Most in-flight fires do not actually become catastrophic. However, the potential exists and when calculating risk it is reasonable to consider the potential outcomes.

According to the AC, a catastrophic event must be “extremely improbable” (defined as conditions having a probability on the order of $1 \times 10^{-9}$ or less). Analysis of in-flight fire events by Captain Jim Shaw shows a greater likelihood of occurrence than that of “extremely improbable.”

This is consistent with the IATA study where during the 36 months examined, there occurred an average of two and a half smoke events each day. Paul Halfpenny, in his research suggests that the probability of a diversion due to cockpit smoke could be a “reasonably probable event ($1 \times 10^{-3}$ to $1 \times 10^{-5}$).”

Reviewing in-flight smoke/fire/fume events shows that there have been more in-flight smoke, fire and fumes events per departure than “extremely improbable”. An in-flight fire can become a “catastrophic” event. Therefore, improved mitigations to reduce the occurrence rate are desirable.
A HISTORICAL LOOK AT SMOKE, FIRE AND FUMES

Characterising the Problem

From the beginning of aviation history uncontrolled in-flight fire has been a serious issue. Aviation’s first fatal accident occurred as a result of an uncontrolled in-flight fire. In July 1785, Jean-François Pilâtre de Rozier’s hydrogen balloon ignited and burned over the English Channel.

A review of the past incidents shows that in-flight fires have continued to occur despite the efforts of manufacturers, regulators and operators. Recently the Federal Aviation Administration (FAA) acknowledged that it is unlikely to “eradicate all possible sources of ignition in fuel tanks” and they also state “the examinations of large transport aircraft … revealed many anomalies in electrical wiring systems and their components, as well as contamination by dirt and debris.” This acknowledgement is important because it shows the need for multiple mitigations to contend with smoke/fire/fumes. Not only must internal fire sources within the aircraft be considered, but the possibility of the detonation of an explosive device and its effect on the aircraft should also be considered in the overall risk assessment.

Some notable in-flight fires can help characterise the risk. An uncontrolled fire caused the crash of a Trans World Airline Lockheed Constellation on 11 July 1946, near Reading, Pennsylvania. Soon after departure on this training flight the crew began to smell burning insulation. The flight engineer opened the flight deck door and reported to the Captain “the whole cabin is on fire.” The flight crew attempted to fight the fire without success. Smoke streamed into the flight deck filling it with dense smoke and obscuring the instruments. The instructor captain opened the window in an effort to find the airport, but was unable to maintain control. The aircraft crashed killing everyone except the instructor captain. “The reason for the loss of control of the aircraft immediately prior to impact and therefore the most immediate cause of the accident, was the inability of the pilots to maintain adequate control because of the denseness of the smoke within the crew compartment.”

This was an early example of smoke causing extreme difficulties for pilots.

The National Transportation Safety Board (NTSB) determined that the probable cause of the fire was the “failure of at least one of the generator lead ‘through-stud’ installations in the fuselage skin of the forward baggage compartment, which resulted in intense local heating due to the electrical arcing, ignition of the fuselage insulation and creation of smoke of such density that sustained control of the aircraft became impossible.” A contributing factor was the “deficiency in the inspection systems, which permitted defects in the aircraft to persist over a long period of time and to reach such proportions as to create a hazardous condition.” Some of the same concerns raised in this accident such as electrical arcing, ignition of insulation and creation of dense smoke remain today almost 60 years later.

Enter the Jet

Following the introduction by British Overseas Airways Corporation (BOAC) of scheduled trans-Atlantic jet services on 4 October 1958, United States commercial airline jet services started on 26 October 1958, when Pan American flew from New York to Paris. As the jets took over commercial flight operations, the accident rate declined. This was due, in part, to the improvements in design and equipment reliability. In addition, the regulatory requirements for commercial aircraft also became more stringent.

However, at least two B707s encountered serious fires that resulted in loss of the aircraft. These two accidents in 1973 caused changes in regulation, design and procedures for the 707 and future aircraft. On 11 July 1973 Varig Flight 860 departed Rio de Janeiro for Paris. After a routine flight they were approaching the Orly airport when a fire broke out in the aft cabin. Smoke filled the cabin and began filling the flight deck. Only five kilometres (three miles) from Runway 07, in a smoke filled flight deck where visibility of the flight instruments was diminishing rapidly, the Captain decided to land off the airport in a field. Opening windows in an effort to improve visibility did not
provide enough visibility to allow the flight to continue to the runway; the aircraft landed in a field after striking trees.

Only 70 seconds remained before Varig Flight 860 would have reached the safety of the runway where Airport Rescue and Fire-fighting crews were standing by. Unquestionably, there would have been a better landing environment on the runway compared to a field, yet the Captain chose the field. Was it due to smoke or fire?

Autopsies of many of the passengers showed that the cause of death was not fire, but smoke. Conditions in the flight deck may have deteriorated to such a point that there was a question about the ability to maintain control of the aircraft for another 70 seconds. An important clue to the condition of the flight deck is that the surviving crewmembers were not burned, but did suffer smoke inhalation. It is possible that the decision was based not on fire entering the cockpit, but the amount and density of smoke affecting visibility. Further evidence that smoke was a more significant issue than the fire is that 117 passengers survived the landing, yet all but one succumbed to asphyxiation by poisonous gas and smoke.

Later in that same year, Pan Am Flight 160 (a Boeing 707-321C) departed New York for Prestwick, Scotland on 3 November. About 30 minutes into the flight of this all cargo jet, the crew reported smoke on board from improperly packed hazardous cargo. Unfortunately, the aircraft crashed just short of Runway 33 Left at the Logan International Airport near Boston, Massachusetts. The NTSB cited the probable cause of the accident “was the presence of smoke in the cockpit which was continuously generated and uncontrollable. The smoke led to an emergency situation that culminated in loss of control of the aircraft during final approach, when the crew in uncoordinated action deactivated the yaw damper which, in conjunction with incompatible positioning of flight spoilers and wing flaps caused loss of control.” The Safety Board further determined that “the dense smoke in the cockpit seriously impaired the flight crew’s vision and ability to function effectively during the emergency.”

Both of these examples show smoke situations so serious that crew members took drastic actions. Varig Flight 860 intentionally landed in a field and Pan American Flight 160’s engineer selected the essential power selector to the “external power” position causing the yaw damper to cease operation. With the flaps set for landing and the spoilers extended (which they had been for the preceding four and half minutes) the aircraft became uncontrollable. This action was probably taken without the knowledge, or agreement, of the Captain. In both aircraft there was a smoke filled flight deck; yet, there is no mention of a flight deck fire on either cockpit voice recorder (CVR). This proved that not only should fire be considered, but the effects of smoke in the flight deck also posed risk.

The loss of Varig Flight 860 and Pan American Flight 160 were instrumental in causing changes in regulation, design and flight crew procedures of transport category aircraft. Some of these changes included improved flight crew procedures for smoke removal, tightened regulation for hazardous material shipping, improved design in cabin airflows, new requirements that waste towel receptacles be made more fire resistant and banned smoking in lavatories.

**The Next Generation**

The next generation of jets included the jumbos. There were new safety issues for the jumbos but not all were foreseen. An example was the airflow pattern of the Boeing 747. In the late 1960s there was no requirement or standard for airflow patterns in transport category aircraft. Yet it was found that smoke could be drawn into the flight deck of the B747SP during a main deck cabin fire during some airflow settings. The FAA proved this in April of 2003 during comprehensive tests. The tests showed the complexity of airflow patterns in some wide body aircraft. These airflow patterns can cause smoke to accumulate in unexpected places in the aircraft.

Advancing technology provided many enhancements in this generation of jets. Some aircraft increased automation allowing the elimination of flight engineers. One consequence of increasing automation was increasing the number of wires in the aircraft. Wire bundles grew in size and
number as more electrical control of systems occurred. Also adding to the number of wires in aircraft was the increase in system redundancy. Dispatch reliability was becoming a major selling point. Therefore, redundancy was increased, thus, increasing the wiring within the aircraft.

Wire adds weight to aircraft. Therefore, manufacturers attempt to lighten the wiring where it can be done safely. One of the more effective methods is by using lighter insulation materials. Some of the lighter material has experienced unexpected consequences. Some lighter insulation has been found to be susceptible to cracking which leads, in some cases, to arcing. This arcing, when combined with combustible material (which can be wire insulation), can cause a self-sustaining fire in just a few minutes. And electrical arcing is only one of the potential sources of fire and smoke in airliners.

The aviation community has recognised that multiple layers of protection are needed if advancement in fire safety is to occur. Multiple layers of protection or multiple approaches to the threat are very necessary as unexpected events occur to crews faced with an in-flight crisis because this can be a complex, once in a lifetime event. The examples show how uncontrolled in-flight smoke/fire/fumes can cause the loss of the aircraft. This historical perspective sets the stage for how aviation can improve in the future.

Smoke/Fire/Fumes Regulations & Advisory Circulars for Transport Aircraft

FAA Regulatory Improvements

The FAA responded to events, incidents and accidents with regulatory improvements. One notable accident that resulted in numerous regulatory improvements was the 2 June 1983 accident of Air Canada Flight 797 in Cincinnati, Ohio. The DC-9-30 experienced an uncontrollable in-flight fire that began in the aft lavatory. This accident resulted in several safety improvements which included, but were not limited to: detection methods for lavatory fires, full-face-mask portable oxygen bottles for cabin crewmembers, methods to identify smoke sources and requirements for aircraft certified under CAR Part 4b to comply with 14 CFR Part 25.1439. These were important steps toward making in-flight fire less likely and providing the crew with better means of detecting and fighting fires.

Before this accident, the FAA did propose in 1975 to amend the regulations (specifically 14 CFR Part 25.1439) to include new standards for oxygen masks, but withdrew the proposal to allow further testing to establish the data on which to base standards. In 1981 the FAA advised the NTSB that they intended to update technical standard order (TSO) C99 that would provide a minimum standard for emergency equipment for “protection of flight crew members from toxic atmospheres.” The intent of the FAA was to use an AC to recommend that operators upgrade protective breathing equipment to the new TSO standards.

Much of the protective equipment in use at that time did not meet the updated TSO standard. It should be noted that neither a TSO nor an AC can provide a regulatory requirement for protective breathing equipment. The NTSB did not believe the FAA’s action was sufficient to “assure passenger safety.”

The FAA did not immediately implement the NTSB recommendations one of which was regarding lavatory fire detectors until after the Air Canada Flight 797 accident in June 1983. In addition to action on lavatory smoke detectors and Protective Breathing Equipment (PBEs), other safety enhancements resulted from NTSB recommendations from Air Canada Flight 797. New emergency lighting standards and recommendations were advised. The Board recommended tactile aisle markers and floor lighting so that people inside a smoke filled cabin could locate an emergency exit by feel alone. Improvements in fire blocking material (this required the retrofit of 650,000 seats) to slow fire propagation and emergency exit lighting requirements, became a requirement in 1986.
Lavatory fires continued to occur, causing the NTSB to recommend smoke detectors and automatic discharge fire extinguishers in the waste receptacles. The FAA implemented the NTSB 1974 recommendation (A74-98) for mandating automatic discharge fire extinguishers in the lavatory waste receptacle after Air Canada Flight 797’s fire in 1987. Also, in 1986 the FAA required that at least two Halon fire extinguishers be in the cabin.

On 29 July 1986 the FAA issued AC 25-9 to provide guidelines for certification tests of smoke detection, penetration, evacuation tests and flight manual emergency procedures. The AC specifically cites continuous smoke as a condition that should be considered in the formulation of smoke and fire procedures. It cited that accidents statistics show there are conditions of continuous fire and smoke in-flight. Interestingly, the AC test procedure for flight deck smoke evacuation states that the smoke generation should be terminated after the flight instruments are obscured. However, all other tests cited in AC 25-9 require continuous smoke be used. The ventilation systems are allowed three minutes to clear the smoke so that a pilot can see the instruments. This test does not represent conditions where smoke continues to be produced.

Air Canada Flight 797 experienced continuous smoke causing the Captain to land with his oxygen mask and smoke goggles on and his face pressed against the windshield. Other cases of continuous smoke in the flight deck include an Air Europe Fokker 100 landing at Copenhagen on 17 December 1989, Varig Flight 860, Pan American Flight 160 and Air Tran Flight 913. The Air Europe flight experienced dense smoke so thick that the pilots could not see each other. There is evidence that continuous smoke can occur in transport aircraft flight decks, yet the flight deck ventilation tests do not require that continuous smoke be present.

To further expand the scope of smoke testing a draft of an update to AC 25-9 began to circulate the industry for comment in July 1992. The revision included recommendations for:

- Addition of regulatory amendments for improved smoke clearance procedures;
- Adherence to updated Part 25 requirements;
- Fire protection;
- Lavatory fire protection;
- Addition of crew rest area smoke detector certification test;
- Use of helium smoke generator in testing; and
- Continuous smoke generation in the cockpit smoke evacuation tests.

The final version of AC 25-9a was published on January 6, 1994. While most of the issues and testing criteria were similar, there were changes from the draft. The revision from the original AC included recommendations for addition regulatory amendments for improved smoke clearance procedures, adherence to updated Part 25 requirements, fire protection, lavatory fire protection, addition of crew rest area smoke detector certification test, use of helium smoke generator in testing and paper towel burn box smoke generator, but not continuous smoke in the flight deck testing. Continuous smoke in the flight deck was referred to in Paragraph 6c (8) : “Although the FAR does not require the consideration of continuous smoke generation/evacuation, the FAA recommends that the airframe design address this situation. Accordingly, paragraphs 12a (1) and 12e (3) recommend addressing continuous smoke generation/evacuation in the cockpit.” The previous test procedure, which terminates the generation of smoke, remained. Rationale for the return to the previous method of testing was not explained in the revised AC.

The FAA testified before Congress on 8 November 1993 just before the final version of the AC was released. During that testimony they stated, “The evacuation of smoke from a cockpit is needed to enable the crew to operate the aircraft. Our standards provide for the effective evacuation of smoke. An aircraft’s equipment and procedures are considered to meet FAA requirements if smoke concentration is reduced within three minutes, so that any residual smoke neither distracts the flight crew nor interferes with operations under either instrument meteorological conditions, IMC or visual meteorological conditions, VMC. We believe these standards provide sufficient reserve for a flight crew to retain adequate visibility of the flight instruments and controls and outside the aircraft,
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to continue safe flight and landing even when a reasonably probable continuous smoke source is present." 40

However, this was not consistent with the experience of Federal Express Flight 1406 (a DC-10 that landed and burned on 5 September 1996), Swissair Flight 111 (MD-11 that crashed after a major in-flight fire on 2 September 1998, described later in the paper), or Air Tran Flight 913, which experienced an in-flight fire on 8 August 2000. 41 The fires aboard these aircraft burned and the crew could not extinguish or evacuate the smoke, so it spread.

**Interior Material Toxicity and Flammability**

The flammability of material in the interior of the cabin became a concern as toxic fumes were found to be released during cabin fires. Therefore, improvements to flammability standards were proposed. The FAA, working with safety recommendations from the NTSB, began a major improvement in cabin interiors following the fires aboard Varig Flight 860 and Pan American Flight 160. In 1972 a United Air Lines B737 crashed near Chicago’s Midway airport. Some of the victims of the accident, including (well known Watergate personality) Howard Hunt’s wife, showed high levels of cyanide in their blood stream. 42 This high visibility accident helped show the need for improvement in the toxicity of cabin interiors. The demand for improvement led to the creation of the Special Aviation Fire and Explosion Reduction (SAFER) Advisory Committee in May 1978, an advisory committee which helped define the types of research needed in fire safety and the issues of interior material toxicity and flammability for in-flight and post crash fires. 43

**Fire Extinguishers**

In addition to smoke detection and evacuation considerations, the NTSB also recommended upgrading fire extinguishers in the final report of Air Canada Flight 797. Experience of major cabin in-flight fires showed that carbon dioxide, dry chemical and water fire extinguishers were effective in some cases, but were insufficient in larger, rapidly spreading fires. In FAA Technical Center tests, Halon (bromo-chloro-di-fluoromethane) showed itself to be superior to carbon dioxide, dry chemical or water fire extinguishers. These tests encouraged the FAA on May 17, 1984, to issue Notice of Proposed Rule Making (NPRM) 84-5. 44 It contained three proposed rules to address some of the NTSB’s concerns expressed during the Air Canada Flight 797 investigation. The proposed rules required the installation of automatic fire extinguishers for each lavatory disposal receptacle used for towels/paper/waste, installation of smoke detector systems in the galleys and lavatories of air transport category aircraft and required two Halon 1211 fire extinguishers to be located in passenger compartments. All air carriers complied with these provisions within one year after the rules became effective. 45

**Single Point Failures and Relationship to Multiple System Failures**

When considering the effect of in-flight fire on the systems of the aircraft, a single point of failure that can, and has, caused multiple systems to completely fail. Wiring failures can be catastrophic, as the loss of a Royal Air Force (RAF) Nimrod proved in May 1995. 46 The Nimrod was forced to ditch in the sea following a severe fire. The investigation found that the direct current (DC) wiring loom for the number one engine had an arcing event caused by an undetermined defect. This arcing caused the wiring loom to fail and for several wires to melt together. This joining of wires caused an uncommanded signal to the number four engine starter valve causing it to open while the engine was operating. As this valve opened the turbine starter began to spin wildly and quickly to over speed. The over-speeding starter turbine wheel flew out of its housing and punctured a wing fuel tank. The ensuing fire was catastrophic causing the need to ditch the aircraft. The belief of the investigators was that chafing of a nearby steel braid hose caused the initial wiring loom fault. Inspection of other Nimrods in the fleet found that 25% of the engines had defects in the wiring looms.

The loss of this Nimrod clearly shows the potential for a fire to cause multiple or cascading problems. The fire started by melting wires caused the uncommanded opening of the starter valve,
defeating all of the protection features that were intended to prevent it from opening during engine operation. This one event acted as a single point of failure and the fire defeated all the redundancies that were designed to protect the aircraft.

The proximity of wires within wire bundles can cause seemingly unrelated systems to fail due to arcing and burning of wires within a single wire bundle. As shown in Swissair Flight 111, the shorting, arcing and burning of wire can cause melting and provide a conductive path for electric power to other wires.

There is no regulatory requirement to evaluate the potential effect of an arcing wire and the effects on multiple aircraft systems. The STC requirements as shown by the in-flight entertainment (IFE) system installation on Swissair Flight 111 may be inadequate. This installation did not consider the proximity of the IFE power wires to critical wires powering the flight instruments. In addition, the STC did not show the routing of the power wires for the IFE. Therefore, there could be no consideration of the location of the IFE power wires contained in the STC. This lack of specific wire routing within the STC could allow for wire chafing and allow the bypassing of the CABIN BUS switch. The overall health of the wires within the bundle of the MD-11 was not evaluated during the installation of the IFE.

Smoke Barriers

Smoke migration is a result of a spreading fire. As a fire burns, heat is created and the products of combustion begin to migrate. Minimising the spreading of smoke and fumes into the flight deck is critical for continued safe operation of the aircraft.

In most modern transports the flight deck door is a major part of the smoke barrier. A review of several accidents found that the flight deck door was opened on at least one occasion, which allowed smoke to enter the flight deck. One example occurred when a cabin crew member aboard a Cubana DC-8 opened the locked door when the cabin was full of smoke, prompting the Captain to shout, “Close the door! Close the door!” However, the entry of smoke and fumes continued (the report is unclear if the door was closed at the Captain’s command). The barrier did not prevent the flight deck from becoming full of smoke and fumes.

Once the flight deck door is opened it is no longer a barrier. Another example was Air Tran Flight 913, which had the flight attendants open the flight deck door while smoke was pouring into the galley area. Although there was already smoke in the flight deck, the flight attendant could not have known this and might have allowed more smoke in. Unfortunately, opening a flight deck door in a smoke event is not a rare exception. This tendency to open a flight deck door shows that crew training does not effectively address the importance of maintaining the smoke barrier.

Other flights have lost an effective smoke barrier even before takeoff. In Air Canada Flight 797, "a 30-inch-long by 6-inch-wide louvered panel at the bottom of the cockpit door was kicked accidentally from its mounts and fell to the floor." This compromised the door as a barrier and allowed smoke to enter regardless of flight crew action. However, the door was kept open throughout most of the fire so that the cabin condition could be observed. The importance of the barrier was not considered.

Location, Location, Location

Experience shows that fires can start in inaccessible locations, making it difficult or impossible to extinguish the fire. The fire in the "attic" of Swissair Flight 111 spread rapidly without the ability of the crew to extinguish it due to its location. There was no means to direct a fire extinguisher agent at the source of the fire in the area above the interior ceiling.

The inability to have access to the source of the fire is a serious limitation. All fire extinguishers work best when they are discharged at the source or the base of the fire. In Air Canada Flight 797,
as the fire grew behind the aft lavatory wall, flight attendants knew that there was growing smoke, but that the fire was inaccessible.

A growing fire needs combustible fuel. Insulation blankets, often located in inaccessible areas, can provide the needed fuel for a fire. The FAA specifies the flammability of insulation blankets during initial certification of the aircraft. However, as the aircraft ages, contaminates such as lubricants, corrosion inhibitors, hydraulic fluid and dust can coat the insulation blankets. As shown in NTSB investigations and FAA tests, these contaminated blankets can burn and provide the fuel necessary for a fire to become self-sustaining. In September 2005, the flammability requirements of thermal acoustic blankets were upgraded. This upgrade was the result of major work done by the FAA Technical Center in flammability testing and material flammability resistance.

Not all fires have insulation blankets providing the fuel. In some electrical fires, the panel material or insulation can provide the fuel. The requirements of the flammability of the insulation material of wires are specified in 14 CFR Part 25.869. These requirements have been improved over the years, but there are some aircraft, such as Air Tran Flight 903, which involve wiring that met the standards of the initial type certificate issuance date but did not meet the current standard.

In some fires the surrounding material and location combine to create a serious hazard. Air Tran Flight 903 experienced an electrical fire in the electrical power centre located just ahead of the flight attendant jump-seat. The flight attendant did not attempt to find the source of the smoke nor did either flight attendant attempt to discharge a fire extinguisher. The source of the smoke was uncertain and the flight attendants were not trained to remove interior panels when searching for smoke sources. Again, the location of the electrical fault and the lack of proper training prevented fire fighting from occurring.

**Ventilation, Open Windows and Visibility**

Adequate ventilation of aircraft cabins is essential. The exchange rate of air within the cabin is carefully regulated. During times of smoke contamination, this exchange rate can be even more important. Greater amounts of fresh air introduced into the cabin dilute the smoke at a faster rate. If the smoke production overwhelms the ability of the ventilation system to send it overboard, smoke will begin to accumulate in the cabin, usually near the outflow valve or main outflow valve for aircraft with more than one outflow valve. This accumulation will then begin to spread through the cabin. One solution to a ventilation system being overcome is to use ram air from outside the aircraft. While the aircraft must be at an altitude where it can be depressurised, some manufacturers installed ram air valves to allow uncontaminated air into the cabin at a higher rate.

Most aircraft use the principle of positive pressure to keep smoke out of the flight deck. Having a slight positive pressure from the flight deck to the cabin can act as a barrier to smoke migration into the flight deck. In some aircraft this positive pressure does not work as well as initially intended. The FAA Technical Center found that during tests in a Boeing B747SP that smoke could migrate into the flight deck because there was not positive pressure to prevent it.

Another consideration in smoke migration patterns is the buoyancy of the smoke. Very buoyant smoke will tend to remain on the ceiling where it will disperse and follow the contours of the ceiling. Cooler, less buoyant smoke will interact differently with the air flow pattern, making its distribution more homogeneous throughout the cabin.

During the investigation of Air Canada Flight 797’s fire the procedure to open a window or door was reviewed. One member of the Structures Group testified “There’s a very strong potential that (the forward airflow) would have pulled the fire out of the lavatory into the cabin and certainly would have moved the smoke forward and faster over the passengers heads.” He stated that it would have endangered the passengers and also the safety of the aircraft.

Boeing’s 737 Smoke Removal Checklist notes that opening a window may not be possible at speeds greater than holding speeds and Airbus’s Smoke/Fumes Removal checklist for
A319/A320/A321 requires that the aircraft be decelerated to 200 knots before opening the window. This requires slowing the aircraft during a time when landing as quickly as possible should be the main concern. There is a conflict between the need for maximum speed to minimise the time to the airport and slowing to holding speed to open a window.

The remaining important issues of opening a flight deck window are effectiveness and consequences. A review of some incidents shows that the effectiveness is variable. Air Canada Flight 797 opened and closed the First Officer’s window several times. The noise level was so high that no communication could take place between the flight crewmembers. The venting was unsuccessful as the cabin and flight deck remained full of smoke.

In cases of continuous smoke, no manufacture suggests opening a window, because it can cause the fire to spread. Several serious in-flight fires show that the flight crews opened the window without improving the visibility significantly and, in some cases it was made worse. An open window creates high wind noise, which prevents effective communication between crewmembers. The high noise level prevents checklist accomplishment and also prevents a crewmember from assisting the flying pilot during the landing with callouts (which may be vital in limited visibility of a smoke filled flight deck).

**Fight the Fire: Diagnosis and Training**

Air Canada Flight 797 departed Dallas, Texas for Toronto, Canada on 2 June 1983. The flight attendants discovered a fire in the aft lavatory. In the next seventeen minutes the flight crew faced a growing in-flight fire. One flight attendant discharged a cabin fire extinguisher into the lavatory, but the fire continued to burn behind the wall. The First Officer planned to discharge another extinguisher into the lavatory, but after feeling the heat of the door wisely decided not to open it. The fire was out of control, and spread rapidly in inaccessible locations of the aircraft.

The flight attendants did not know either the location of the fire or the most effective placement of the fire extinguisher. A general discharge into the lavatory did not arrest the fire’s progress because the fire was behind the lavatory wall. Had there been access ports in the wall, it is possible that this fire might have been extinguished, provided the flight attendants had been trained to access and fight hidden fires through such access ports.

As with the Varig B707 accident, the FAA modified the regulations after evaluating NTSB recommendations and industry input. The installation of Halon fire extinguishers, automatic fire extinguishers in lavatory trash receptacles, and more stringent flammability standards for interior components were a few changes to the transport aircraft fleet.

As recently as 8 August 2000, another in-flight fire showed that the lessons from Air Canada Flight 797 were incomplete. An Air Tran DC-9-32 (the same type as Air Canada Flight 797), Flight 913, departed Greensboro, North Carolina for Atlanta. Shortly after takeoff two flight attendants began to smell smoke. One of them opened the flight-deck door only to find it full of smoke and the pilots wearing oxygen masks and smoke goggles. The Captain advised the flight attendant that they were returning to Greensboro. The flight attendants heard “popping noises” and saw “arching and sparking” at the front of the cabin. While the flight attendants considered using a Halon fire extinguisher, they took no action as they were unsure where to aim it. There was no open flame and their training did not address hidden fires.

The fires of Air Tran Flight 913 and Air Canada Flight 797 have some similarities. In both cases the fires escalated quickly and became self-sustaining so that the opening of the circuit breakers did not stop the fire. Flight crew training did not prepare the crew to successfully extinguish the fire, communicate effectively, or maintain the smoke barrier in place (by keeping the flight deck door closed).
Wires and Fires

The FAA has recognised that electrical systems are, and are going to be, potential sources of ignition. In the 23 November 2005 NPRM for fuel tanks, the FAA acknowledged, “We have concluded we are unlikely ever to identify and eradicate all possible sources of ignition.”

The most frequent source of fire in transport aircraft is electrical. A Boeing study showed that between November 1992 and June 2000 that almost two thirds of the in-flight fires on Boeing aircraft were electrical.

A major ignition source for electrical fires is aircraft wiring. In a modern large transport there is over 500,000ft of wire. As the complexity and diversity of systems has grown in transport jets, so has the amount of wire. The addition of more wire has increased the probability of wiring-caused problems and fires. The industry is recognising that the wiring does not last the life of the aircraft.

The US Navy found that between 1995 and 1997 their transport aircraft experienced just over an average of two fires per month and that most would have been prevented by arc fault circuit interruption protection.

Another issue is the Supplemental Type Certificate (STC) additions to aircraft using existing circuit breakers to power equipment that is being added to the aircraft. FAA Technical Center experts found this to be the case in a study of 316 circuit breakers. They found that “many of the lugs contained two wires and had two different size conductors.” This is in violation of 14 CFR Part 25.1357. It can cause overloading of the circuit and the circuit breaker will not provide proper protection. In the past, STC engineering requirements were not as stringent as the requirements for original type certificates.

Electrically caused fires can grow rapidly, as the Air Canada Flight 797 illustrated. Boeing stated “review of historical data on the rare fire events that resulted in hull loss indicates that the time from first indication of smoke to an out-of-control situation may be very short – a matter of minutes.”

A well-known example of the rapidity of a fire is an MD-11 that was lost on 2 September 1998, Swissair Flight 111. Of significant importance was the cascade of multiple failures as the fire affected electrical wiring throughout the overhead of the MD-11. This caused multiple simultaneous system failures, causing the flightcrew’s workload to increase dramatically.

Rapid growth and severity of the fire are reasons why minimising ignition sources is necessary. Yet examination of transport aircraft has shown that many had ignition risks on board. It should be assumed that every transport aircraft in service also has a risk of electrical fire.

Another example of an accident caused by a wiring fault is Trans World Airlines (TWA) Flight 800. The B747 took off from JFK and exploded climbing through 13, 000 feet. The NTSB found the cause to be an explosion of the centre fuel tank. In the recovered wreckage was evidence of arcing in the wiring, which could have allowed high voltage electricity into the fuel quantity wiring causing an explosion of the centre fuel tank. During the investigation the NTSB examined the wiring in 25 transport aircraft. Only one of the aircraft (a new B737) did not have metal shavings on or near wiring bundles. Many of the aircraft had foreign material (lint, metal shavings, washers, screws, rivets, corrosion prevention compound, paint and pieces of paper) between wires or wiring bundles. Wire insulation was damaged or cut by the metal debris. There were cases of the core conductor being exposed. Five of the aircraft showed signs of fire or heat damage in wiring. This in-flight explosion accident, set in train a great investigation on fuel tank safety and also included ageing aircraft electrical systems. It produced a number of Airworthiness Directives and AC’s etc, including a huge inspection programme.
Detection and Protection

There is fire detection and protection in the engines, auxiliary power unit (if installed) and cargo compartments of modern transport aircraft. Smoke detectors are installed in lavatories with automatic fire extinguishers in the waste bins. But other parts of the aircraft are unprotected. In the unprotected areas detection of a fire depends upon the flight-crew.

Smell is usually the first indication of a fire or potential fire. Once the odour is detected, it can be difficult to locate the source. Locating the source is made more difficult by the high air exchange rate in the cabin of a jetliner. The air is exchanged once every two or three minutes, on average with all air conditioning packs operating. This causes rapid dilution of the smoke and dispersal throughout the cabin. This exchange rate can be reduced significantly as a flight crew shuts off recirculating fans and/or air conditioning packs during the Smoke/Fire/Fume checklists. Increasing the number of detectors would help in the early detection of smoke/fire/fumes and help pinpoint the source location.

Maintenance

Wiring Insulation and Debris

An example of wire insulation breakdown and how it can result in multiple simultaneous failures that may be confusing to the flight crew was United Airlines Flight 95, a Boeing 767 on 9 January 1998. After take off and while climbing, the Engine Indication and Crew Alerting System (EICAS) displayed abnormalities with several systems. Circuit breakers were pulled and reset with no effect. Other circuit breakers tripped and the First Officer’s Electronic Flight Information System (EFIS) flickered along with both the engine and systems screen.

Investigation found that there was evidence of arcing and heat damage to a wire loom and heat damage to another wire loom in the Electronics and Equipment (E&E) bay. Investigators saw arcing and hot spots when power was applied to the aircraft in these wiring looms. Further investigation found that there evidence of heat as the copper wire had melted and spattered. Nearby wires were found to have nicks in the insulation and areas of abrasion.

As the investigators looked for causes for the nicks, they learned that a galley ‘chiller’ had been replaced the day before the incident. The replacement should have been accomplished according to the Boeing maintenance manual but neither mechanic had replaced a Boeing 767 chiller previously. There were some deviations from the recommended work method, resulting in misalignment of the chiller unit. This resulted in pressure on the wiring bundles or looms and was a contributing factor to the initial arcing event.

Another issue uncovered by the investigation was the presence of conductive debris in the E&E bay. Items such as coins, locking wire (stainless steel) and copper wire were found. Non-conductive wire cable ties made of plastic were also found. In addition, a puddle of water one inch deep was seen on top of a thermal acoustic insulation blanket.

This finding raised the question of the amount of debris found in other in-service aircraft and led to a general investigation of wiring conditions. A review of significant service difficulty reports supported the need for further inspection to determine the significance of failures of wire looms caused by wire damage, chafing, damage caused by objects, or mishandling. Several aircraft were examined and in almost all there was conductive and non-conductive debris. One aircraft had its wiring looms covered in grime, dirt and dust. Metal shavings were found on many aircraft’ wiring, and where these shavings were located between the wires, the insulation was cut. Some of the lint-like debris was almost an inch thick and is known to be flammable. There was residue that was black and sticky on some wires, which attracted lint onto the wires. Cracked insulation was found
both in sunlit areas and in darker areas, showing that the aging process was occurring throughout the aircraft.\textsuperscript{73}

Wiring insulation breakdown and the potential for debris to be nearby provides the setting for an ignition source and a combustible material. Improved wiring inspection is needed as noted by the FAA in their NPRM of 6 October 2005.\textsuperscript{74}

\textbf{Wiring Health}

Good wiring health requires a comprehensive wiring inspection programme. It is known that in the areas where maintenance activities contact wiring bundles there is an increase in wear. This wear can lead to abrasion and chafing, which can cause arcing events to occur. There is need for improvements in maintenance practices and inspections.

From 1995 to 2002 the FAA found reports of 397 wiring failures. Only two thirds would have been detectable using current means. Of these failures 84\% were burned, loose, damaged, shorted, failed, chafed or broken wires. The FAA noted that these wiring failures cause over 22 flight delays per year and over 27 unscheduled landings per year on average.\textsuperscript{75} The number of reports should be considered as a minimum number as it is widely believed that this type of finding is underreported by the industry.

Additionally, investigation of the in-flight explosion of TWA Flight 800 and the in-flight fire aboard Swissair Flight 111, led to examination of other aircraft where examples of wire deterioration, improperly installed wires and contamination of wire bundles with dust, fluids and metal shavings were commonly found. The FAA realised that today’s maintenance practices do not address the condition of wires to a satisfactory level and that improvements need to be made.\textsuperscript{76}

In 2003, MITRE, (the Research & Development Agency), reported on inspection efforts to evaluate the state of wiring in transport aircraft.\textsuperscript{77} The non-intrusive inspections of electrical wiring on large transport aircraft found that of the 81 aircraft inspected, there were 40 wiring anomalies per aircraft on average. These finding resulted in the issuance of 23 Airworthiness Directives (ADs). On small transport aircraft, 39 aircraft were inspected with 58 anomalies found per aircraft on average.\textsuperscript{78}

This led to the FAA issuing a NPRM on 6 October 2005, to “improve the design, installation and maintenance of their electrical wiring systems as well as by aligning those requirements as closely as possible with the requirements for fuel tank system safety.”\textsuperscript{79} The FAA NPRM addresses type certificate holders, applicants and supplemental type certificates. In this NPRM, focus on the health of the wiring in the aircraft is specifically required (if the NPRM is adopted as proposed) for the first time.

\textbf{RECOMMENDATIONS}

Previous sections of the paper have shown the risks of in-flight fire and provided historical accounts of aircraft accidents in which fire occurred. The history of in-flight fire is important because it illustrates the successes and where further improvements are needed. The following recommendations are intended to address realistic solutions to many of the issues presented.

\textbf{Airworthiness}

\textbf{Recommendation} : Evaluate aircraft for single point failures of wiring and potential effect on systems of the aircraft. Evaluate modifications using the same approval process for supplemental type certificate modifications as for type certificates.

Fires are capable of inflicting damage on multiple aircraft systems as they spread. Wires within a wiring bundle where the fire starts are particularly susceptible. This can cause multiple circuit
breakers to trip in a short time. This is noted in AC120-8080 as one warning symptom of a fire in a hidden area.

A common feature of modern transport aircraft is not to co-locate critical wires so that arcing in one wire can cause failure of another critical system. However, the installations of supplemental equipment, such as in-flight entertainment systems, have not always been evaluated for their wiring proximity to critical system wiring. This was noted as a problem in the report of Swissair Flight 111. The STC engineering did not specify the routing of some of the wires of the in-flight entertainment system. As a result, entertainment system wiring was placed in close proximity to critical system wires. It is believed by TSBC this was the location of the original arcing or short in the fire sequence.

**Cascading Failures**

While similar to multiple failures, cascading failures are a specific type of multiple failures. The failure of a system due to the failure of another is known as cascading because the effect to the pilots is failures that occur in a sequence. An example would be the failure of an autopilot because the electrical system failed.

In today’s complex aircraft (fly by wire and conventional) the interrelationship of systems is extensive. Similar to multiple failures, evaluation of the effects of fires in various locations in the aircraft causing predictable cascading failures should be considered and include sub or interrelated systems.

**Recommendation:** Improve the engineering and installation of wires so that the routing does not endanger by proximity any critical system wiring.

Swissair Flight 111’s in-flight entertainment system was installed under an STC. The FAA required that the IFE be tested in accordance with 14 CFR 25.1309 and AC 25.1309-1a. It was considered a non-essential item with any failure considered to have a minor effect on the aircraft systems. This process did not require detailed engineering drawing for wiring routing which allow for the installation to wire the IFE into the system in such a way that it was not unpowered by the CABIN BUS switch.

While the FAA group that approved the STC included several specialists, it was not as comprehensive as the original type certificate. The testing for this STC proved inadequate and demonstrated a need to bring the STC process more closely to the original type certificate requirements.

**Recommendation:** Install arc-fault circuit interrupter technology on new and existing transport aircraft.

The FAA in AC120-80 states, “[a] majority of hidden in-flight fires are the result of electrical arcs along wire bundles.” One means to dramatically reduce the ability for a wire to arc is to provide arc fault circuit breakers or interrupters for the circuit. Conventional circuit breakers do not provide acceptable protection from arcing. Therefore, replacing existing circuit breakers with arc fault circuit interrupters would mitigate the arc hazard.

Tests have shown these circuit interrupters are effective and are not prone to nuisance activation. There is the availability of most needed types of arc fault interrupter circuit (AFIC) breakers to replace existing circuit breakers and a new released NPRM for a TSO for AFIC. Arc fault circuit interrupters would probably have prevented many of the fires cited in this paper.

**Recommendation:** Conduct continuous smoke testing for flight deck smoke evaluation tests.
Unlike other smoke tests, the flight deck smoke evacuation test is unusual because the smoke is not required to be continuously generated (although it is recommended) throughout the test. All other smoke tests contained within AC 25-9a require the applicant to continuously generated smoke.

Although the FAA knew of incidents and accidents of continuous smoke, and they recommended that applicants use continuously generated smoke, it was not required for compliance. The manufacturers have obtained the type certificate for new aircraft partially based on the testing standards of AC25-9a. None to date have followed the recommendation for flight deck smoke evacuation test using continuous smoke.

As there have been a considerable number of in-flight fires with continuous smoke, the test standards for flight deck evacuation does not always represent conditions that can be found in actual fires. As noted earlier, the smoke evacuation procedures may not be effective against a growing, self-sustaining fire that produces continuous smoke.

**Recommendation:** Install fire access ports or dedicated fire detection and suppression systems to inaccessible areas of aircraft.

Fires in inaccessible areas of the aircraft continue to pose a threat to transport aircraft. The area of the aircraft without fire detection is large. Should there be a fire in an unprotected area, the ability to fight the fire will be limited by lack of access. As in the example of Swissair 111, once the fire was detected there was no way to access the area where the fire was burning and to allow the application of extinguishant. This deficiency can be corrected with strategically located ports throughout much of the currently inaccessible areas of the aircraft.

An example of the criticality of access to inaccessible areas and the effectiveness of an access port occurred on November 29, 2000 as American Airlines Flight 1683 (a DC-9-82) experienced an in-flight fire in a fluorescent light ballast unit soon after departure. A flight attendant observed dark, dense black smoke coming from the ceiling panels. Borrowing a passenger’s knife the flight attendant cut a circular hole allowing access for a Halon fire extinguisher. The fire was successfully extinguished.87

Some wide body aircraft may have attics so large that a fire access port will not provide adequate coverage of extinguishant. In those aircraft alternative means of extinguishing a fire should be installed such as a dedicated fixed fire extinguishing system.

**Recommendation:** Mark locations of minimal damage for access to inaccessible areas of the aircraft.

AC 120-80 provides guidance to flight crew for a fire in hidden or inaccessible areas of the aircraft. “If this is the only way to gain access to the fire … the risk of damaging equipment behind the panelling and the possibility of creating a bigger problem must be weighed against the catastrophic potential of in-flight fires left unattended.” 88 The NTSB noted in the investigation of Air Tran 913 “although the emergency training requirements specified in 14 CFR 121.417 require instruction in fighting in-flight fires, they do not explicitly require that crewmembers be trained to identify the location of a hidden fire or to know how to gain access to the area behind interior panels.” Gaining access would improve by marking locations of access where minimal damage would occur.

**Recommendation:** Increase the number and location of sensors to alert the flight crew of smoke/fire/fumes. These sensors should take advantage of new technology to minimise the false alarm rate.

Detection of a fire or a potential fire is one of the most important steps towards a successful outcome. A small fire is much easier to extinguish than a well-established, self-sustaining one. The adage of “the earlier the detection the better” is very true and should be a prime consideration in the design and operation of aircraft.
Protected areas within the aircraft contain a means of detection. Unfortunately, detection of a fire within most of the cabin and flight deck is up to the ability of a flight crew member to see or smell smoke. There are technologies available that could help flight crewmembers detect smoke and/or fire earlier.

In some cases, smoke can be a good indicator of a fire or potential fire. However, there can be cases where there is minimal smoke as the temperature rises. The types of infrared detectors used by fire departments throughout the world could help a flight crewmember locate “hot spots” within the cabin. Once the flight-crew determines an accurate location they can gain access and fire fighting can begin at the source. There have been tests conducted with this technology. While this technology depends on surface heating and smoke may be evident, there is overall benefit to the ability to locate area of high heat.

Another means of detection is thermal sensors in the areas where wiring bundles are located. This newer and evolving technology has the potential to provide the flight crew information of rising temperatures in a wire bundle which could be located in an inaccessible area long before the smouldering grows the point where a crewmember could detect it. Research should continue to advance this technology.

AC 120-80 provides guidance to the flight crews in locating a hidden fire. The indication of a fire can include:
- Failure or uncommanded operation of an aircraft component
- Circuit Breakers tripping especially multiple circuit breakers tripping
- Hot Spots
- Odour
- Visual Sighting – Smoke

However, these indications usually represent a well-established fire. A fixed detection system throughout the aircraft would allow fire fighting to begin earlier and improve the ability of the flight crew to locate the actual source of the fire.

The United Kingdom’s Civil Aviation Authority published the need for enhanced protection from fires in hidden areas. Their conclusion using a mathematical model was that enhancing the detection of and the protection from fires in hidden areas could save a significant number of lives.

Detection devices or systems are now available and it should be an industry priority to study the effectiveness of these devices and systems to find the most effective solutions (both in cost and sensitivity).

**False detection rates**

During a 36 month study from January 2002 to December 2004, The International Air Transport Association (IATA) found 2,596 reports (including jets, turbo props and helicopters) of fire/sparks/smoke/fume occurrences. Of the 2,596 reports, 525 (20%) were false warnings with 11% of in-flight diversions due to false warnings. Approximately 50% of cargo compartment fire warnings were false.

Following the May 1996 accident of ValuJet Flight 592, the FAA required the installation of fire detection and suppression systems of class D cargo compartments in air carrier aircraft by 19 March 2001. Approximately 3,000 aircraft required retrofitting. This requirement, as expected, caused a significant increase in cargo compartment fire warnings. The 14 CFR Part 25.858 (a) (and EASA/JAA) requires that detection system must provide a visual indication to the flight crew within one minute after the start of the fire. There is a compromise of speed of the warning and the susceptibility to false warnings.
The FAA Technical Center studied the ratio of false warnings in cargo compartments to actual smoke or fire events in 2000. They found that the false alarm rate was increasing at that time. The rate of false warning is too high and improvements in the reliability of smoke and/or detectors should be improved.

**Multi-source sensors**

False engine fire warnings plagued pilots in the past. Modern jets now use a dual loop system to provide redundancy and reduce the potential for false fire warnings. Dual loop systems require fire to be sensed on both systems before illuminating the fire warning on the flight deck. This improved system also has the benefit of improving the dispatch reliability by having a redundant system. The idea of redundancy demonstrated by dual loop systems could be used in cargo and other fixed detection systems.

Another technology to reduce false warnings while providing rapid warning is using two different types of sensors (e.g. smoke and thermal) with an algorithm to interpret inputs in order to determine a nuisance input from a real fire.

Cargo compartments on aircraft manufactured up to 2005 have only single source fire detectors. Some manufacturers have proposed using multi-source sensors in new aircraft. This technology dramatically reduces the possibility of false fire warnings. Using similar technology, now that it is proven, should be considered for application is other areas of the aircraft. Detection of a fire in the vast inaccessible areas of the aircraft should use multi-source sensors.

**Protective Equipment**

**Recommendation:** Implement vision assurance technology for improved pilot visibility during continuous smoke in the flight deck.

Pilot vision during a smoke event is essential. The FAA’s Aviation Safety Reporting System (ASRS) has numerous pilot reports of restricted visibility during smoke events. Some pilots report smoke so thick that they could not see each other.

Following Air Canada Flight 797, the FAA required the installation of Protective Breathing Equipment (PBE) on all 14 CFR Part 121 aircraft. As 14 CFR Part 25.1439(b)(1) states, in pertinent part, that PBE must be designed to protect the flight crew from smoke, carbon dioxide and other harmful gases, while on the flight deck and while combating fires in cargo compartments. The need for visibility to combat the fire was included in the justification for the need for PBEs. There is a similar need for pilot visibility to fly the aircraft during continuous smoke events.

The visibility must be enough to see the attitude indicator or primary flight display and to see outside the aircraft for landing. In addition, the pilots must see instruments to navigate and they must see to program the flight management computer, if installed. The checklist must be visible so that procedures can be followed to prepare for landing and fight the smoke/fire/fumes. Adequate visibility on the flight deck should be maintained during a smoke/fire/fume event.

**Head Up Display**

Head Up Display (HUD) technology is a growing addition to the civil transport fleet. Many new aircraft have HUDs available and some older aircraft are being retrofitted.

BAE Systems has done research to take that technology and adapt it to the environment of smoke on the flight deck. A 1998 study by Embry-Riddle for BAE Systems showed that the visibility of the HUD was viewable for much longer than the Electronic Flight Instrument Systems (EFIS) display. This visibility difference could make a major difference in the outcome of a smoke event.
The use of the HUD eliminates the need to open the window to improve visibility, thereby maintaining the ability of the flight crewmembers to communicate with each other. If two HUDs are installed, there is the ability to monitor the flying pilot’s performance, which is an important element of transport aircraft operations. A single HUD installation does not allow the First Officer to monitor the Captain unless the normal flight instruments are visible.

While this technology provides improvement in visibility over the standard flight instruments or EFIS, it does not provide improvement in the ability to see outside the aircraft. This limitation is important, as there are examples of fire causing the flight instruments to fail. This dependence of aircraft electrical power could allow this type of failure to affect the HUD and require the pilot to look at the natural horizon for attitude reference.

HUD is an improvement in the vision available to pilots, but its cost is high and it has operational limitations.

**Emergency Vision Assurance System**

The need for clear vision in a smoke filled flight deck can be met in many cases by a clear plastic bubble filled with clear air. This device is known as Emergency Vision Assurance System (EVAS). Like the HUD, it provides the pilot with the ability to see critical flight instruments regardless of the density of smoke. It has the additional advantage of providing clear vision to the windshield.

EVAS is a clear plastic device that allows a pilot place his/her goggles and mask against the unit and see the flight instruments and outside the windshield. The unit inflates in less than 30 seconds, using a self contained battery and blower, thereby not being dependent on the aircraft's electrical system. The flight deck air is filtered and cleaned of smoke then used to inflate the device. Like the HUD, this device eliminates the need of opening a window and therefore avoids interfering with flight crew communications.

It is possible that improved vision of the flight instruments and the windshield would have allowed Varig Flight 860 to land on the runway instead of in a field. This is the most dramatic example of potential improvements with vision assurance technology, but others, such as Air Canada Flight 797, Pan American Flight 160 and the Air Europe Fokker landing in Copenhagen may also be have been positively affected.

In a smoke filled flight deck, the ability of the non-flying pilot to monitor the other pilot is dependent on his/her ability to see the flight instruments and if they are functioning.

This monitoring activity is a fundamental part of transport aircraft training and operations. EVAS allows pilot monitoring to continue during smoke/fire/fume events thereby maintaining normal pilot redundancy.

**Recommendation:** Provide full-face oxygen masks and sufficient flight crew oxygen for descent and landing during a smoke/fire/fume event.

Flight crews must be protected from toxic fumes to safely fly and land their aircraft. Protecting the crew primarily consists of oxygen masks and smoke goggles. Providing an independent oxygen source and clean air for protection for the eyes of the crew is essential. In the past smoke goggles have been found to be ill fitting and not providing a complete seal around the face of some wearers. As noted by the NTSB in the report of Pan American Flight 160, "examination disclosed that if a crewmember wore corrective glasses, the smoke goggles would not fit properly at the temples and, therefore would not provide the needed protection against smoke." These goggles were improved after a one-time inspection of the air carrier fleet. Yet, problems with goggles continued such as the limited ability to purge smoke from the smoke goggles.

NTSB noted in their investigation of Federal Express Flight 1406 that the Captain did not don his smoke goggles. The Board expressed their concern that this failure to don the goggles could have
exposed the Captain to toxic smoke.\textsuperscript{100} Masks that cover the entire face, known as full-face oxygen masks, alleviate this concern, as it is a single unit. These single unit masks and goggles allow a better, tighter fit and more effective purging in the mask.

**Increase Flight Crew Oxygen Quantity**

The quantity of oxygen available to a flight crew determines how long their uncontaminated supply of air will last. The demand of oxygen will depend on several factors, such as the number of crewmembers using oxygen and the rate at which each crewmember breathes. As in-flight fire is one of the highest stress events a pilot can face,\textsuperscript{101} it is reasonable to expect higher than normal oxygen consumption during a smoke/fire/fume event. The capacity of the oxygen bottle and the level of fullness then determine how much time is available to the crew before depletion. In some cases, the time required to descend and land may be greater than the time of available oxygen. Depletion of the oxygen would eliminate the source of uncontaminated breathing gas and force the flight crew to breathe the smoke filled flight deck air. The performance of the flight crew would be adversely affected.

Aircraft can be dispatched with crew oxygen at minimum levels in accordance with the Minimum Equipment List (MEL). The consideration is only the demand for an emergency descent and not the demand of a smoke/fire/fume event. There should be sufficient supply of oxygen for the flight deck crew to descend and land the aircraft.

**Recommendation:** Increase size of fire flight deck and cabin fire extinguishers to five pounds of Halon or an equivalent effective agent.

By regulation (14 CFR Part 25.851 (6)), air carrier transport aircraft are required to have two Halon fire extinguishers. Halon is a liquefied gas that extinguishes fires by chemically interrupting a fire’s combustion chain reaction, rather than physically smothering it. This characteristic, along with the property of changing into a gas when discharged and spreading throughout the area, are two of the main reasons that Halon extinguishers are effective, especially when the exact source or type of the fire cannot be positively determined.\textsuperscript{102}

Halon is now carried in two-and-one-half-pound fire extinguishers on board air carrier transports. However, tests at the FAA Technical Center found that in some test conditions the amount of extinguishing agent was insufficient to extinguish a test fire in a Class B cargo compartment fire.\textsuperscript{103} During the tests flight attendants attempted put out a fire. All failed with two-and-one-half-pound extinguishers.

**Maintenance**

**Recommendation:** Inspect thermal acoustic insulation blankets and smoke barriers to ensure cleanliness.

The regular inspection and cleaning of thermal acoustic blankets and smoke barriers during scheduled maintenance could allow the removal of contaminates. This improved cleanliness would reduce the flammability of the blankets.

**Recommendation:** Modify maintenance procedures to minimise the possibility of contamination of thermal acoustic insulation blankets.

When a maintenance procedure is designed, consider the possibility of thermal acoustic blanket contamination. As an example, the application of corrosion blocking material to the aircraft should not contaminate a thermal acoustic blanket.

**Recommendation:** Improve wiring inspection maintenance programmes by using new inspection technology and not rely exclusively on visual inspection of wiring bundles.
“It is clear ... that the vast majority of aircraft electrical wiring problems are related to improper installation and inadequate inspection and maintenance.” Therefore, many electrical hazards in aircraft can be mitigated through an improved maintenance programme.

The finding that circuit breakers and wires were exposed to significant amounts of dust and grease shows the need for improved maintenance programmes for wiring. The recognition of the effect of contaminants (conductive and non-conductive) on the potential of contribution of in-flight fire is essential. The philosophy and practice of careful cleaning and debris containment during all maintenance activity must not only be adopted, but must be meticulously adhered to.

The inclusion of wiring considerations in an overall maintenance plan must also include the careful inspection of insulation blankets for contaminants. An example of this “holistic” approach would be to modify the application procedure of corrosion blocking sprays so that there would be no contamination of insulation blankets in or near the sprayed area.

Maintenance training which emphasises the susceptibility of wiring to contamination and the need to “clean as you go” has the potential to improve some of the maintenance-induced incidents. The need for ongoing or recurrent maintenance training specific to fire reduction techniques is clear.

**Wiring Inspection Programme**

Regular inspection of wiring is an essential check of the overall health of the aircraft. Wiring bundles should be inspected particularly for conductive material that can chafe the insulation and allow arcing. Inspection of remote or hidden areas of the aircraft should be scheduled regularly for wiring that can be covered in dust, grease and other contaminants. All nearby thermal acoustic insulation blankets should also be carefully inspected. Cleaning or removal of contaminants should be a priority so that the source of fuel for a fire can be reduced.

Visual inspection of wiring has proven inadequate in some cases. In a test by ‘Letromec’, visual inspection located two potential breaks in a test wire-bundle in a recently retired transport aircraft. Higher technology inspection found over 60 breaks. This finding was later verified in a laboratory.

**PILOT PROCEDURES**

**General**

Recommendation: Improve flight-crew procedures to use autoflight systems to reduce pilot workload. Included in the procedures should be provisions for the failure or unserviceability of the autoflight system.

The use of the autoflight system can provide a dramatic reduction in pilot workload during smoke/fire/fume events. Engaging the autoflight system while accomplishing the complex checklists, required by some manufacturers, during smoke/fire/fumes conditions allows both pilots to be involved in diagnosing the type of event that is occurring, thereby improving the accuracy, the speed of the analysis and the accomplishment of necessary procedures. During a time of high stress situational awareness is essential to avoid controlled flight into terrain.

Additionally, the necessary reprogramming of Flight Management System (FMS) computers can be done more effectively. Reconfiguration of the air conditioning/pressurisation system, electrical system and/or other necessary system adjustments can be made with the redundancy of two pilots using the proven method of challenge response checklist.

However, as previously shown, there is the possibility of multiple system failure or cascading failures, which could eliminate the autoflight system and should be considered in procedure design.
Smoke removal

Recommendation: Eliminate procedures to open flight deck window to vent smoke and improve smoke removal procedures to ensure maximum effectiveness.

Once smoke enters the flight deck its effects can be significant. Aircraft manufacturers include procedures for a flight crew to evacuate or remove flight deck smoke. Notably, there is difference in methods chosen by manufacturers to remove smoke from the aircraft.

The procedure for opening windows continues to be part of some manufacturers smoke removal checklist despite the examples of ineffectiveness. Unfortunately, there are flight deck crewmembers who continue to believe that opening a window will help vent the flight deck of smoke. One negative result of attempting to open a flight deck window is the requirement to slow the aircraft before it can be opened, which delays the aircraft from landing.

With the window open the noise level may have a severe impact on intra flight deck communication. The inability of a flight crew to communicate during an emergency is serious hazard that should be avoided. Orderly communication is necessary to complete complex procedures contained in abnormal and emergency checklists; this requires a flight deck noise level far below that when a window is open.

Abnormal Situations Checklists

Recommendation: Redesign all transport aircraft checklists pertaining to smoke/fire/fumes to be consistent with the Flight Safety Foundation smoke/fire/fume checklist template. Consider: memory items, prevention of checklist “bottlenecks,” font size and type, where it should be found (quick reference handbook [QRH] or electronic), smoke removal, number of checklists for smoke/fire/fumes and the length of the checklists.

The foundation of modern transport aircraft operations is compliance with Standard Operating Procedures (SOP). Within SOPs are carefully designed checklists. These checklists provide a flight crew procedural guidance through most normal, non-normal (abnormal) and emergency conditions.

The use of checklists is an integral part of a pilot training and usage of checklist is essential to modern safe flight operations.

In cases of in-flight fire, there are numerous checklists that should be completed before the aircraft lands. Furthermore, the priority of completion of these checklists can change, depending on the situation, adding confusion and increasing the likelihood of errors.

Many checklists in current use still adhere to an old philosophy of attempting to locate the source of the smoke/fire/fume before directing the crew to land the aircraft. Landing is suggested to crews only after all troubleshooting items have been exhausted and found to be ineffectual. However, recently the industry has acknowledged the need to get flight crews considering and/or conducting a diversion early in the checklist, and to stress the need to land as soon as possible or even consider landing immediately, if necessary. This shift in priority is important and should improve response to smoke/fire/fume events in the future.

Careful procedural development, checklist design and training are necessary to have the best outcome. Integrated checklists can be designed so that a flight crew member can remain within a single checklist to the maximum extent possible. These reports clearly show that pilots can become task saturated and distracted during smoke/fire/fume events.

Font size and type style should be easily read by a pilot wearing an oxygen mask and smoke goggles in low visibility conditions. The verbiage of the checklist should be as unambiguous as possible, including specific tasks of the crewmembers.
Pilots involved in smoke events comment that they “feel rushed” which can easily lead to committing errors. The investigation of Federal Express Flight 1406 reported that, “during post accident interviews, the flight engineer said that he felt rushed with the workload during the descent.” In the NTB report the failure of the flight engineer to complete the “Fire and Smoke” checklist caused the aircraft be pressurised on the ground after landing, thereby delaying the evacuation.

A noteworthy example is a regional jet landing without accomplishing the pre-landing checklist. As described by the pilot during a smoke event “I feel that I became too focused on finding the circuit breakers and that communications between me and the captain broke down. I found myself unaware of our location and when I realised where we were, we were already on short final.” The priority for this First Officer was completion of the Quick Reference Handbook checklist, but other critical items in the pre-landing checklist were not accomplished and there was loss of situation awareness.

Effective fire fighting is best accomplished by using all available crewmembers. Cabin and flight deck smoke/fire/fume checklists should be integrated to maximise their effectiveness and compatibility with specific tasks assigned to specific crewmembers. By clearly assigning tasks, crew coordination can occur.

**Flight Safety Foundation Checklists Presentation Template**

The Flight Safety Foundation recognised the need for improvements in checklist design and in 2005 led an industry group that published a checklist template and an accompanying philosophy for in-flight smoke/fire/fume events that are not annunciated through aircraft alert and warning systems (e.g. air conditioning smoke or electrical fire). This template was developed through consensus by several industry participants representing major manufacturers, air carriers and professional organisations. The Air Line Pilot Association (ALPA), one of its participants, presented the need for, and the applicability of, this template at the International Flight Safety Seminar in 2005.

This template streamlines the checklists used by a flight crew to address smoke of unknown origin. It does so by integrating all or most of the smoke, fire and fumes checklist used to respond to unannounced smoke/fire/fume events into a single checklist. A single integrated checklist eliminates the need for flight crews to first make a determination of what type of smoke/fire/fumes they are encountering in order to know which checklist to access. Checklists developed using the template also stress the need to consider diversion at early stages of the event and the need for an immediate landing if the fire is uncontainable.

The FAA has indicated plans to integrate the template, philosophy and development rationale into AC 120-80, which addresses issues related to in-flight fires. This, in turn, will hopefully lead to manufacturers and operators revising their smoke/fire/fume checklists accordingly.

**Checklist Priority**

Setting the proper priority of checklists can be essential. During a rapid descent to an airport for landing following the discovery of smoke/fire/fumes within an aircraft is, as shown, very workload intensive. Yet, there is a necessity that the aircraft be prepared to land safely and configured so that an evacuation can be initiated if necessary.

There is a conflict that arises when the need to complete the Smoke/Fire/Fume checklist takes more time than is available to land. When is the FMS going to be reprogrammed? When is the pressurisation going to reset to the new landing airport? When are the navigation radios going to be re-tuned? When is the descent checklist going to be accomplished? When is the before landing checklist going to be accomplished? Who is going to talk to air traffic control? These are just a few
of the questions that a flight crew must answer in the brief time as they prepare to land a smoke filled aircraft. Within the template is recognition that there may be occasions, such as when landing is imminent, that smoke, fire and fumes checklist completion should be suspended so the crew can turn their attentions to the more pressing task at hand (i.e. landing). Adoption of the new template will help flight-crew prioritise the necessary tasks.

**Flight Crew Training**

**Recommendation:** Assure improved flight crew and cabin crew training on the importance of maintaining a smoke barrier during smoke/fire/fume events and the ineffectiveness of, and potential problems with, opening a flight deck window, the necessity of proper fire extinguisher operation, the proper use of a crash axe, the proper accomplishment (or abandonment) of checklist during simulated smoke/fire/fume events, during realistic line oriented flight training.

**Smoke Barrier**

The success of maintaining the smoke barrier can depend on the training of the flight crew in communications. The examples of Air Canada Flight 797 and Air Tran Flight 913 show that the flight deck door may be opened by well-intentioned flight crewmembers who unwittingly compromise the smoke barrier. One success of the Federal Express Flight 1406 flight crew was their ability to keep a smoke barrier in place and their flight deck relatively free from smoke. This important training should be included in much more realistic training than is currently required.

**Fire Extinguisher and Crash Axe Training**

Specialised training for the proper use of access ports when they are installed will be needed. The fire extinguisher operation in the access port should be demonstrated to the flight crew. They should demonstrate the proper use of the fire extinguisher.

Should an air carrier use the axe as a means of access, more detailed training should be accomplished. The location and routing of wiring bundles and other important components should be shown and provided in a manual available to flight crewmembers in-flight. The NTSB in the report of Air Canada Flight 797 recommended this. Interior panel removal methods should be demonstrated and marked, as should the location of good access points for extinguisher discharge.

The NTSB recommended changes to 14 CFR 121.417 in their January 4, 2002 letter to the FAA. Those recommended changes will improve the initial and recurrent training of flight crews, however the recommendations included in this paper exceed the NTSB’s and would help improve flight crew performance to in-flight fire even more.

**CONCLUDING REMARKS**

There will continue to be in-flight fires because it is not possible to eliminate all the ignition sources that could start a fire in remote locations of the aircraft. Effective mitigation is required to reduce the risk and effect of fire aboard aircraft.

Improving the aircraft equipment design, the procedures and the regulations will give flight crewmembers the best chance. In recent times the best chance for success has been industry consensus initiatives such as the Flight Safety Foundation checklist template. Co-operation of the regulators, manufacturers, air carriers and professional associations is needed to implement these safety recommendations. Only through execution of a comprehensive mitigation strategy along with developing and implementing a plan to maximise fleet coverage can we reduce the risk of in-flight smoke, fire and fumes.

APPENDIX 1

Comparison of Airworthiness Requirements between FAA & EASA/JAA

The European Aviation Safety Agency (EASA), the Joint Aviation Authorities (JAA) and FAA have adopted, or harmonized, many of their aviation regulations. However, some key regulations remain different. The harmonization efforts continue to work with the conditions of aging aircraft, aircraft wiring and arc fault. Four regulations, 14 CFR Part 25.831, 25.1309, 25.1353 and 25.1357 are significant when considering in-flight fire issues.

FAA 14 CFR Part 25.831 and EASA Certification Specification (CS) 25.831 titled “ventilation” are mostly harmonized, but still have a few inconsistencies within subpart (a). The European regulations state that:

(a) **Each passenger and crew compartment must be ventilated and each crew compartment must have enough fresh air (but not less than 0.28 m3/min. [10 cubic ft per minute] per crewmember) to enable crewmembers to perform their duties without undue discomfort or fatigue).**

14 CFR Part 25.831 does give a standard for air flow, but it differs from EASA CS 25.831, stating:

(a) **Under normal operating conditions and in the event of any probable failure conditions of any system that would adversely affect the ventilating air, the ventilation system must be**
designed to provide a sufficient amount of uncontaminated air to enable the crewmembers to perform their duties without undue discomfort or fatigue and to provide reasonable passenger comfort. For normal operating conditions, the ventilation system must be designed to provide each occupant with an airflow containing at least 0.55 pounds of fresh air per minute.

Do these airflow amounts compare?

The most inconsistent of the regulations is 25.1309 titled “Equipment, systems and installations.” Although the Europeans have separated some of 14 CFR Part 25.1309 into JAA CS 25.1310 titling it “Power source capacity and distribution,” CS 25.1310 equates to 14 CFR Part 25.1309 (e), (f) and (g) respectively. 14 CFR Part 25.1309 states that equipment, systems and installations “must be designed to ensure that they perform their intended functions under any foreseeable operating condition.” The European regulations do not have an equivalent for this paragraph. Sub-paragraph (b) in Federal Aviation Regulations and (a) in Joint Aviation Regulations relate to system design.

(b) The airplane systems and associated components, considered separately and in relation to other systems, must be designed so that:

(1) The occurrence of any failure condition which would prevent the continued safe flight and landing of the airplane is extremely improbable, and

(2) The occurrence of any other failure conditions which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions is improbable.

Whereas JAA CS 25.1309 states that “equipment and systems must be designed and installed so that:

(1) Those required for type certification or by operating rules, or whose improper functioning would reduce safety, perform as intended under the aeroplane operating environmental conditions.

(2) Other equipment and systems are not a source of danger in themselves and do not adversely affect the proper functioning of those covered by sub-paragraph (a)(1) of this paragraph” (see above).

In relation to the failure modes within the regulations, the European regulations do list in subparagraph (b), design criteria for systems and associated components to be designed so that:

(1) Any catastrophic failure condition
   (i) is extremely improbable; and
   (ii) does not result from a single failure; and
(2) Any hazardous failure condition is extremely remote; and
(3) Any major failure condition is remote.

Several key regulations have finished the harmonizing process. 14 CFR Part 25.1353 and EASA CS 25.1353 titled “Electrical equipment and installations” have recently been harmonized. The Federal Aviation Regulations now read as the European regulations read. Noteworthy are the changes below:

(d)(1) The electrical cables used must be compatible with the circuit protection devices required by §25.1357 of this part, such that a fire or smoke hazard cannot be created under temporary or continuous fault conditions.

(3) Electrical cables must be installed such that the risk of mechanical damage and/or damage caused by fluids, vapours or sources or heat, is minimized.
14 CFR Part 25.1357 and JAA CS 25.1357 titled “Circuit protective devices” are now harmonized as of the 2006 Federal Aviation Regulations. Some of the important changes highlight:

(a) Automatic protective devices must be used to minimize distress to the electrical system and hazard to the airplane in the event of wiring faults or serious malfunction of the system or connected equipment.

(b) The protective and control devices in the generating system must be designated to de-energize and disconnect faulty power sources and power transmission equipment from their associated busses with sufficient rapidity to provide protection from hazardous over-voltage and other malfunctioning.

While the harmonizing process is not complete, there has been and continues to be an effort by the FAA and EASA/JAA to integrate the best of the previous regulations into the harmonized ones. This process can help incorporate some of the multiple layers of mitigation recommended within this paper.

The current differences in relevant regulations are shown in the table.

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<th>EASA/JAA</th>
<th>Differences</th>
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Mention should also be made to the section of FAR 25, JAR 25 and CS 25 which specifically deals with Fire Protection, that is 25.851 to 25.853 inclusive. As indicated in the paragraphs that follow, these and other JAR/CS requirements also cross-refer in their text to AMC material (Acceptable Means of Compliance) and fire test requirements.

It is worth pointing out that all regulatory materials issued by the FAA is listed as FARs, e.g., FAR 25.1309 etc., but the associated Advisory Material, e.g., AC 25.1309, is not cross referenced in the primary regulatory text.

Similarly, the JAA regulatory material is listed as JARs, e.g., JAR 25.1309 and, in this case, for EASA, as CS 25.1309. However associated advisory material such as AMC or test requirements is referenced in the primary text of the JARs and the CS. This makes it more difficult when making a comparison between the codes.

**Downloading information from the Internet**

The full text of all FAA ACs, including those mentioned in preceding paragraphs, may be downloaded from one of the FAA Internet sites as follows. Go to www.faa.gov/regulations_policies/ then click on the red line Federal Aviation Administration – Regulation and Policies then click the tab *Regulation and Certification Advisory Circulars*, then click on Advisory Circulars in the centre column, then click *Current ACs by number* in the left block and take your pick.
Main Text References

SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT


38. FAR refers to aviation regulations under Title 14 Code of Federal Regulation.


43. http://www.bts.gov/publications/the_changing_face_of_transportation/chapter_03.html


47. FAA. (2005, September 1).


49. FAA. (2005, November 23).


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74. FAA. (2005, October 6). Notice of proposed rulemaking (NPRM): Enhanced airworthiness program for airplane systems/fuel tank safety (EAPAS/FTS); Proposed advisory circulars; Proposed rule and notices, 70(193), Federal Register p. 58508-58561. Doc 233


APPENDIX 3

Do You Smell Smoke? Issues in the Design and Content of Checklists for Smoke, Fire and Fumes

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Abstract

An in-flight smoke or fire event is an emergency unlike almost any other. The early cues for conditions such as air conditioning smoke or an electrical fire are often ambiguous and elusive. Crews may have very little time to determine if there really is smoke, fire, or fumes and if so, to locate the source and extinguish it. The checklists crews use for these conditions must help them respond quickly and effectively and must guide their decisions. This paper discusses three sets of issues in the design and content of checklists for in-flight smoke, fire, and fumes events.

Introduction

When a smoke, fire, or fumes (SFF) event occurs in-flight, time is the most precious resource crews have. Yet, at least some of this resource must be invested to determine if suspicious cues do in fact indicate smoke or fire, as cues are often ambiguous, especially for air conditioning, electrical and other non-alerted sources (i.e., SFF for which there are no aircraft detection systems). Also, false alarms occur frequently enough (e.g., Blake, 2000) to make crews want to have a definitive picture of their situation before committing to a diversion and emergency landing.

When smoke or fire does occur, a cascading loss of systems is likely if it spreads, and the crews’ ability to respond effectively may become impaired (e.g., National Transportation Safety Board (NTSB), 1974; Transportation Safety Board (TSB) of Canada, 2003). Thus, rapid isolation and elimination of the ignition source are necessary to prevent the condition from escalating. However, timely decisions to divert and complete an emergency landing are also essential if the ignition source cannot be identified or if efforts to extinguish a fire are unsuccessful.

The stress and workload of responding to these events is exceptionally high and unlike many other types of emergency or abnormal situations, the flight and cabin crews absolutely must communicate and coordinate their assessment and response. However, even the most rigorous joint training cannot realistically present crews with the full extent of the demands they will face when dealing with smoke, fire, and fumes in flight.

Checklists are indispensable tools to guide crews’ decision-making and response when faced with multiple tasks during these high stress events. Checklist designers must carefully consider all essential tasks crews must perform and prioritize when those tasks are to be accomplished, given the wide range of potential SFF events: those that are easily identified, isolated and extinguished as well as those whose sources are unknown, hidden, and cannot be put out. Further, designers must determine the best way to help crews access the correct checklist quickly, especially when the crews may not be able to tell what kind of SFF they are dealing with. Designers must make sure that no bottlenecks exist within the checklists, especially given the time-criticality of many of these events, and must design the checklist to facilitate the high degree of communication and coordination that is needed between flight and cabin crews. Clearly, a wide variety of difficult issues face designers of checklists for in-flight SFF.
Part of what makes responding to some of these issues so difficult is that they involve tradeoffs that require making choices that may conflict with each other. For example, toxic fumes and smoke can quickly enter a cockpit during a SFF event. Therefore, oxygen masks and goggles should be donned by a flight crew at the first sign of SFF; a delay in donning them may result in the crew realizing they are needed when it is too late and the crew’s ability to function effectively has already become impaired (NTSB, 1998). On the other hand, oxygen masks can make communication difficult and goggles can restrict one’s vision; should donning such protective gear be required if the SFF event is unlikely to cause the flight crew difficulty (e.g., a burnt muffin in the back galley)? How does one write a checklist so that crews will be adequately protected when they need to be but also not be unduly restrained when such equipment is unnecessary?

This paper will examine SFF checklist design and content issues related to three areas: 1) accessing the correct checklist; 2) guidance to divert, descend, and complete an emergency landing; and 3) source identification, isolation, and elimination. The ways that these issues have been addressed in many current SFF checklists will be compared to newer approaches taken in an air carrier checklist and in a new SFF checklist template, proposed by an aviation industry “steering committee” (Flight Safety Foundation, 2005). [1] Design trade-offs that exist between some of the issues will also be addressed. The issues will be considered only as they relate to checklists for non-alerted, rather than alerted, SFF events. As stated earlier, non-alerted SFF are those for which no sensors, detectors, or alarms exist, other than the humans onboard the aircraft. They commonly include such events as air conditioning smoke or fumes; electrical smoke, fire, or fumes; galley fires; cabin fires; fluorescent light ballast smoke or fire; and fires of “an unknown origin.”

**Accessing the Correct Checklist**

Currently, when crews wish to complete a checklist for a SFF situation, they typically access a checklist that has been developed for a specific type of smoke, fire, or fumes, (e.g., Air Conditioning Smoke). Thus, crews are presented with a list of several different SFF checklists and they must first determine what type of SFF they have in order to select the proper checklist from the list. However, some cues for non-alerted events are often quite ambiguous and making a distinction between air conditioning, electrical, materials, fluorescent light ballast, dangerous goods (i.e., hazardous materials), or some other type of SFF can be quite difficult. Precious time is wasted if a crew completes a checklist for the wrong type of SFF.

In response to these issues, a few air carriers (e.g., United Airlines) have independently developed a single integrated checklist to be used for multiple types of non-alerted SFF events. With such an integrated checklist, the time crews would initially spend trying to figure out which checklist to complete is actually spent by completing actions that have applicability for all types of non-alerted events. Similarly, the template developed by the steering committee, and proposed for industry-wide use, is for an integrated non-alerted SFF checklist. As can be seen in the template, which is included in this Appendix, the first 11 steps/sections are to be accomplished irrespective of the specific type of SFF faced. Actions that are pertinent to specific types of SFF are grouped according to SFF type and appear in sections 12, 13, and 14.

Even though the template guides development of a single checklist to be used for multiple types of SFF events, crews may still be required to access more than one checklist during their response to such events. For example, the template calls for crews to refer to a separate Smoke Removal Checklist when necessary. (A template for the separate smoke removal checklist was not developed by the steering committee; manufacturers and/or air carriers are expected to provide them.) Similarly, the integrated checklists developed by individual air carriers also do not generally include all items that might be required to respond to all SFF events. For example, the integrated checklist developed by United Airlines requires that crews refer to a separate checklist if they have avionics smoke. (A more complete description of the United Airlines checklist, as well as the checklist itself, is also included in this Appendix.)

**Design Tradeoffs: Integrated vs. Separate Checklists**. The decision whether or not to include all SFF-related items in a single integrated checklist represents one of the many checklist design tradeoffs that exists. Integrating all types of non-alerted SFF checklists into one can result in a
very lengthy checklist and longer checklists require more time to complete. (The United checklist in
this appendix is an example of an integrated checklist that is *not* overly long, however.)
Additionally, such a comprehensive integrated checklist might require crews to perform a number
of jumps within the checklist, to get to those items that are applicable for their specific situation
(e.g., air conditioning smoke), thus increasing the likelihood of checklist navigation errors.
Nonetheless, with an integrated checklist crews always know the correct checklist to access and
are not required to make difficult (or sometimes impossible) distinctions between different types of
SFF before beginning their response to such a time-critical event.

**Diversion and Landing Guidance**
Some of the most hotly debated issues in the design of non-alerted SFF checklists concern
whether or not crews should be given guidance to divert and, if so, where in the checklist this
guidance should appear (i.e., at the beginning, at the end, etc.). In many current non-alerted SFF
checklists, guidance to complete a diversion and/or emergency landing is given as one of the last
steps, if it is given at all, and the guidance to complete such a diversion is only pertinent if all
efforts to extinguish the SFF have been unsuccessful (e.g., TSB of Canada, 2003, NTSB, 1998).
The philosophy implicit in this design is that continued flight to a planned destination is acceptable
if in-flight smoke or fire is extinguished. If crews follow these types of checklists exactly as written,
a diversion is initiated only after the completion of steps related to all other actions, such as crew
protection (i.e., donning of oxygen masks and goggles), establishing communication, source
identification and troubleshooting, source isolation and fire fighting, and smoke removal, and then
only if the SFF is continuing.

In a study of 15 in-flight fires that occurred between January 1967 and September 1998, the TSB
of Canada determined that the amount of time between the detection of an on-board fire and when
the aircraft ditched, conducted a forced landing, or crashed ranged between 5 and 35 minutes
(TSB of Canada, 2003). These findings indicate that crews may have precious little time to
complete various checklist actions before an emergency landing needs to be completed and,
hence, the checklist guidance to initiate such a diversion should be provided and should appear
early in a checklist.

However, some types of fire or smoke may be relatively simple to identify and extinguish, such as
a burned muffin in a galley oven. Few people would argue that an emergency landing is required
in such a situation and it is undesirable to complete an unscheduled landing unnecessarily
because of the many safety and operational concerns involved (e.g., tires bursting and a possible
emergency evacuation after an overweight landing). Thus, developers struggle with the priority to
place on guidance to complete a diversion in non-alerted SFF checklists.

In the newly developed template, the very first item states “Diversion may be required.” The intent
of this item, and the reason it appears first in the checklist, is to “establish the mindset that a
diversion may be required” (see the philosophy developed by the Steering Committee to
accompany the template also in this Appendix). The placement of this item as the very first in a
SFF checklist represents a significant change from the current philosophy about how crews are to
respond to SFF events described above. It is not intended that crews read this item as direction to
immediately initiate a diversion or even begin planning a diversion however, just that they should
keep in mind that a diversion may be necessary.

Step 10 is the first place in the template where crews are specifically directed to “Initiate a
diversion to the nearest suitable airport” and they are to do this “while continuing the checklist.”
This step follows five steps/sections (5, 6, 7, 8, 9) pertaining to source identification and/or source
isolation/elimination. The actions to be completed in sections 5 and 9 do not require the crew to
know the actual source of the SFF but have crews eliminate “likely sources” (discussed in greater
detail below), as determined by aircraft or fleet history. The actions in sections 6, 7, and 8, are to
be completed when the source is “immediately obvious and can be extinguished quickly.”
The steering committee believes that crews will be able to complete all of the actions in these five
sections fairly quickly – the philosophy even states “Checklist authors should not design
procedures that delay diversion.” Thus, using a checklist developed according to the template,
crews will complete items for self-protection and establishing communication (steps 2, 3, and 4), five sections of actions to eliminate probable or known sources of SFF, and then initiate a diversion in Step 10 if the earlier actions to eliminate the SFF source were unsuccessful.

Current checklists developed by some air carriers and manufacturers reflect a different approach as directions to divert, initiate a descent, or “land ASAP” are given earlier and do not follow actions to extinguish an easily identifiable and accessible source of SFF. For example, United Airlines’ integrated SFF checklist directs crews to initiate a descent after completing seven steps: donning smoke masks and goggles, establishing communication with flight attendants, turning off or overriding four different switches (eliminating “likely sources”), and turning on the Cabin signs. Further, their checklist warns crews “Do not delay descent or diversion to find the smoke source.” Checklist items for extinguishing a known source of SFF are given after the direction to initiate a descent.

**Design Tradeoffs: Divert vs. Descend.** It is important to note that guidance to divert is not the same as guidance to descend. Some in the industry believe that at the first sign of SFF, crews should initiate a descent to the minimum en-route altitude or get fairly close to the water if flying over the ocean. This would allow a crew to complete the descent and landing/ditching quickly in the event that a situation becomes uncontrollable. Others in the industry point out that such a descent may commit a crew to completing an unscheduled landing as they may no longer have enough fuel to reach their planned destination (due to the higher rate of fuel consumption at lower altitudes). The template is constructed so that crews will always have the option to continue to their planned destination if the source of SFF “is confirmed to be extinguished and the smoke/fumes are dissipating” and thus, only mentions diversion, not descent. Checklists developed by some carriers and manufacturers are more compulsory in their directions for crews to descend and land. The United checklist included in this Appendix requires a descent. This represents not only their philosophy about how to best respond to these situations but a descent is also necessary in the event that smoke removal procedures, which involve depressurization of the aircraft, are required. United crews are to land at the nearest suitable airport if the fire has not been extinguished and may also choose to divert if it seems warranted even after a fire has been confirmed to be extinguished.

**Source Identification / Isolation / Elimination**
In many current non-alerted SFF checklists, a number of items are devoted to identifying the specific source of SFF and concurrently isolating and eliminating it. Thus, in a checklist for Air Conditioning Smoke, crews are often told to, in a stepwise fashion, turn off various pack switches, bleed air switches, and other air conditioning system components, and after each configuration change, make a determination about whether the smoke is continuing or decreasing. If it is continuing, crews are commonly instructed to reverse the action(s) just taken (i.e., turn the switch(es) back on) and proceed with making the next configuration change. One drawback to this approach is that it can be quite time consuming to complete these steps particularly because it can take several minutes for crews to tell if the configuration change they just completed has had the desired effect. Nonetheless, given the state of current technology and aircraft design, completing such stepwise actions is typically the only way that crews can identify and isolate a hidden source of SFF.

The steering committee’s checklist template and integrated air carrier SFF checklists do include sections of system-specific source identification items (in the template, these are sections 12, 13, and 14). However, in both the template and in United Airline’s integrated checklist, these system-specific steps follow earlier steps designed to isolate and eliminate a source of SFF that do not involve a systematic, system-specific analysis of actions. As mentioned above, these earlier steps remove “the most likely sources” of SFF as determined by the history of the aircraft type.

For example, following the completion of crew self-protection and communication steps in the template (steps 1-4), crews would complete items related to step 5, which states “Manufacturer’s initial steps……Accomplish.” In the accompanying philosophy document, “manufacturer’s initial steps” are described as those “that remove the most probable smoke/fumes sources and reduce
risk...These steps should be determined by model-specific historical data or analysis.” Furthermore, the philosophy specifies that these initial steps “should be quick, simple and reversible; will not make the situation worse or inhibit further assessment of the situation; and, do not require analysis by the crew.”

Thus, when using a checklist designed according to the template, crews will eliminate the most likely sources of SFF early on during checklist completion without making a determination first as to whether one of these sources is in fact causing the smoke, fire, or fumes; this step involves source isolation/elimination but not source identification. Hence, a crew may complete the checklist successfully (i.e., fire is extinguished, smoke is dissipating) without ever having positively identified the source of the SFF.

Design Tradeoffs: Lengthy Source Identification vs. Quick Source Elimination. The inclusion of both system-specific source identification items as well as smoke elimination items that do not require source identification in integrated SFF checklists addresses two, sometimes competing needs felt by the crews when dealing with these events. When they are needed and time is available, items that support a systematic identification of a SFF source are available. Likewise, actions that will eliminate the most likely sources of SFF are also provided allowing the possibility of quickly eliminating a source without requiring lengthy and systematic analysis.

Conclusion
The construction and design of checklists to be used for non-alerted SFF events is very challenging. The types of events for which they might be needed vary widely but, at their extreme, are highly time-critical and life threatening. Additionally, the cues available to crews may not be very helpful in determining their situation and at times may actually be misleading. The industry is moving toward the use of integrated checklists to guide crew response to non-alerted SFF events. In this way, it is hoped that crews may be better supported in their handling of these very challenging events.

Acknowledgements
The author would like to thank Key Dismukes, Ben Berman, and Mike Feary for their helpful comments on an earlier draft of this paper. An earlier version of this paper appeared in the Proceedings of the 2005 International Society of Air Safety Investigators (ISASI) Annual Meeting. The author is also very grateful to Captain Rich Gilbert, Captain Emil Lassen, and Captain Jerry Gossner for their able assistance, insight, and guidance, and to United Airlines for permission to use their checklist in this Appendix.

Endnotes
[1] Beginning in 2004, a “steering committee” of approximate 10 individuals began meeting to develop non-alerted SFF checklist design guidance that could be adopted across the industry. Representatives from four major aircraft manufacturers (Airbus, Boeing, Bombardier, and Embraer), the International Federation of Air Line Pilots Associations (IFALPA), and four air carriers (Air Canada, British Airways, Delta, and United) comprised the steering committee. During the development process, one meeting was also held, which the author attended, whereby feedback was solicited from individuals representing other industry groups (e.g., FAA, NASA, NTSB, TSB of Canada, etc.).

The steering committee has recently completed two products it hopes will be adopted by the international aviation industry as the standards that will guide the design and content of non-alerted SFF checklists (Flight Safety Foundation, 2005). One product is a template to be used by designers when developing a non-alerted SFF checklist and the other is a description of the philosophy upon which the template is founded, as well as a few definitions of various terms and concepts used in the template. Both products are included in this Appendix. It is important to note that the template is not, in and of itself, a checklist. As its name states, it is a framework to guide checklist design and content. Some of the steps on the template are actually sections and several checklist items might be developed for a single template “step.” The accompanying philosophy and concept definitions must also be consulted during checklist development so that the resulting checklist is truly in keeping with the intent of the template.
References


A340 – Toronto landing overrun – Late Summer of 2005
### Industry Template

**Smoke / Fire / Fumes Checklist Step Sequence and Rationale**

The numbered items below comprise the industry template for an integrated, non-alerted SFF checklist. The accompanying rationales include the purpose of each step and the reason for each step’s sequential placement within the checklist.

**Protect the flight crew then assess the situation**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Diversion may be required</td>
<td>This step establishes the mindset that a diversion may be required. We use the word “may” because the crew should not initiate a diversion before a preliminary assessment of the immediate fire/source. This step is placed at the beginning of the checklist to establish immediately in the minds of the flight crew a diversion may be required.</td>
</tr>
<tr>
<td>2</td>
<td>Oxygen Masks (If required) …………………………..ON, 100%</td>
<td>These steps protect the flight crew from smoke inhalation and fume absorption. Oxygen masks are on at 100% so O2 supply does not mix with smoke or fumes. Steps are early in the checklist to ensure the cockpit crew is protected immediately after smoke/fumes detection. Steps are separate because they may be separate devices. The flight crew should don oxygen masks any time smoke/fumes are detected on the flight deck. The trigger to don masks is the smoke not the checklist. The steps are not recall nor are they required because oxygen masks and smoke goggles may not be required for all smoke events. We rely on cockpit crew judgment to decide when to don the devices. The “if required” statement also permits airlines to be flexible in training when to don the masks or to leave the timing decisions to the cockpit crew’s discretion.</td>
</tr>
<tr>
<td>3</td>
<td>Smoke Goggles. (If required) ……………………ON</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Crew &amp; Cabin Communications ……………………Establish</td>
<td>This step initiates timely coordination and communication between the cabin and cockpit crew. The step is placed after 2 and 3 to not delay donning of oxygen masks and goggles if required. The communication with cabin crew is made explicit in the step because the cabin crew is an important resource for assisting the cockpit crew with source identification and confirmation of elimination.</td>
</tr>
<tr>
<td>5</td>
<td>Manufacturers initial steps …………………….Accomplish</td>
<td>These steps quickly isolate probable ignition sources based on historical fleet data or analysis. The cockpit crew is expected to take action without delay and without assessment. The steps are placed early in the checklist to immediately isolate probable sources to reduce the risk of event escalation.</td>
</tr>
</tbody>
</table>

**Smoke Removal Reminder**

At any time smoke or fumes becomes the greatest threat accomplish SMOKE OR FUMES REMOVAL checklist. Page x.x.
### Rationale
Smoke removal should be accomplished only when the smoke/fumes are the greatest threat or when the source is confirmed extinguished. Smoke removal may change the airflow and make the situation worse by fanning an ignition source or it may mask the source. Smoke removal steps must be clearly identified and be easy to find. The removal steps may be left out of the checklist to keep the checklist uncluttered and short.

### Issue
All manufacturers need to review the smoke removal checklist to ensure compatibility with this new SFF checklist.

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Source is immediately obvious and can be quickly extinguished: If Yes, Go to Step 7. If No, Go to Step 9.</td>
<td>This step is an immediate assessment of the source and situation without waiting for the effect of initial actions. The crew must determine if the source is extinguishable. The outcome of the assessment is a decision to extinguish the source or initiate a diversion.</td>
</tr>
<tr>
<td>7</td>
<td>Extinguish the source. If possible, remove power from affected equipment by switch or circuit breaker on the flight deck or in the cabin.</td>
<td>After source is identified the crew should use all available resources to actively extinguish the source. This step comes after the source is identified.</td>
</tr>
<tr>
<td>8</td>
<td>Source is visually confirmed to be extinguished: If Yes, Consider reversing initial manufacturer steps Go to Step 17. If No, Go to Step 9.</td>
<td>The crew must confirm that the source is extinguished. The outcome of the assessment is a decision the source is extinguished or to continue the checklist. This step is placed early in the checklist to prevent escalation of the event.</td>
</tr>
<tr>
<td>9</td>
<td>Remaining minimal essential manufacturer action steps (do not meet initial step criteria but are probably ignition sources based on historical fleet data or analysis</td>
<td>Additional manufacturer action steps that do not meet the “Initial actions” criteria outlined in the SFF philosophy. For example, steps that make the cabin dark or may interfere with source identification. No further assessment should be made prior to diversion</td>
</tr>
<tr>
<td>10</td>
<td>Initiate a diversion to the nearest suitable airport while continuing the checklist.</td>
<td>The cockpit crew should not delay a diversion if the source remains unknown or cannot be extinguished. The step is placed here to get the airplane headed toward a suitable airport</td>
</tr>
</tbody>
</table>

### Warning
If the SFF situation becomes unmanageable consider an immediate landing. 

### Rationale
The purpose of this warning is to remind the crew an immediate landing may be required if the situation deteriorates. The step is placed here after the initial probable source elimination steps have been accomplished, but before the additional source elimination steps which may be lengthy.
# Additional source identification/elimination steps

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
<th>Rationale</th>
</tr>
</thead>
</table>
| 11   | Landing is imminent:  
If Yes …………….. Go to Step 16.  
If No ……………..Go to Step 12. | If landing is imminent, the crew should stop the checklist and focus on landing the airplane without the added workload and distraction of doing this checklist. This step is placed here because all probable source isolation steps have been accomplished. |
| 12   | XX system actions ……………. Accomplish  
[Further actions to control/extinguish source.]  
If dissipating ………………… Go to Step 16. | | | |
| 13   | YY system actions ……………. Accomplish  
[Further actions to control/extinguish source.]  
If dissipating ………………… Go to Step 16. | | | |
| 14   | ZZ system actions ……………. Accomplish  
[Further actions to control/extinguish source.]  
If dissipating ………………… Go to Step 16. | Additional source identification and isolation guidance may be required when the airplane is far from a suitable landing site. These system steps are presented here to systematically isolate an unknown source. These steps come late in the checklist after a diversion was initiated because they may take time. The sequence of these steps is determined by the greatest hazard they pose to the airplane. |
| 15   | Smoke/fire/fumes continue after all system related steps are accomplished:  
**Consider Landing Immediately**  
Go to Step 16. | This is the final assessment step in the checklist. The outcome of the assessment is an immediate landing or landing at a suitable airport if the additional steps identified the source. |

## Follow-up actions

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Review operational considerations</td>
<td>Operational considerations provide information to support crew decision making. The cockpit crew may need to be reminded to review considerations that may affect continued flight operations and decisions. Operational considerations may vary by airplane model and may be lengthy so should be provided outside of the checklist.</td>
</tr>
</tbody>
</table>
| 17   | Accomplish Smoke Removal checklist, if required.  
Page X.X | This step reminds the cockpit crew to remove smoke or fumes. This step is best accomplished after the source has been isolated and extinguished. |
| 18   | ■ ■ (End of Checklist) ■ ■ | This step indicates there are no more steps in the checklist. |
Operational Considerations

These items appear after the checklist is complete. This area should be used to list operational considerations – such as overweight landing, tailwind landing, etc. are OK in an emergency.

End of Industry checklist template on Smoke, Fire and Fumes drills.

PHILOSOPHY AND DEFINITIONS

Industry Checklist Template for Smoke / Fire / Fumes

This philosophy was derived by a collaborative group of industry specialists representing aircraft manufacturers, airlines/operators and professional pilot associations. The philosophy was used to construct the Smoke/Fire/Fumes Checklist Template.

General
- The entire crew must be part of the solution.
- For any smoke event, time is critical.
- The Smoke/Fire/Fumes Checklist Template:
  - Addresses smoke/fire/fumes events (smoke/fire/fumes event not annunciaged to the flight crew by aircraft detection systems);
  - Does not replace alerted checklists (e.g., cargo smoke) or address multiple events;
  - Includes considerations to support decisions for immediate landing (an overweight landing, a tailwind landing, a ditching, a forced off-airport landing, etc.); and,
  - Systematically identifies and eliminates an unknown smoke/fire/fumes source.
- Checklist authors should consider a large font for legibility of checklist text in smoke conditions and when goggles are worn.
• At the beginning of a smoke/fire/fumes event, the crew should consider all of the following:
  – Protecting themselves (e.g., oxygen masks, smoke goggles);
  – Communication (crew, air traffic control);
  – Diversion; and,
  – Assessing the smoke/fire/fumes situation and available resources.

Initial Steps for Source Elimination
• Assume pilots may not always be able to accurately identify the smoke source due to ambiguous cues, etc.
• Assume alerted-smoke-event checklists have been accomplished but the smoke’s source may not have been eliminated.
• Rapid extinguishing/elimination of the source is the key to prevent escalation of the event.
• Manufacturer’s initial steps that remove the most probable smoke/fumes sources and reduce risk must be immediately available to the crew. These steps should be determined by model-specific historical data or analysis.
• Initial steps:
  – Should be quick, simple and reversible;
  – Will not make the situation worse or inhibit further assessment of the situation; and,
  – Do not require analysis by crew.

Timing for Diversion/Landing
• Checklist authors should not design procedures that delay diversion.
• Crews should anticipate diversion as soon as a smoke/fire/fumes event occurs and should be reminded in the checklist to consider a diversion.
• After the initial steps, the checklist should direct diversion unless the smoke/fire/fumes source is positively identified, confirmed to be extinguished and smoke/fumes are dissipating.
• The crew should consider an immediate landing anytime the situation cannot be controlled.

Smoke or Fumes Removal
• This decision must be made based upon the threat being presented to the passengers or crew.
• Accomplish Smoke or Fumes Removal Checklist procedures only after the fire is extinguished or if the smoke/fumes present the greatest threat.
• Smoke/fumes removal steps should be identified clearly as ‘removal steps’ and the checklist should be easily accessible (e.g., modular, shaded, separate, stand-alone, etc.).
• The crew may need to be reminded to remove smoke/fumes.
• The crew should be directed to return to the Smoke/Fire/Fumes Checklist after smoke/fumes removal if the Smoke/Fire/Fumes Checklist was not completed.

Additional Steps for Source Elimination
• Additional steps aimed at source identification and elimination:
  – Are subsequent to the manufacturer’s initial steps and the diversion decision;
  – Are accomplished as time and conditions permit, and should not delay landing; and,
  – Are based on model-specific historical data or analysis.
• The crew needs checklist guidance to systematically isolate an unknown smoke/fire/fumes source.

Definitions:
Confirmed to be extinguished: The source is confirmed visually to be extinguished. (You can “put your tongue on it.”)

Continued flight: Once a fire or a concentration of smoke/fumes is detected, continuing the flight to the planned destination is not recommended unless the source of the smoke/fumes/fire is confirmed to be extinguished and the smoke/fumes are dissipating.

Crew: For the purposes of this document, the term “crew” includes all flight deck and cabin crewmembers.
Diversion may be required: Establishes the mindset that a diversion may be required.

Land at the nearest suitable airport: Commence diversion to the nearest suitable airport. The captain also should evaluate the risk presented by conditions that may affect safety of the passengers associated with the approach, landing and post-landing.

Landing is imminent: The airplane is close enough to landing that the remaining time must be used to prepare for approach and landing. Any further smoke/fire/fumes-identification steps would delay landing.

Land immediately: Fly immediately to the nearest landing site. Conditions have deteriorated and any risk associated with the approach, landing or post-landing is exceeded by the risk of the on-board situation. "Immediate landing" implies immediate diversion to a landing on a runway; however, smoke/fire/fumes scenarios may be severe enough that the captain should consider an overweight landing, a tailwind landing, a ditching, a forced off-airport landing, etc.

End of Industry Smoke, Fire and Fumes Checklist Template Philosophy and Definitions

Appendix 4 includes the RAeS Flight Operations Group recommendations and thoughts on the subject of designing checklists for in-flight smoke, fire and fumes. Neither the industry template above nor the checklist that follows reflects some Flight Operations Group (FOG) recommendations. For example, six (boxed) recommended ‘memory’ steps do not appear at the beginning (See Appendix 4).

UNITED AIRLINES’ SMOKE AND FIRE CHECKLIST

Below is an integrated checklist for non-alerted smoke and fire that was developed by United Airlines for use on A319/A320 aircraft. This checklist was developed prior to the development of the industry template and much of the thinking behind its design was adopted by the industry steering committee when devising the template. We are grateful to United Airlines for permission to use their SMOKE, CABIN/COCKPIT Drill in this Appendix.

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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
- Cabin signs: On
- Descent: Initiate

WARNING: Do not delay descent or diversion to find the smoke source.

CONTINUED FROM QRC

If dense smoke at any time, accomplish reverse side.

REFERENCE ACTION:

If 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
  Just before landing gear extension:
  - Generator 2 switch: On
  - Bus tie switch: Auto

END OF CABIN OR GALLEY EQUIPMENT SMOKE

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

END OF AIR CONDITIONING SMOKE

If electrical or avionics smoke is suspected:


END OF ELECTRICAL OR AVIONICS SMOKE

United Airlines A319/A320 ‘SMOKE CABIN/COCKPIT’ drill – Front Page
### Dense Smoke

**WARNING:** Accomplish this side after fire has been extinguished or smoke is so dense that it is an emergency in and of itself.

#### EMERGENCY DESCENT
- FCU altitude (safe altitude/10,000 feet). Set
- FCU expedite switch Push
- Target speed Confirm, .80M/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

  Just before landing gear extension:
  - Generator 2 switch On
  - Emergency electrical generator 1 line switch On

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Reverse of United Airlines A319/A320 ‘SMOKE, CABIN/COCKPIT’ drill page
United Airlines A319/A320 ‘SMOKE, CABIN/COCKPIT’ Checklist – Description

Location
United Airlines’ paper checklists for irregular (i.e., abnormal) and emergency conditions are located within airplane Flight Manuals rather than in separate quick reference handbooks or manuals (QRH or QRM) that are comprised only of checklists. The SMOKE, CABIN/COCKPIT checklist is a two-sided checklist that can be found within the red-tabbed section of Emergency Procedures in the Flight Manual. Additionally, information that further describes various checklist actions and how the checklist is intended to be used is provided at the beginning of the Flight Manual Emergency Procedures section.

Memory items and immediate action items from this checklist also are printed on Quick Reference Cards (QRCs). In A319/320 aircraft, there are two QRCs, which are stored on the outboard side of each pilot in pockets on the cockpit walls near the pilots’ legs.

Physical Properties
Most of the pages in the A319/A320 Flight Manual, including the checklists, measure approximately 14 cm wide by 22 cm long (5 ½ x 8 ½ inches). However, the SMOKE, CABIN/COCKPIT checklist has been turned on its side and measures 22 cm wide by 28 cm long (8 ½ x 11 inches). Thus, holes for placing it in the manual binder are at the top of the checklist rather than at the side; the checklist has been folded twice (using an accordion fold) so that when folded, its length measures the same as the width of other pages in the Manual (i.e. 14 cm (5 ½ inches)).

The paper used for the SMOKE, CABIN/COCKPIT checklist is slightly glossy and a heavier stock than that used for most of the other pages of the Flight Manual.

The QRCs are heavy, laminated cardstock and measure 22 cm by 28 cm (8 ½ x 11 inches). On the QRCs are printed all of the memory items and immediate action items from every United Airlines checklist that has them (for that aircraft type).

Use
When crews use the SMOKE, CABIN/COCKPIT checklist, they are to perform the first two items from memory without reference to either the QRC or the checklist itself in the Flight Manual. These items appear in a dashed box on the QRC and in the checklist.

Following completion of the two memory items, crews are to access the QRC and complete the SMOKE, CABIN/COCKPIT checklist immediate action items printed on it. These are the next six items that follow the memory items on the QRC. As with the memory items, the immediate action items are also re-printed in the checklist itself.

After the descent has been initiated, as directed by the last immediate action item, the QRC instructs crews to turn to page 15.50.5 in the Flight Manual to locate the rest of the SMOKE, CABIN/COCKPIT checklist items (called “Reference Actions” by United Airlines).

The crews are expected to remove the Smoke, Cabin/Cockpit checklist from the Flight Manual Binder before completing any Reference Actions (it is printed on heavier paper than most checklist pages specifically to accommodate this removal and handling).

Before crews complete any Reference Actions on the first side of the checklist, they are informed that if at any time the smoke becomes so dense that it becomes the more immediate emergency, they should turn to the second side of the checklist and complete the DENSE SMOKE procedures for smoke removal. When crews do that, they will abandon the first side of the checklist (no matter how far they have gotten in accomplishing procedures on that side) and will complete only the items on the second side of the checklist – they will not return to the first side of the checklist.

There are a few reasons why returning to the first side, once the second side has been initiated, is neither approved nor necessary. One is that some items on the first side would reverse actions carried out on the second side. For example, both pack switches are to be turned off for smoke
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

removal (second side of the checklist). However, on the first side of the checklist, the items for identifying the specific source of air conditioning smoke call for one pack switch to be on and the other to be off, thus conflicting with the configuration needed for smoke removal. Additionally, any items from the first side that might need to be accomplished during smoke removal (and completion of an emergency decent and landing) are also included on the second side, thus eliminating the need to return to complete first side items.

The DENSE SMOKE set of procedures in the SMOKE, CABIN/COCKPIT checklist are for the removal of smoke and emergency electrical configuration (if needed). All items on the second side are written in a large font size to facilitate reading them under low visibility conditions. Removing the checklist from the binder also allows crews to move the checklist closer to their faces, if necessary, to more easily read checklist items when dense smoke is in the cockpit.

The Reference Actions on the first side of the SMOKE, CABIN/COCKPIT checklist are divided into three sections according to where the smoke originated and which aircraft system is thought to be involved:

- Cabin or galley equipment smoke/fire items are to be completed for smoke or fire in the cabin that does not appear to be air conditioning related

- Air conditioning items are to be completed for smoke that comes from air outlets or other air vents

- Crews are directed to accomplish the Avionics Smoke ECAM procedure or Avionics Smoke checklist in the Flight Manual for any smoke or fire that is thought to be electrical in origin and did not originate in the cabin. Thus, crews will complete a separate set of procedures that have not been integrated into the SMOKE, CABIN/COCKPIT checklist when avionics or electrical smoke that did not begin in the cabin is suspected. (ECAM stands for Electronic Centralised Aircraft Monitoring. Checklist actions are presented electronically on the ECAM display for some types of sensed conditions on Airbus Aircraft.)

Crews are expected to pick the section of system-specific items associated with the type/origin of smoke or fire they believe they have. If the completion of one of these three sets of items is not successful in reducing/extinguishing the smoke/fire, crews are to determine if a different set of items might be more appropriate for completion. For example, if accomplishing the items pertaining to Cabin or Galley Equipment Smoke/Fire has proved unsuccessful, crews should consider completing the items for Electrical or Avionics Smoke.

When crews have been successful in extinguishing the smoke/fire using Reference Actions on the first side of the SMOKE, CABIN/COCKPIT checklist, they are to turn to the second side and complete the DENSE SMOKE items.

Although it is not stated on the checklist itself, after the fire has been positively confirmed to be extinguished, crews are to use all available resources to determine if they should divert to another suitable airport or continue to their planned destination. If the fire has not been extinguished, crews are to land at the nearest suitable airport and evacuate the passengers. This information, as well as all of the information above pertaining to the use of the SMOKE, CABIN/COCKPIT checklist, is included in the introductory information located at the beginning of the red-tabbed Emergency Procedures section of the Flight Manual.
APPENDIX 4

FLIGHT OPERATIONS GROUP VIEWS ON AIRCRAFT FIRE EVENTS & CHECKLISTS
Compiled by Captain Ralph Kohn, FRAeS, (BAC & UK CAA Ret)

With thanks to Captain ‘Phil’ H.S. Smith, MRAeS (BA Ret), Captain ‘Chris’ N. White, FRAeS (BA Ret), and SFEO Peter G. Richards, IEng, FRAeS (BA Ret), who are all members of the Royal Aeronautical Society Flight Operations Group committee, for their help with this Appendix.

SUBJECT MATTER IN THIS APPENDIX BY THE FLIGHT OPERATIONS GROUP IS COMPLEMENTARY TO RECOMMENDATIONS FOUND IN THE CORE DOCUMENT, WITH WHICH THE ‘FOG’ IS IN FULL AGREEMENT.

The RAeS Flight Operations Group (FOG) sympathises with the Flight Safety Foundation (FSF) template philosophy presented in Appendix 3 of this Specialist Document. In support, Appendix 4 is offered as suggestions for further discussion on the development of the subject in the general context of Smoke, Fire and Fumes in aircraft, and on checklists for use in such events.

Some of the recommendations contained in this Appendix have already been adopted by a few operators but there is a long way yet to go, if the industry is to achieve improved conditions that would preclude such events and also provide better in-flight detection and fire fighting facilities. To illustrate the advocated concept, the sample checklist presentation examples are built round a contemporary aircraft set of drills, offered in a generic ‘consolidated’ format.

Although the main thrust of this Appendix is the content and vital priorities in Smoke, Fire and Fumes (SFF) control drills, the Appendix is not limited to the discussion of checklists for use when dealing with smoke, fires and noxious fumes events on aircraft in flight. The discussion is broadened to include the need for positive action under various headings, from the part of Airlines, Air Traffic Control Services, Aircraft Constructors, Manufacturers of fire detection equipment and from Providers of fire-fighting materials.

Guidance is also offered for the attention of compilers of Quick Reference Manuals in general and for checklist drills specific to aircraft smoke, fire and fumes events in flight and their presentations. In the case of such drills, it is advocated that checklists to be used during SFF events should be self-contained all the way down to landing the aircraft. Therefore, in addition to and apart from drills to combat SFF events in flight, Descent, Approach, Landing and after landing Evacuation drills are all incorporated in the preferred all-inclusive checklist, so that once it is started, the flight crew does not need to put drill cards down until the aircraft has been landed. This Appendix contains subject matter under the following headings:

Smoke, Fire and Fumes Checklists - primary vital considerations
Recommendations regarding crew protection and fire extinguishing
Flight Operations Group Observations also for Consideration
- Airline Management
- Smoke Drill Analysis
- Checklist Methodology
- Air Traffic Control Assistance
Manufacturers’ Responsibilities
- Electrical System
- Essential Battery Bus Supply
- Fire Detection
- Aircraft Thermal Sensors
- Fumes from Aircraft Systems
Safety Equipment and Procedures (SEP) Training
The Quick Reference Manual (QRM)
Emergency Passenger Evacuation Drill
QRM – Emergency & Abnormal Drill index example
Integrated Smoke, Fire or Fumes drill steps based on the Flight Safety Foundation template
Examples of Consolidated Checklist Presentations
- Sequentially numbered steps for navigation (Black print on Yellow paper)
- Arrows for Navigation (Black print on Yellow paper)
- Coloured Arrows for navigation (Black print & coloured arrows on white paper for better colour contrast)
CHECKLISTS IN GENERAL

Checklists construction will generally conform to guidance offered by the UK CAA in CAP 676 (see Appendix 5 of this Specialist Document).

In parallel with CAP 676 data, it would be extremely useful to be guided by the US NASA publication titled *ON THE TYPOGRAPHY OF FLIGHT-DECK DOCUMENTATION*, by Asaf Degani of the San Jose State University Foundation, San Jose, California. This NASA document was prepared in December 1992 for the National Aeronautics and Space Administration, Ames Research Center, Moffett Field, California 94035-1000, under Contract NCC2-327. It is an excellent and exceptionally comprehensive reference source for the optimum presentation of the printed word in checklists. The web link directly to Asaf Degani’s paper is


It is important to note that the above mentioned paper makes no reference to checklists that need to be used in low visibility conditions, such as for smoke and fire drills. Thus, smoke and fire checklist developers will need to increase the font size used for text on such checklists, from that recommended by Asaf Degani.

SMOKE, FIRE AND FUMES CHECKLISTS – Vital Primary Considerations

In the opinion of the Flight Operations Group, the opening sequence of the Smoke, Fire & Fumes drill for flight deck crew should be the MEMORY ITEMS shown hereunder

<table>
<thead>
<tr>
<th>CALL</th>
<th>RESPONSE (With comment to explain)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. OXYGEN MASKS (full face) Then, <em>(but should not be an option...)</em></td>
<td>ALL CREW - ON, 100 %, MIKE TO MASK (Confirm oxygen switch is set to 100% &amp; mask-microphone is selected)</td>
</tr>
<tr>
<td>2. SMOKE GOGGLES (if not full face mask)</td>
<td>ALL CREW - ON (Don &amp; fit to face)</td>
</tr>
<tr>
<td>3. CREW &amp; CABIN COMMUNICATIONS</td>
<td>ALL CREW - ESTABLISH (Notify Cabin Crew using mask-mike inter-comm)</td>
</tr>
<tr>
<td>4. FLY THE AIRCRAFT</td>
<td>CAPTAIN - DECLARE (Decides who by and how – manually or autopilot).</td>
</tr>
<tr>
<td>5. ATC COMMUNICATIONS</td>
<td>CAPTAIN - DECLARE EMERGENCY &gt; MAYDAY CALL (On route frequency or 121.5 &amp; SSR code 7700 if required)</td>
</tr>
<tr>
<td>6. DIVERSION FOR LANDING</td>
<td>CAPTAIN - CONSIDER / INITIATE &amp; REVIEW LATER (Review / cancel if situation under control)</td>
</tr>
</tbody>
</table>

NON - HANDLING PILOT NOW COMMENCES SMOKE, FIRE & FUMES DRILL

Note 1. Regarding Step 1 and Oxygen checks, it is VITAL to ensure during pre-flight checks, that the oxygen system is turned fully ON and that individual mask checks test the flow for a significant period and not just perfunctorily for a very brief second, to confirm the system is fully pressurised.

Note 1a. Step 1 (and 2 if not a full face mask) - Oxygen masks (and Goggles where necessary) must be donned at the first indication of air contamination, not as the FSF table suggests "... if Required". The idea is to stay alive and not become incapacitated. It is strongly felt by the FOG that by waiting to assess the situation subjectively, it may be too late to protect oneself if rapidly disabled, particularly by noxious fumes. Due to the complex cocktail of fumes and smoke generated at the onset of some fires in the air, a crew can be easily overcome before realizing or discovering the onset of impairment.
Note 1b. Whether the 100% oxygen flow selector is wire-locked to that switch position or not and notwithstanding that it might have been so set during pre-flight checks, this vital toggle position selection MUST be confirmed after donning the oxygen mask, when the mask microphone is also switched ON. ‘Flow Indication Irises’ such as those fitted on ‘EROS’ mask sets, must be checked to confirm flow both pre-flight for at least 10 seconds and at the time of donning for use in anger.

Note 1c. The FOG, and many within the industry, support the use of full face masks and encourage all Operators to install and Regulators to require, full face masks and stop the use of the two stage so-called protection where separate goggles are donned after the oxygen mask, so wasting precious time with eyes unprotected. Furthermore, goggles do not assure eye protection whereas a full-face mask does.

Note 2. Step 4 requires that a pilot is nominated to fly the aircraft while the rest of the crew deals with the emergency. It appears as step 4 in this checklist because other higher priority ‘survival’ aspects need addressing first. In other checklists, this step should be the first item in every emergency drill as a vital standard SOP requirement, where donning an oxygen mask first is not required to stay alive.

Note 3. At Step 5, the Captain advises ATC on the frequency being used at the time of the occurrence, that an abnormal fire smoke or fumes situation exists and declares an emergency by way of a Mayday call. Surprisingly, a Pan call may not be understood by controllers outside the UK and the USA or even in certain parts of Europe, hence the need for a Mayday call.

Note 3a. When outside VHF coverage, it is recommended that a MAYDAY call be made on 121.5 even if a MAYDAY call has been made and acknowledged on HF. Although far from normal VHF coverage, relays through other aircraft that maintain a listening watch on VHF frequency 121.5 as per International Regulations and normal practise, may overcome HF bands communication problems on what could otherwise be congested ATC non-VHF route frequencies. Even if a Mayday call is made on HF and acknowledged, a repeat of the call on 121.5 is worth giving as it may be picked-up by a satellite and relayed to a ground station that could assist in some way, thus maximising all available help.

Note 3b. SSR Squawk Code 7700. To indicate an emergency condition, this code should be selected as soon as is practicable after declaring an emergency situation and having due regard for the over-riding importance of controlling aircraft and containing the emergency. However, any SSR code setting previously assigned by ATC (other than the conspicuity code 7000) should be retained unless, in special circumstances, the pilot has decided or has been advised otherwise. Obviously, in mid-Atlantic an aircraft would not normally have an allocated SSR code and therefore squawking 7700 is required and will be prompted by the checklist.

Note 4. Steps 5 and 6 follow-on from one another. Step 5 demands a bit of explanation. It is thought preferable to be going towards a place where a successful landing might be made, than spending precious time initially trying to work out where the smoke or fumes are coming from. The pilots can always change their minds later, ‘review’ the situation and recover a lot of the ‘lost journey’ if the problem is resolved unequivocally and any minor fire fully contained and extinguished. In that case, the emergency can be cancelled and the flight resumed to the original intended destination.

Note 4a. That “a diversion for an immediate landing may be required” is an important step. So as not to take such a rigid position that the industry does not ‘hear’, an early choice is provided in the checklist by stating “CONSIDER (diversion for an immediate landing)”. In that way if the source of the smoke is a windshield heat control box for example, the Captain can assess and apply the appropriate procedures. Then, if the known source is unequivocally confirmed as extinguished, there may be no need to request diversion for an en-route landing. However, a precautionary landing to assess the extent of any hidden collateral damage is worth considering.
Note 4b. The need for an early landing is based on the fact that the all-fly-by-wire aircraft systems are interconnected in such a complex way, that a rapid preliminary assessment may do little good. It is better to assess the situation on the ground. We must also remember that most of the aircraft structures are not accessible and have no thermal sensing or fire suppression capability. So getting on the ground may have to be a primary consideration on such aircraft.

Note 5. The question "Is a ‘landing’ airport distant ?" should be asked at some suitable point in the drill. It is a consideration of importance. If YES, then there may be time for trouble-shooting. For example, after all main electrical power is switched-off as a part of the drill, the rebuilding process begins. If time is short, then the aircraft may need to be landed on essential power only. Drills should be constructed accordingly.

Note 6. The idea of maximising airflow from front to aft appears to serve most of the conditions. If available, using high airflow from the packs can be achieved in many situations. This has the added benefit of providing increased airflow into the flight deck and thereby increasing the positive pressure. This positive airflow can act as a smoke barrier if needed, in addition to a closed flight deck door. The suggested/recommended Heavy/Dense Smoke Removal drill reflects this.

Recommendations regarding crew protection and fire extinguishing

1. When fire-fighting, as for flight-deck crew use, a full face mask is strongly recommended rather than an oxygen mask with separate goggles which do not reliably provide the vital seal between the face area around the eyes and the oxygen mask covering mouth and nose.

2. The use of Halon is environmentally problematic. However, nothing discovered to date is nearly as effective and so we should continue its use for now. Halon, or an equivalent agent that is just as effective, is needed as stated in recommendations. It is a matter of risk management where the needs of an in-flight fire clearly outweigh the environmental issue.

2.1 Other applications such as computer-room fire protection, can use other types of extinguishant. However, for in-flight fires in such an enclosed space as an aircraft cabin, the dispersal characteristics of Halon make it the best performer.

2.2 In the circumstances, Governments and Regulators should allow the continued use of Halon as an extinguishant on aircraft until an equivalent ‘green’ alternative is made available.

The FAA 120-80 Advisory circular (In-flight Fires) also has some additional information related to the use of Halon that should be considered. It can be located on the FAA web site, at http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/ed51f1681e9d8c5e86256e4a00744607/$FILE/AC120-80.pdf

FLIGHT OPERATIONS GROUP OBSERVATIONS ALSO FOR CONSIDERATION

AIRLINE MANAGEMENT

1. Management guidance and regulatory compliance documentation (Flying Crew General Orders) should include a version of the following statement: Emergencies involving smoke or fire from unknown sources during flight require a commitment to land as soon as possible. If the source of the smoke is known, such as from a lavatory waste paper bin or a seat upholstery fire, the Captain can assess the situation once the cabin crew has applied the appropriate procedures. There may be no need to request diversion for an en-route
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

1. Every accident or serious incident involving smoke and/or fire on the flight deck is unique, or will encounter unique combinations of factors.

2. Having analysed a wide cross-section of different operators, with a cross-section of 20 aircraft types, checklists typically delay what the working group called the "divert/land prompt" to well down the checklist sequence. Indeed, some checklists do not give this prompt at all, but refer the reader to other manuals. Delaying landing may be fatal.

3. The concept of landing overweight is alien to many operating regimes due to the nature of the operation and the flexibility of the aircraft. The downtime required for subsequent maintenance checks polarises management philosophy and hence a pilot's training. Pilots must have the option to carry-out an overweight landing in an emergency, such as in the case of an in-flight fire situation.

4. The "divert/land ASAP" (As Soon As Possible) prompt in the fire and/or smoke emergency checklist must not be biased by any consideration of the weight of the aircraft. A generally acceptable pre-calculated minimum runway length/stopping distance for an emergency landing could be usefully provided on relevant drill cards to help with a 'diversion' choice.

5. Smoke Fire & Fumes checklists should contain a step on the need to plan with the cabin crew an emergency passenger evacuation after landing and to review their pre-evacuation drill or ditching drill cabin preparations. The cabin crew will then brief passengers accordingly before the approach commences. The step should be at a suitable point in the drill sequence, before the aircraft is landed. When to stop trying to locate the source of a fire or smoke to prepare the cabin for landing and the evacuation, should also be discussed and agreed.

Comment: The cabin crew should start the evacuation at the captain’s command, after the aircraft has come to a stop. This is to allow the pre-evacuation flight-deck drill to be run, to assist with the evacuation. For example, the aircraft must be depressurised prior to landing to allow the opening of doors and over-wing exits. Flaps should also be set to assist sliding off the wing to the ground, once out of the fuselage, when using over-wing exits. The brakes are set to park and all the engines shut down (including the APU if fitted), not to cause unnecessary injury. The reason for any delay in the evacuation order should be investigated by the Senior cabin crew-member, who must then take the initiative and start the evacuation, if the flight deck crew is incapacitated.

The crew may be faced with the need to ‘ditch’ the aircraft and this is a completely different drill, both in the planning time and post ‘landing’ activity. The cabin crew will be expected to begin an evacuation without any command from the flight deck, as flight crew incapacitation is a strong possibility. These emergency drills are the highest-level demonstration of all aircrew’s competence levels and teamwork is vital throughout.
CHECKLIST METHODOLOGY

1. Checklist familiarisation and management are flight crew skills, whereas hard copy availability is an Airline responsibility that should take heed of Manufacturers’ and Regulators’ guidance on the subject of checklist presentation and contents.

2. Computer managed 'glass cockpit' aircraft require an even greater need for checklist management discipline. One pilot must always fly the plane independently of what the other pilot is attempting to rectify. For example, in glass cockpit aircraft in which electronic checklists are available, only one pilot should look at the electronic checklist screen(s).

3. Computer generated checklist management requires the discipline of completing each ‘page’. However, this denies the compelling human instinct to override and recover a rapidly deteriorating emergency situation. If dealing with one page on the Airbus ECAM or Boeing ECL and there is a need to refer to another system 'page', the process of doing this should be simple and swift.

4. Paper QRM checklists or readily reachable cards are essential to guard against screen failure.

5. Large scale print on drill cards and Airbus ECAM/Boeing ECL screens is both essential and achievable.

6. Abnormal and Emergency checklists that contain vital secondary information should have this information presented in such a way as to ensure that it is not overlooked by the user who might miss words printed in a smaller font. A highlighted ‘NOTE’ could be one way of presenting such information in a larger font than the rest of the words in the checklist.

7. There appears to be an entrenched or enduring style to checklist philosophy. This may have come about due to the introduction of aircrew training on a "need to know" only basis for commercial considerations. Specific Behavioural Objective technical training was well intentioned initially but commercial forces appear to have reduced this to minimalistic levels.

9. Most modern aircraft only have a two-pilot crew who can find themselves in situations where their limited systems knowledge and too many choices with little guidance, force errors when faced with a serious emergency. ‘CRM’, ‘Selection’, ‘Training’ and ‘Formal Appraisal' have little value when the basic technical knowledge relies completely on adherence to a checklist.

AIR TRAFFIC CONTROL ASSISTANCE

1. ATC has a vital role both in situation management and resource supply.

2. When a PAN or a MAYDAY call is received, especially if involving smoke, it is vital that the aircraft in trouble is "Control Isolated" from any distractions.

3. ‘Timing’ of ATC instructions and ‘Rate of Delivery’ are of the essence. The developing situation within the flight deck will mean frequent breaks in concentration by the crew with respect to ATC, and instructions will almost certainly need repeating. The sympathetic handling by calm professionals on the ground will have a positive impact on the outcome of the emergency.

4. ATC should be prepared to assume a level of support to the crew by providing immediate information as to the nearest suitable runway. The requirement here is demanding. It cannot be expected that an individual ATCO will have such rarely required and disparate
information committed to memory. It is emphasised that ATC management has to provide for ATCOs, immediate access to available information that might be needed by an aircraft in serious trouble, for example the nearest runway suitable for the aircraft in difficulty, having regard to the following factors:-

a. Weather at the selected ‘diversion’ destination and en-route to it.
b. A dedicated frequency allocation, especially between adjacent centres.
c. Emergency services capability, though in extremis, any long enough cleared length of concrete will suffice.

MANUFACTURERS’ RESPONSIBILITIES

Electrical System

1. The Electrical Architecture of an aircraft is probably its most vital system and crew training and simulator exercises should vigorously pursue the need to demonstrate a complete knowledge of the aircraft’s electrical system architecture.

2. The design of the electrical system should be such that it should have two parts. Past experience suggests a requirement for the first component to be an ESSENTIAL area that supplies sufficient power only dedicated for safe flight. The second or MAIN area should duplicate the first, together with additional provision for all other aircraft systems.

3. Ideally, a simple guarded Emergency Switch should be provided, accessible to either pilot, which would completely isolate the Essential system from the Main in the event of "Smoke or Fire of unknown origin" within the flight deck. The Essential battery-powered supply bus would feed basic ‘Emergency Standby Flight Instruments’ that are clearly visible to both pilots and easily legible especially in reduced visibility conditions, one means of contacting ATC, a basic navigation information facility and a cabin crew communication link.

4. The Emergency switch should also have the capability of ‘de-powering’ the Essential area, once it has been proved that the Main area is safe to use and that it is not the source of the "Smoke or Fire of Unknown Origin”.

5. It is felt that the duration (endurance) of the Essential only selection should be greater than it now is and should reflect the type of operation that the aircraft is designed for. A possible solution is discussed under the next heading.

Essential Battery Bus Supply

The majority of electrical systems in modern aircraft give an absolute maximum of 30 minutes battery-only electrical power. While this may meet the majority of requirements on overland flight operations, in the case of a diversion involving smoke and fire where the smoke or fire can be controlled, this battery power may be insufficient to allow a safe diversion and landing.

In consequence, very serious consideration should be given to the provision of a supplementary charging facility to top-up the battery in original manufacturer designs or as a retro-fit requirement, such as an extendable/retractable Ram Air Turbine (RAT). The aim is to extend the battery power-supply endurance indefinitely, thus beyond the present thirty minutes battery-life capability to feed the Essential Instruments Bus after all electrical power has been removed from aircraft systems, when dealing with electrical fires and smoke sources on the way to landing the aircraft.

The rationale behind a need for a retractable RAT is that if normal supplies can be partly restored and the flight then completed at normal cruise speeds, the RAT could then be retracted so as not to damage it or produce unnecessary drag.
Fire Detection

Because crews do not have a secondary system to confirm Fire and Smoke warnings, there have been many false Cargo hold fire warnings in recent years, with resultant unnecessary diversions and passenger injuries from evacuation. As a parallel, an engine is not shut-down based on a single gauge abnormal indication, yet a single detection loop warning is accepted for cargo holds. Credence in the fire and smoke detection systems will diminish if false alarms continue. Then, one day, a real fire warning will be ignored with catastrophic results.

To guard against this happening, it is recommended that provision be made during manufacture, or indeed retrospectively, for cargo holds to have dual detection systems based on complementary technologies so that one system detects smoke and the other heat or flame. This will allow greater confidence in making a distinction between genuine and false warnings and so avoid unnecessary diversions.

In addition, visual inspection panels should be placed above holds that are inaccessible in flight. On wide-bodied aircraft, there should be at least one such viewing window appropriately fitted in each aisle. Better still, a panel that can be opened to view and ascertain whether 'Smoke' or 'Mist' has triggered the fire detector, could usefully assist human noses and eyes to confirm a warning, or otherwise.

Airframe Thermal Sensors

Remote thermal and smoke sensors should also be installed in all the inaccessible areas of the aircraft and areas which cannot be seen behind the pressurized cabin wall liners or outside pressurized areas, to provide a fire warning where no protective sensing now exits. Facilities for visual inspections from within the pressurised cabin could be made available to advantage.

SAFETY EQUIPMENT AND PROCEDURES (SEP) TRAINING

Cabin crewmembers should be regularly reminded that all unusual occurrences should always be reported to the flight deck crew and that no one should ever assume that the pilots are aware of what is going on behind their closed door. The Kegworth accident might have never happened if the Captain had been told that the left engine was on fire as noted from the cabin but not reported to him by the cabin crew.. The captain shut-down the right-hand engine on the wrong assumption that it was the cause of the air system smoke he was experiencing in the cockpit. He was never told during a recent variant upgrade technical conversion course that, on the mark of B737 he was now flying, cockpit air was supplied from both engines. The left engine disintegrated soon after and the aircraft crashed short of the airfield, at night and with no engines running, due to this avoidable breakdown in communications.

The change from hybrid electro-mechanical instruments to LED displays for engine indications had reduced conspicuity, particularly in respect of the engine vibration indicators. No additional vibration alerting system was fitted that could have highlighted to the pilots which of the two engines was vibrating excessively, which did not help. Although the cause of the accident was the shutting down of the wrong engine, had the cabin crew made the pilots aware of what they had seen, the serviceable engine might have been restarted in time to avoid an accident that raises many questions, not the least of which is training.

THE QUICK REFERENCE MANUAL (QRM)

Normal Operations and Quick Reference Manual checklists and drills are produced by the Aircraft Manufacturer. It is the manufacturer’s responsibility to ensure they remain up-to-date in the light of experience from both normal flight operations and by using feedback from incidents or accidents.
Operators cannot change anything within them without the total agreement of the Manufacturer and the express permission of the Certifying Regulatory Authority.

Both QRM and Normal operations drills do not include such sundry items as selecting Fasten Seat Belts or No Smoking signs to ON or OFF for example. Such entries are for the operator to place at a suitable point in the checklist, to satisfy the in-house Standard Operating Procedure (SOP). Before an Operator can change a published sequence, the Manufacturer needs to amend the Aircraft Flight Manual with the Approval of the Regulatory Authority.

Using an old but good set of now out-of-date manuals for illustration as pictured below, ‘Normal’ checklists could be usefully printed in a Black sans-serif font on white card, to differentiate them from Quick Reference Manual (QRM) pages with Emergency and Abnormal drills that are best printed in a Black sans-serif font on a yellow background for optimum legibility and on stout cards for durability. There are differences of opinion in Academic circles as to what combination offers most contrast but it is felt that black on yellow may be best in difficult light conditions. However, some operators and manufacturers use white paper for QRMs to allow for colour they consider shows-up better against a white background. To illustrate, a sample checklist with colour on a white background is given as one of three examples at the end of this Appendix. Words in red and ochre may cause reading difficulty in some lighting, therefore care is needed when choosing colour of both print and paper. QRM and normal checklist cards should be ring-bound for ease of folding-over, to hold with one hand while using the thumb as a cursor to mark progress down a page.

A QRM should also contain a logical index by which the appropriate drill can be quickly located. Precious time can be lost if the mechanics of using the drill cards is not crew user friendly. Note the QRM thumb-index illustrated and an example of another, this time a two-card QRM contents listing, as also shown after the end of these recommendations, to illustrate what a good alternative QRM index could be. The manufacturer and the Certifying Regulatory Authority will determine the “Logical Index”, taking into consideration the risk levels associated with any kind of emergency situation. Historically, engine fires were the ‘Number One’ risk but these have been superseded statistically by Smoke of unknown origin.

While the contents and sequences within all checklists remain the manufacturer’s responsibility, QRM production, distribution and amendment control are the responsibility of the Operator who should ensure that each ‘aircraft set’ is identical, functional and serviceable for use. They are a critical component of the Aircraft Library, especially where such developments as Electronic Flight Bag are in place. Where these cards are stored and their method of use, are competencies that operators and their flight crews will need to develop and maintain. The on-board library ‘Change-management’ strategy should be robustly audited and rigorously enforced.

When checking the aircraft library before taking over an aircraft, it is essential that a confirmatory verification is made by the operating crew, that all volumes of the operations manual on-board library, including checklists and the QRM, are the correct ones for the aircraft type and variant
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

about to be flown. Such checklists and QRMs must be stowed within easy reach of each pilot, for immediate use in the event of an electrical failure or malfunction of the displays. During flight, there should be no need to look for them in the technical volumes of the operations manual. This check is particularly important on glass-cockpit aircraft, because hard copies of the checklist are the final fallback on in an emergency.

EMERGENCY PASSENGER EVACUATION DRILL

Particular attention is drawn to the last recommendations in CAP 676 (see Appendix 5) regarding the Emergency Evacuation drill which should either be the very last QRM drill, or on the cover (perhaps outside the front or back cover) of the QRM and/or on a separate quick access card. Rejected take-off and overrun drills should also be easily found. They should be located near the evacuation drill on a cover of the Handbook for ease of rapid retrieval and immediate availability, maybe inside the front or back cover of the QRM. Similarly, the In-flight Decompression Emergency Descent drill should also be easily located for immediate reference.

The Emergency Evacuation Drill should be carried out simultaneously by all flight deck operating crew-members, initially from Memory. However the flight deck crew MUST then use the checklist on the QRM cover, to confirm individually that all necessary actions have been carried out.

Consideration should be given to the sequence of actions and who does what. Whenever possible, and if feasible, the parking brake needs to be set, the spoilers returned flush with wing and the flap selected to optimum for use to slide off the wing if close to the ground. The Start / Fuel levers must then be selected to Cut-off to stop all live engines and the APU shut down if running (where fitted). When no structural damage has occurred, the aircraft must also be depressurized before the evacuation is initiated and ATC informed of the evacuation where practicable. Finally, the master battery switch should be selected to OFF before the flight deck is vacated.
Smell smoke? Better land NOW as the three gentlemen did. They were piloting this UPS DC-8-70 from Atlanta to Philadelphia, at around midnight on 8 February 2006.

Crew first smelled smoke twenty-three minutes prior to scheduled landing and declared an emergency. The SMOKE/FIRE warning light illuminated three minutes prior to landing. Aircraft burst into flames upon emergency landing in Philadelphia. The crew evacuated through cockpit windows using escape ropes. They were examined for smoke inhalation and released. It was a total hull loss with zero reportable injuries. Two known pieces of HAZMAT were on board: amyl methyl-ketone and tire repair kits. These guys did a brilliant, by-the-book job of saving their own lives. Note that the Captain elected to stop on the runway to allow fully unrestricted access to rescue and fire fighting equipment.
INTEGRATED SMOKE, FIRE OR FUMES DRILL STEPS BASED ON THE ‘FSF’ TEMPLATE

An integrated Smoke, Fire & Fumes drill for a ‘generic’ aircraft is presented on the pages that follow. The checklist is in accordance with broad FSF Template guideline steps, using UK CAA CAP 676 and NASA checklist layout parameters and FOG recommendations. It is laid out in numbered steps on yellow pages. The same drill is then presented again, the second time using arrows for Navigation and the third time, using colour on a white background for comparison. Points to note in particular are:

- This Emergency Drill should be printed in Black letters on Yellow card, like all other QRM drills.
- Some operators and manufacturers use white paper for QRMs to allow use of colour that they consider shows up better against a white background.
- The font is a plain Sans Serif Arial, set at 12+ points for improved legibility in smoke.
- ‘Boxed’ memory items are carried out by crew members as shown (Steps 1 to 6 and 68.1 to 68.12).
- Memory items should always be followed by reading/using the checklist for confirmation.
- The dots leading to responses are interspaced with blanks to reduce clutter.
- There is a space of 6 points above each line for clarity & separation of instructions.
- The 20mm margin allows the thumb to be used as a cursor.
- It shows precisely where to look for any other drill that needs to be carried out at a given step.
- It shows that the drill continues overleaf at the bottom of each page. A prominent self-evident arrow pointing downwards might also be used to indicate the drill continues on the next page.
- It shows when the drill ends.
- Every page clearly indicates the aircraft type and the drill name.
- The aircraft type and drill name is repeated overleaf to show it is a continuation of the previous page.
- **Aircraft Series** (100, 200, 700, etc.,) or Marks (Mk1, M2, Mk3, etc.,) and any **Engine Variants** must be clearly identified at the top of the page of every checklist with the **Drill Name**, so that only correct documents are placed in the relevant aircraft’s library when changes due to amendments occur. Clearly captioned pages are best used on the preferred yellow paper for all QRMs.
- Where a decision must be made leading to a choice of actions, an unambiguous question should allow a simple YES or NO answer, each leading to the necessary move. YES an NO remain in the same relative position to one another throughout the drill. If answer YES comes first, then it remains so throughout the checklist.
- ‘Question’ blocks are clearly separate from preceding and following text for clarity.
- Abbreviations such as Lt or Rt are not used. To prevent misreading, words are spelled-out, for example, Left and Right.
- The drill includes an early step which directs the crew to a possible source of smoke or fumes for appropriate actions.
- The drill also requires that an after-landing emergency passenger evacuation strategy be agreed with the cabin crew at an early stage of the descent before landing.
- As an example of a FULLY INTEGRATED checklist, it includes all items required all the way to landing and for any subsequent evacuation, so that no other checklist is necessary once this one is commenced; except for the heavy/dense smoke & fumes removal / evacuation drill that immediately follows it in the QRM.
- Once the Smoke/Fumes removal drill is commenced and the aircraft descended as indicated therein, the pilots are committed to an early landing. The last step of the **Dense/Heavy smoke/fumes removal** checklist reflects this.

The FSF philosophy template sequence is largely used in the generic checklist layout that follows. The drill is arranged in numbered steps. A different presentation using arrows to direct the reader to various other points in the checklist, is also offered in a second example.

The numbered steps example given in the following pages reflects the RAeS Flight Operations Group (FOG) checklist presentation philosophy and recommended practises. It uses guidelines based upon a previous FOG Specialist Document on Smoke and Fire Drills written in 1999, the latest FSF layout guidance template for Fire and Smoke drills or checklists and the UK CAA CAP 676 together with the NASA guidelines on the preparation of checklists.
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

(AIRCRAFT TYPE X – Series A/B – CF6 Engines)
SMOKE IN CABIN AND / OR FLIGHT DECK

Situation - Smoke, Fire, or Fumes are present
Objective - Extinguish source of smoke, fire, or fumes and plan to divert
Immediate Landing may be required

1. Oxygen masks (full-face) ............... ON, 100%, MIKE TO MASK ............... ALL
2. Smoke goggles (if not full-face mask) .... ON ........................................ ALL
3. Crew & Cabin intercommunications .... ESTABLISH .......................... ALL
4. Fly the Aircraft .......................... DECLARE WHO ....................... C
5. ATC communications ................... DECLARE EMERGENCY > MAYDAY CALL .. C
(on route frequency or 121.5 & code 7700 if needed)
6. Diversion for Landing .................. CONSIDER / INITIATE & REVIEW LATER .... C

THE NHP (Non Handling Pilot) NOW ACTIONS SMOKE, FIRE OR FUMES DRILL

7. Is Smoke/Fire cause directly obvious? YES ... > GOTO 8
7.1 NO ... CONSIDER LANDING ASAP > GOTO 11

8. If obvious/accessible & extinguishable FIGHT FIRE, & FULLY EXTINGUISH
9. Faulty Equipment ....................... ISOLATE & MONITOR FOR REST OF FLIGHT

10. Divert to Land to assess damage? YES ... LAND > USE NORMAL CHECKLIST
10.1 NO ... END > CANCEL EMERGENCY AND > RETURN TO NORMAL CHECKLIST

11. Is a ‘landing’ airport distant? ...... YES ... TRY TO FIND SMOKE SOURCE > GOTO 12
11.1 NO ... CONCENTRATE ON LANDING > GOTO 50

WARNING: Do not delay descent or diversion to find smoke source.
IF HEAVY/DENSE SMOKE or FUMES AT ANY TIME, RUN PAGE 4 DRILL THIS ORM THEN GOTO 50

12. If Suspected source of smoke is from CABIN or GALLEY .... GOTO 13
    If Suspected source of smoke is from AIR CONDITIONING ... GOTO 20
    If Suspected source of smoke is .......... ELECTRICAL ........ GOTO 34
    If Smoke source is UNKNOWN ............ LAND ASAP .......... GOTO 50

13. IF CABIN OR GALLEY EQUIPMENT SMOKE/FIRE IS SUSPECTED
14. Emergency exit light switch .......... ON

15. Is commercial switch installed .......... YES ... GOTO 16
15.1 NO ... GOTO 17

16. Commercial switch .................... OFF
17. Bus tie switch .......................... OFF
18. Generator 2 switch .................... OFF

END OF CABIN OR GALLEY EQUIPMENT SMOKE DRILL

19. Does smoke decrease? ................. YES ... END > (or LAND > use NORMAL C/L)
19.1 NO ... LAND ASAP - GOTO 50

DRILL CONTINUES ON NEXT PAGE OVERLEAF
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

(AIRCRAFT TYPE X – Series A/B – CF6 Engines)

SMOKE IN CABIN AND / OR FLIGHT DECK

20. IF AIR CONDITIONING SMOKE IS SUSPECTED
21. APU bleed switch .............................. OFF
22. Blower switch .................................. AUTO
23. Extract switch .................................. AUTO
24. Pack 1 switch ................................. OFF

25. Does smoke decrease? ...................... YES ... END > (or LAND > use NORMAL C/L)
25.1 NO .... GOTO 27

26. Pack 1 switch ................................. ON
27. Pack 2 switch ................................. OFF
28. Cargo heat aft isolation valve switch ... OFF

29. Does smoke decrease? ...................... YES ... END > (or LAND > use NORMAL C/L)
29.1 NO .... GOTO 31

30. If smoke persists Pack 2 switch ...... ON
31. Blower switch ................................ OVERRIDE
32. Extract switch ................................ OVERRIDE

END OF AIR CONDITIONING SMOKE DRILL

33. Does smoke decrease? ...................... YES ... END > (or LAND > use NORMAL C/L)
33.1 NO .... GOTO 50

34. IF ELECTRICAL OR AVIONICS SMOKE IS SUSPECTED
35. Shed AC BUS 1 as follows
35.1 GEN 2 ........................................ CHECK ON
35.2 ELEC page ..................................... SELECT
35.4 AC ESS FEED ................................. ALTN
35.5 GEN 1 .......................................... OFF
35.6 Smoke dissipation ......................... CHECK

36. Does smoke decrease? ...................... YES ... END > (or LAND > use NORMAL C/L)
36.1 NO .... GOTO 37

37. GEN 1 .......................................... ON
38. AC ESS FEED .................................. NORM
39. Shed AC BUS 2 as follows
39.1 GEN 1 ........................................ CHECK ON
39.2 ELEC page ..................................... SELECT
39.3 AC ESS FEED ................................. ALTN
39.4 BUS TIE ....................................... OFF
39.5 GEN 2 .......................................... OFF
39.6 Smoke dissipation ......................... CHECK

40. Does smoke decrease? ...................... YES ... END > (or LAND > use NORMAL C/L)
40.1 NO .... GOTO 41

DRILL CONTINUES ON NEXT PAGE
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

(AIRCRAFT TYPE X – Series A/B – CF6 Engines)
SMOKE IN CABIN AND / OR FLIGHT DECK

41. GEN 2 .............................. ON
42. BUS TIE .............................. ON
43. EMER ELEC GEN 1 LINE .............. OFF
44. EMER ELEC POWER .................. MAN ON
45. EMERGENCY CONFIGURATION ...... SET & OPERATING > APPLY ECAM DRILL
46. APU GEN .................................. OFF WHEN EMER GEN AVAILABLE
47. GEN 2 .............................. OFF
48. Cockpit Door Video LCD monitor ...... OFF
END OF ELECTRICAL OR AVIONICS SMOKE

49. Does smoke decrease? ................. YES ... END > (or LAND > use NORMAL Checklist)
49.1 NO ... GOTO 50

50. TOP OF DESCENT BEFORE APPROACH
51. Request Immediate Priority Landing ... CALL ATC
52. Cabin fans switch ....................... OFF
53. Blower switch ........................ OVERIDE
54. Extract switch ........................ OVERIDE
55. Galley / galley and cabin switch ...... OFF
56. Cabin signs ............................. ON
57. Crew Briefing ........................ COMPLETE
58. Cabin Crew (Via Intercom) ............ REVIEW EVACUATION AFTER LANDING
59. Pressurisation ......................... SET TO 3000 FEET AAL
60. Descent ................................. CHECK MSA & SET > THEN INITIATE

61. At 3000 FEET (10 Miles out) -- before landing gear extension
62. GEN 2 .............................. ON
63. Bus Tie switch ......................... AUTO
64. PRESSURISATION ...................... CHECK DEPRESSURISED / DEPRESSURISE
65. Cabin Crew Report ..................... RECEIVED
66. Cabin Crew Reminder .................. EVACUATE AFTER LANDING

67. APPROACH & LANDING CHECKS ...... ECAM ITEMS
67.1 Landing Gear ........................ DOWN by 1500 feet
67.2 Cabin Signs ........................... ON
67.3 Spoilers ............................... ARM
67.4 Flaps ................................. SET 3 or FULL
67.5 ECAM Memo .......................... NO BLUE, LANDING

68. PAX EVACUATION DRILL ............. ALL CREW SIMULTANEOUSLY,

| 68.1 TURN AIRCRAFT INTO WIND .......... BLOW FLAMES AWAY FROM EXITS ... C |
| 68.2 Brakes .............................. SET TO PARK ....................... C |
| 68.3 Spoilers ............................. IN ........................................ C |
| 68.4 Flaps ................................. SET 2 or 30° CHECK SET .......... C |
| 68.5 Engines .............................. CUT OFF .............................. C |
| 68.6 Evacuation ........................... ORDER & SIDE TO USE ............ C |
| 68.7 Pressurisation ...................... DEPRESSURISED / DEPRESSURISE .. F |
| 68.8 APU ................................. CONFIRM OFF ........................ F |
| 68.9 ATC .................................. INFORM EVACUATING, VHF BOX 1 ... F |
| 68.10 Battery Switch ...................... OFF ................................. F |
| 68.11 Evacuation checklist .............. READ THROUGH TO CONFIRM .... C/F |
| 68.12 EVACUATE ........................... GO .................................. ALL |

END OF CHECKLIST
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

(AIRCRAFT TYPE X – Series A/B – CF6 Engines)

HEAVY / DENSE SMOKE & FUMES EVACUATION

WARNING: Carry out this side after fire has been extinguished or smoke is so dense that it is an emergency in and of itself.

EMERGENCY DESCENT
1. FCU altitude (MSA/10,000 feet) ........... SET
2. Emergency Exits Lights ................. CONFIRM ON
3. FCU expedite switch .................... PUSH
4. Target speed ............................... CONFIRM (.80M/340KIAS)
5. Thrust ........................................ CONFIRM IDLE
6. Speed brakes ............................... EXTEND
7. ATC .......................................... ADVISE

SMOKE/FUMES REMOVAL
8. Cab Fans ................................. ON
9. Pack flow selector ....................... HIGH

When at MSA or at 10,000 feet (WHICHEVER IS HIGHER)
10. Packs 1 & 2 ................................. OFF
11. Cabin Pressure Mode ................. MANUAL
12. Manual Vertical Speed Control ....... FULL UP

When differential pressure is less than 1 PSI
13. Ram Air .............................. ON

14. KEEP FLIGHT DECK DOOR CLOSED

15. KEEP AIRFLOW TO MAXIMUM TO SUCK FUMES FROM FLIGHT DECK TOWARDS REAR OF THE AIRCRAFT

16. RETURN TO STEP 50 IN SMOKE & FIRE DRILL ON PREVIOUS PAGE (REVERSE OF THIS PAGE) AND PREPARE FOR LANDING

CHECKLIST COMPLETE
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

THE SAME CHECKLIST USING ARROWS FOR NAVIGATION INSTEAD OF STEP NUMBERS

(AIRCRAFT TYPE X – Series A/B – CF6 Engines)
SMOKE IN CABIN AND/OR FLIGHT DECK

Situation - Smoke, Fire, or fumes are present
Objective - Extinguish source of smoke, fire, or fumes and plan to divert
Immediate Landing may be required

Oxygen masks (full-face) ............ ON, 100%, MIKE TO MASK ............ ALL
Smoke goggles (if not full-face mask) .... ON .......................................... ALL
Crew & Cabin intercommunications .... ESTABLISH .......................... ALL
Fly the Aircraft ........................ DECLARE WHO .......................... C
ATC communications ................. DECLARE EMERGENCY > MAYDAY CALL < C
(on route frequency or 121.5 & code 7700 if needed)
Diversion for Landing ................. CONSIDER / INITIATE & REVIEW LATER < C

THE HNP (Non Handling Pilot) NOW ACTIONS SMOKE, FIRE OR FUMES DRILL
Is Smoke/Fire cause directly obvious? .... YES

If obvious/accessible & extinguishable ... FIGHT FIRE, & FULLY EXTINGUISH
Faulty Equipment ........................ ISOLATE & MONITOR FOR REST OF FLIGHT
Divert to Land (to assess damage)? ....... YES... LAND > USE NORMAL CHECKLIST
NO... END > CANCEL EMERGENCY THEN RETURN TO NORMAL CHECKLIST

Is a 'landing' airport distant? ........... YES... TRY TO FIND SMOKE SOURCE
NO... CONCENTRATE ON LANDING ASAP

WARNING: Do not delay descent or diversion to find the smoke source.
IF DENSE SMOKE AT ANY TIME, ACCOMPLISH PAGE 4 DRILL THIS QRM THEN LAND

1. If Suspected source of smoke is from ......... CABIN or GALLEY
2. If Suspected source of smoke is from ......... AIR CONDITIONING
3. If Suspected source of smoke is ............... ELECTRICAL
4. If Smoke source is UNKNOWN ............... LAND ASAP

1. IF CABIN OR GALLEY EQUIPMENT SMOKE/FIRE IS SUSPECTED
Emergency exit light switch .............. ON
Is commercial switch installed? .......... YES

Commercial switch ...................... OFF
Bus tie switch ............................ OFF
Generator 2 switch ...................... OFF
END OF (1) CABIN OR GALLEY EQUIPMENT SMOKE DRILL

DRILL CONTINUES ON NEXT PAGE OVERLEAF

2 3 4
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

(AIRCRAFT TYPE X= Series A/B – CF6 Engines)

SMOKE IN CABIN AND / OR FLIGHT DECK

Does smoke decrease? ........................................ YES . . END > (or LAND > use Normal Checklist)
NO . . . . LAND ASAP

2. IF AIR CONDITIONING SMOKE IS SUSPECTED
APU bleed switch ........................................... OFF
Blower switch .............................................. AUTO
Extract switch ............................................. AUTO
Pack 1 switch ............................................. OFF

Does smoke decrease? ........................................ YES . . END > (or LAND > use Normal Checklist)
NO . . .

↓
Pack 1 switch ............................................. ON
Pack 2 switch ............................................. OFF
Cargo heat aft isolation valve switch . . OFF

Does smoke decrease? ........................................ YES . . END > (or LAND > use Normal Checklist)
NO . . .

↑
If smoke persists Pack 2 switch . . . . . . . . . . ON
Blower switch ............................................. OVERRIDE
Extract switch ............................................. OVERRIDE
END OF (2) AIR CONDITIONING SMOKE DRILL

Does smoke decrease? ........................................ YES . . END > (or LAND > use Normal Checklist)
NO . . . . LAND ASAP

3. IF ELECTRICAL OR AVIONICS SMOKE IS SUSPECTED
Shed AC BUS 1 as follows
GEN 2 ....................................................... CHECK ON
ELEC page ................................................... SELECT
BUS Tie ..................................................... OFF
AC ESS FEED ........................................... ALTN
GEN 1 ....................................................... OFF
Smoke dissipation ......................................... CHECK

Does smoke decrease? ........................................ YES . . END > (or LAND > use Normal Checklist)
NO . . .

↑
GEN 1 ....................................................... ON
AC ESS FEED ........................................... NORM
Shed AC BUS 2 as follows
GEN 1 ....................................................... CHECK ON
ELEC page ................................................... SELECT
AC ESS FEED ........................................... ALTN
BUS TIE ..................................................... OFF
GEN 2 ....................................................... OFF
Smoke dissipation ......................................... CHECK

Does smoke decrease? ........................................ YES . . END > (or LAND > use Normal Checklist)
NO . . .

↓
DRILL CONTINUES ON NEXT PAGE
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

(AIRCRAFT TYPE X – Series A/B – CF6 Engines)

**SMOKE IN CABIN AND / OR FLIGHT DECK**

- **GEN 2**.............................. ON
- **BUS TIE**.............................. ON
- **EMER ELEC GEN 1 LINE**......... OFF
- **EMER ELEC POWER**.............. MAN ON
- **EMERGENCY CONFIGURATION**.... SET & OPERATING > APPLY ECAM DRILL
- **APU GEN**............................. OFF WHEN EMER GEN AVAILABLE
- **GEN 2**.............................. OFF
- **Cockpit Door Video LCD monitor** OFF
- **END OF (3) ELECTRICAL OR AVIONICS SMOKE**

Does smoke decrease?........... YES... END > (or LAND > use Normal Checklist)

---

**TOP OF DESCENT BEORE APPROACH**

- **Request Immediate Priority Landing**...... CALL ATC
- **Cabin fans switch**........................... OFF
- **Blower switch**............................... OVERRIDE
- **Extract switch**............................. OVERRIDE
- **Galley / galley and cabin switch**......... OFF
- **Cabin signs**.................................. ON
- **Crew Briefing**.............................. COMPLETE
- **Cabin Crew (Via Intercom)**.............. DISCUSS EVACUATION
- **Pressurisation**............................ SET TO 3000 FEET AAL
- **Descent**...................................... CHECK MSA & SET > THEN INITATE

At 3000 FEET (10 Miles out) -- before landing gear extension

- **GEN 2**.............................. ON
- **Bus Tie switch**............................ AUTO
- **PRESSURISATION**......................... CHECK DEPRESSURISED / DEPRESSURISE
- **Cabin Crew Report**..................... RECEIVED
- **Reminder**................................. EVACUATE AFTER LANDING

**APPROACH & LANDING CHECKS**...... ECAM ITEMS

- **Landing Gear**.......................... DOWN by 1500 feet
- **Cabin Signs**............................ ON
- **Spoilers**................................. ARM
- **Flaps**..................................... SET 3 or FULL
- **ECAM Memo**.............................. NO BLUE, LANDING

**PAX EVACUATION DRILL**........... ALL CREW SIMULTANEOUSLY

- **TURN AIRCRAFT INTO WIND**........... BLOW FLAMES AWAY FROM EXITS... C
- **Brakes**.................................. SET TO PARK... C
- **Spoilers**.................................. IN... C
- **Flaps**.................................. SET 2 or 30°, CHECK SET... C
- **Engines**.................................. CUT OFF... C
- **Evacuation**............................... ORDER & SAY SIDE TO USE... C
- **Pressurisation**.......................... DEPRESSURISED / DEPRESSURISE... F
- **APU**....................................... CONFIRM OFF... F
- **ATC**...................................... INFORM EVACUATING, VHF BOX 1... F
- **Battery Switch**.......................... OFF... F
- **Evacuation checklist**.................. READ THROUGH TO CONFIRM... C/F
- **EVACUATE**.............................. GO... ALL

**END OF CHECKLIST**
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

(AIRCRAFT TYPE X – Series A/B – CF6 Engines)

HEAVY SMOKE / FUMES EVACUATION

WARNING: Carry out this side after fire has been extinguished or smoke is so dense that it is an emergency in and of itself.

EMERGENCY DESCENT
FCU altitude (MSA/10,000 feet) ........... SET
Emergency Exits Lights ............... CONFIRM ON
FCU expedite switch ................. PUSH
Target speed .................................. CONFIRM (.80M/340KIAS)
Thrust .................................. CONFIRM IDLE
Speed brakes ...................... EXTEND
ATC .................................. ADVISE

SMOKE/FUMES REMOVAL
Cab Fans .................................... ON
Pack flow selector ..................... HIGH

When at MSA or at 10,000 feet (WHICHEVER IS HIGHER)
Packs 1 & 2 ................................. OFF
Cabin Pressure Mode ................... MANUAL
Manual Vertical Speed Control ...... FULL UP

When differential pressure is less than 1 PSI
Ram Air ..................................... ON

KEEP FLIGHT DECK DOOR CLOSED

KEEP AIRFLOW TO MAXIMUM TO SUCK FUMES FROM FLIGHT DECK TOWARDS REAR OF THE AIRCRAFT

RETURN TO SMOKE & FIRE DRILL ON PREVIOUS PAGE TO PREPARE FOR LANDING AND START BELOW THE ARROWED LINE:

TOP OF DESCENT BEFORE APPROACH

SMOKE EVACUATION DRILL COMPLETE

A repeat of the checklist on the last 4 pages follows but with coloured arrows for ease of navigation, to compare with the All Black example above and to adopt and adapt as seen fit.
THE SAME CHECKLIST USING COLOURED ARROWS FOR NAVIGATION ON WHITE PAPER

(AIRCRAFT TYPE X – Series A/B – CF6 Engines)

SMOKE IN CABIN AND / OR FLIGHT DECK

Situation - Smoke, Fire, or fumes are present
Objective - Extinguish source of smoke, fire, or fumes and plan to divert
Immediate Landing may be required

<table>
<thead>
<tr>
<th>Oxygen masks (full-face)</th>
<th>ON, 100%, MIKE TO MASK</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoke goggles (if not full-face mask)</td>
<td>ON</td>
<td>ALL</td>
</tr>
<tr>
<td>Crew &amp; Cabin intercommunications</td>
<td>ESTABLISH</td>
<td>ALL</td>
</tr>
<tr>
<td>Fly the Aircraft</td>
<td>DECLARE WHO</td>
<td>C</td>
</tr>
<tr>
<td>ATC communications</td>
<td>DECLARE EMERGENCY &gt; MAYDAY CALL</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>(on route frequency or 121.5 &amp; code 7700 if needed)</td>
<td></td>
</tr>
<tr>
<td>Diversion for Landing</td>
<td>CONSIDER / INITIATE &amp; REVIEW LATER</td>
<td>C</td>
</tr>
</tbody>
</table>

THE NHP (Non Handling Pilot) NOW ACTIONS SMOKE, FIRE OR FUMES DRILL

Is Smoke/Fire cause directly obvious? ...  YES

... NO .......

CONSIDER LANDING ASAP

If obvious/accessible & extinguishable ...
FIGHT FIRE, & FULLY EXTINGUISH

Faulty Equipment ...
ISOLATE & MONITOR FOR REST OF FLIGHT

Divert to Land (to assess damage)? ...
YES ...
LAND > USE NORMAL CHECKLIST

NO ...
END > CANCEL EMERGENCY THEN

RETURN TO NORMAL CHECKLIST

Is a ‘landing’ airport distant? ........ 
YES ....
TRY TO FIND SMOKE SOURCE

NO ...
CONCENTRATE ON LANDING ASAP

WARNING: Do not delay descent or diversion to find the smoke source.
IF DENSE SMOKE AT ANY TIME, ACCOMPLISH PAGE 4 DRILL THIS QRM THEN LAND

1. If Suspected source of smoke is from ...
CABIN or GALLEY

2. If Suspected source of smoke is from ...
AIR CONDITIONING

3. If Suspected source of smoke is ...
ELECTRICAL

4. If Smoke source is UNKNOWN ...
LAND ASAP

1. IF CABIN OR GALLEY EQUIPMENT SMOKE/FIRE IS SUSPECTED
Emergency exit light switch .............. ON

Is commercial switch installed? ....... YES

NO

Commercial switch ................. OFF

Bus tie switch ................... OFF

Generator 2 switch ................ OFF

END OF (1) CABIN OR GALLEY EQUIPMENT SMOKE DRILL > GOTO NEXT LINE

DRILL CONTINUES ON NEXT PAGE OVERLEAF

↓  2  3  4
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

(AIRCRAFT TYPE X – Series A/B – CF6 Engines)

SMOKE IN CABIN AND / OR FLIGHT DECK

Does smoke decrease?  . . . . . . . . . . . . . YES . . END > (or LAND > use Normal Checklist)
NO . . . LAND ASAP

2. IF AIR CONDITIONING SMOKE IS SUSPECTED

APU bleed switch . . . . . . . . . . . . . . . . . .  OFF
Blower switch . . . . . . . . . . . . . . . . . . . . AUTO
Extract switch . . . . . . . . . . . . . . . . . . . . AUTO
Pack 1 switch . . . . . . . . . . . . . . . . . . . . OFF

Does smoke decrease?  . . . . . . . . . . . . . YES . . END > (or LAND > use Normal Checklist)
NO . . .

Pack 1 switch . . . . . . . . . . . . . . . . . . . . ON
Pack 2 switch . . . . . . . . . . . . . . . . . . . . OFF
Cargo heat aft isolation valve switch . . OFF

Does smoke decrease?  . . . . . . . . . . . . . YES . . END > (or LAND > use Normal Checklist)
NO . . .

If smoke persists Pack 2 switch . . . . ON
Blower switch . . . . . . . . . . . . . . . . . . . . OVERRIDE
Extract switch . . . . . . . . . . . . . . . . . . . OVERRIDE

END OF (2) AIR CONDITIONING SMOKE DRILL > GOTO NEXT LINE

Does smoke decrease?  . . . . . . . . . . . . . YES . . END > (or LAND > use Normal Checklist)
NO . . .

3. IF ELECTRICAL OR AVIONICS SMOKE IS SUSPECTED

Shed AC BUS 1 as follows
GEN 2 . . . . . . . . . . . . . . . . . . . . . . . . . . . . CHECK ON
ELEC page . . . . . . . . . . . . . . . . . . . . . . . . SELECT
BUS Tie . . . . . . . . . . . . . . . . . . . . . . . . OFF
AC ESS FEED . . . . . . . . . . . . . . . . . . . . . . ALTN
GEN 1 . . . . . . . . . . . . . . . . . . . . . . . . . . . . OFF
Smoke dissipation . . . . . . . . . . . . . . . . . . CHECK

Does smoke decrease?  . . . . . . . . . . . . . YES . . END > (or LAND > use Normal Checklist)
NO . . .

GEN 1 . . . . . . . . . . . . . . . . . . . . . . . . . ON
AC ESS FEED . . . . . . . . . . . . . . . . . . . . NORM

Shed AC BUS 2 as follows
GEN 1 . . . . . . . . . . . . . . . . . . . . . . . . . CHECK ON
ELEC page . . . . . . . . . . . . . . . . . . . . . . . SELECT
AC ESS FEED . . . . . . . . . . . . . . . . . . . . . ALTN
BUS TIE . . . . . . . . . . . . . . . . . . . . . . . . OFF
GEN 2 . . . . . . . . . . . . . . . . . . . . . . . . . . OFF
Smoke dissipation . . . . . . . . . . . . . . . . . . CHECK

Does smoke decrease?  . . . . . . . . . . . . . YES . . END > (or LAND > use Normal Checklist)
NO . . .

DRILL CONTINUES ON NEXT PAGE
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

(AIRCRAFT TYPE X – Series A/B – CF6 Engines)

SMOKE IN CABIN AND / OR FLIGHT DECK

GEN 2 ................................................. ON
BUS TIE ........................................... ON
EMER ELEC GEN 1 LINE ................. OFF
EMER ELEC POWER ......................... MAN ON
EMERGENCY CONFIGURATION ........-set & operating > apply ECAM drill
APU GEN ........................................... OFF WHEN EMER GEN AVAILABLE
GEN 2 ................................................. OFF
Cockpit Door Video LCD monitor ........ OFF
END OF (3) ELECTRICAL OR AVIONICS SMOKE DRILL > GOTO NEXT LINE

Does smoke decrease ? ...................... YES .... END > (or LAND > use Normal Checklist)
NO . . .

TOP OF DESCENT BEFORE APPROACH
Request Immediate Priority Landing ....... CALL ATC
Cabin fans switch ......................... OFF
Blower switch ............................... OVERRIDE
Extract switch ............................. OVERRIDE
Galley / galley and cabin switch ....... OFF
Cabin signs ................................. ON
Crew Briefing ............................... COMPLETE
Cabin Crew (Via Intercom) ............... DISCUSS EVACUATION
Pressurisation ............................. SET TO 3000 FEET AAL
Descent ............................. CHECK MSA & SET > THEN INITIATE

At 3000 FEET (10 Miles out) - - - before landing gear extension
GEN 2 ................................................. ON
Bus Tie switch ............................... AUTO
PRESSURISATION .......................... CHECK DEPRESSURISED / DEPRESSURISE
Cabin Crew Report ......................... RECEIVED
Reminder ............................... EVACUATE AFTER LANDING

APPROACH & LANDING CHECKS ...... ECAM ITEMS
Landing Gear ............................... DOWN by 1500 feet
Cabin Signs ................................. ON
Spoilers ................................ ARM
Flaps ..................................... SET 3 or FULL
ECAM Memo ............................... NO BLUE, LANDING

PAX EVACUATION DRILL .......... ALL CREW SIMULTANEOUSLY

| TURN AIRCRAFT INTO WIND ................ BLOW FLAMES AWAY FROM EXITS ........ C |
| Brakes ...................................... SET TO PARK ............................... C |
| Spoilers .................................... IN ........................................ C |
| Flaps ...................................... SET 2 or 30°, CHECK SET ............. C |
| Engines .................................... CUT OFF .................................. C |
| Evacuation ................................ ORDER & SAY SIDE TO USE ........... C |
| Pressurisation ........................... DEPRESSURISED / DEPRESSURISE .. F |
| APU ........................................ CONFIRM OFF ............................. F |
| ATC ........................................ INFORM EVACUATING, VHF BOX 1 ... F |
| Battery Switch ........................... OFF ....................................... F |
| Evacuation checklist .................... READ THROUGH TO CONFIRM ....... C/F |
| EVACUATE .................................... GO ..................................... ALL |
WARNING: Carry out this side after fire has been extinguished or smoke is so dense that it is an emergency in and of itself.

EMERGENCY DESCENT
FCU altitude (MSA/10,000 feet) .......... SET
Emergency Exits Lights ................. CONFIRM ON
FCU expedite switch .................... PUSH
Target speed ............................ CONFIRM (.80M/340KIAS)
Thrust .................................. CONFIRM IDLE
Speed brakes ............................ EXTEND
ATC ................................... ADVISE

SMOKE/FUMES REMOVAL
Cab Fans ................................ ON
Pack flow selector ....................... HIGH

When at MSA or at 10,000 feet (WHICHEVER IS HIGHER)
Packs 1 & 2 .............................. OFF
Cabin Pressure Mode .................... MANUAL
Manual Vertical Speed Control ........... FULL UP

When differential pressure is less than 1 PSI
Ram Air ................................. ON

KEEP FLIGHT DECK DOOR CLOSED
KEEP AIRFLOW TO MAXIMUM TO SUCK FUMES FROM FLIGHT DECK TOWARDS REAR OF THE AIRCRAFT

RETURN TO SMOKE & FIRE DRILL ON PREVIOUS PAGE TO PREPARE FOR LANDING AND START BELOW THE ARROWED LINE:

TOP OF DESCENT BEFORE APPROACH

SMOKE EVACUATION DRILL COMPLETE
APPENDIX 5

RECOMMENDATIONS FOR THE PRESENTATION OF CHECKLISTS

The recommendations contained in this Appendix are found in the Executive Summary of the UK Civil Aviation Authority (CAA) Civil Aviation Publication CAP 676 and in Guidance on the Design, Presentation and Use of Emergency and Abnormal Checklists.

This Appendix also contains detailed guidance from NASA on the Typography of Flight Deck Documentation, to complement CAA advice for compilers of aircraft checklists.

Copies of both documents may be downloaded from the Internet in PDF format that is opened and read using Adobe Acrobat reader. Adobe 7.0 is a free programme that can be downloaded.

DOWNLOADING INSTRUCTIONS

1. CAA Publication CAP 676

To download a copy of CAP676,

In the address bar of your internet browser enter: http://www.caa.co.uk/docs/33/CAP676.PDF

A copy of the document should be displayed. Now select Save As in the File menu (top line of the screen, first caption) to save to a folder of your choice.

Alternatively,

Enter CAA CAP 676 in your search engine and click on Search/Find. An early entry in the list that comes up on the screen will be the document captioned CAP 676 - Guidelines for the Design and Presentation of Emergency and Abnormal Checklists. Click on this line to bring up the document. Select File then Save As (top line of the screen, first caption) and save to a folder of your choice (such as Checklists).

2. NASA Publications

2.1 On the Typography of Flight Deck Documentation

To download a copy of this paper, in the address bar of your internet browser enter:


A copy of the document should be displayed. Now select Save As in the File menu (top line of the screen, first caption) to save to a folder of your choice.


You may also want to refer to this report by the same Author, Asaf Degani and Earl L. Wiener of the University of Miami, Coral Gables, FL USA. It is on the subject of aircraft checklists.

To download a copy of this paper, in the address bar of your internet browser enter:


A copy of the document should be displayed. Now select Save As in the File menu (top line of the screen, first caption) to save to a folder of your choice.”
CAP 676 - EXECUTIVE SUMMARY ON CHECKLISTS PRESENTATION

Concern has been expressed that the potential for an accident or incident is increased by the pilot misinterpreting the checklist due to poor design.

The primary goal of this guidance is to improve Emergency and Abnormal Checklist usability in assisting the flight crew to manage and contain system faults and other situations that adversely affect flight safety. Additionally this CAP will assist all stakeholders involved in the design, presentation and use of Emergency and Abnormal Checklists to take account of best human factors principles within their processes.

It is the responsibility of both the aircraft manufacturer and aircraft operator to work together throughout the Emergency and Abnormal Checklist design, development and amendment process to ensure that optimum system configuration following a failure is assured commensurate with best operational practice.

In addition to providing process information in Chapters 2 through to 6 of this report, guidance is provided in the application of good human factors principles in the design of the checklist. This covers the physical structure, content and layout. A Checklist Audit Tool (CHAT) has been developed to allow Regulators, Manufacturers and Operators to review checklists against these design principles and thus be able to recognise a potentially error-prone checklist. The tool provides usability rationale, to support the design attributes which are contained in Chapter 7 of this report. CHAT is a stand-alone paper-based tool and is presented as part of the Executive Summary in the tables hereunder.

<table>
<thead>
<tr>
<th>Physical Characteristics</th>
<th>1.1 Document size</th>
<th>Is the size of the document appropriate to the stowage space available?</th>
<th>The checklist must be able to be stowed in an accessible location and easily retrieved in an emergency.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Can the document be used without interfering with the controls or obscuring the displays?</td>
<td>This check needs to be carried out on the flight deck. The document should be reduced in size if there is any interference or obscuration.</td>
<td></td>
</tr>
<tr>
<td>1.2 Binding</td>
<td>Can the document be opened through 360°?</td>
<td>Access to required page(s) needs to be accomplished without requiring the crew to hold the pages open. Thus ideally the checklist will be able to fold back on itself. Recommend change if this cannot be achieved.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can amendment pages be easily inserted?</td>
<td>Ring binders are recommended.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Is binding robust? – can it fall apart?</td>
<td>If the binding is loose, pages could be lost. Recommend change binding.</td>
<td></td>
</tr>
<tr>
<td>1.3 Cover</td>
<td>Is the cover robust to protect pages within?</td>
<td>If not, provide a heavier card cover</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Is the colour significantly different to minimise incorrect checklist selection?</td>
<td>The Emergency and Abnormal operation should be easy to distinguish. Recommend change colour of cover.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Is the cover easily distinguishable from the pages within?</td>
<td>If the checklist is folded back on a particular page when stowed it may not be easy to locate. Recommend change the colour or size.</td>
<td></td>
</tr>
<tr>
<td><strong>1.4</strong> Tabs and dividers</td>
<td>Are the tabs clearly identified? Tabs are used to assist in the location of drill.</td>
<td>If they are not clearly identified this will cause delay in finding the correct drill. Recommend change tab numbering to be consistent throughout document.</td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Are the tabs logically linked to the index?</td>
<td>If they are not logically linked this will cause delay in locating the correct drill. Recommend change tabs to provide logical linking (see CAP 676 Example 1, Appendix 3).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Are the tabs wide enough to place a thumb on?</td>
<td>If the tabs are too small access to the correct drill will be more difficult. Recommend changing the size of the tabs (see CAP 676 Example 1, Appendix 3).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Are the tabs and dividers consistent in colour?</td>
<td>Where colour coding has been used to discriminate drills the colour coding should be consistent. Recommend changing the colours of the tabs and dividers to maintain consistency.</td>
<td></td>
</tr>
<tr>
<td><strong>1.5</strong> Font type</td>
<td>Does the font type used provide clear differentiation between characters?</td>
<td>Difficulty in reading the text may cause errors to be made. Recommend sans serif fonts (without tails) such as Helvetica, Gill Medium or Arial fonts are used.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Is lower case with upper case initial letters used for blocks of text?</td>
<td>Research has shown that lower case text is easier to read than upper case (see CAP 676 Example 6, Appendix 3). Recommend change text to lower case. Upper case can be used for titles and attention getting warnings and alerts.</td>
<td></td>
</tr>
<tr>
<td><strong>1.6</strong> Print size</td>
<td>Is the checklist legible at arms’ length?</td>
<td>Text must be legible under all lighting conditions at arms length (approximately 600mm). Smaller text will cause eye fatigue and may not be legible particularly in low visibility conditions. Recommend increase font size until it is legible at 600mm.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Are the smoke procedures in large print? (Also consider any procedures that may be carried out under poor lighting conditions.)</td>
<td>Font size should be large to be legible in a smoke filled cabin. Recommend increase size of font.</td>
<td></td>
</tr>
<tr>
<td><strong>1.7</strong> Margins</td>
<td>Does the binder obscure any of the text?</td>
<td>The binding should not hide the text. Recommend changing margin to typically 19mm.</td>
<td></td>
</tr>
<tr>
<td>1.8</td>
<td><strong>Emphasis and differentiation</strong></td>
<td>Are similar action items on the checklist clearly differentiated?</td>
<td>Similar lines of text could result in an action item being missed. Recommend highlighting the difference in the sentence using bold type.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>1.9</td>
<td><strong>Contrast and colour</strong></td>
<td>Has black text on a white or yellow background been used?</td>
<td>Coloured backgrounds provide a poor contrast ratio, which is difficult to read. Recommend using white or yellow background. If other colours are used check legibility under low ambient lighting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Is all the text in black?</td>
<td>Coloured text is difficult to read particularly under low ambient lighting conditions and should be avoided. Recommend changing coloured text back to black. Alert cues may be coloured (see 2.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>When the Emergency and Abnormal procedures are in the Operating Manual are the pages distinguished from the main drills?</td>
<td>It is important to be able to quickly and accurately locate the correct drill. Recommend using colour tabs – red for emergency and amber for abnormal procedures.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Where colour shading has been used to discriminate actions or notes, is there sufficient contrast between the text and background?</td>
<td>Colour shading provides a good method of discrimination but must be used with care. Recommend the use of pastel colours (low saturation) for shading.</td>
</tr>
<tr>
<td>1.10</td>
<td><strong>Contents list and index</strong></td>
<td>Does the checklist have a tabbed content list at the beginning of the checklist?</td>
<td>The checklist is unusable without a contents list. Recommend adding a contents list (see CAP 676 Appendix 3, Example 1).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Does the contents list clearly identify the sub-systems?</td>
<td>The pilots should be trained to know in which sub-system the fault has occurred. Recommend clearly listing each sub-system (see CAP 676 Appendix 3, Example 1).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Are critical drills highlighted in the index?</td>
<td>The critical drills need to be attended to very rapidly. Recommend highlighting in some manner to make these drills easier to find. Alternatively put the critical drills at the top of the index.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Does the checklist have an index of all fault captions covered in the checklist?</td>
<td>An alphabetical index will provide a quick route to the correct drill particularly when the Pilot is unfamiliar with the fault and does not know which sub-system to try first. Recommend including an alphabetical index.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Is there a contents list at the beginning of each sub-system section of the checklist?</td>
<td>Lack of a list can make the checklist unusable. Recommend putting an index at the beginning of each sub-system section.</td>
</tr>
</tbody>
</table>
### 1.11 Numbering

<table>
<thead>
<tr>
<th>Problem</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within each sub-system section do the page numbers correspond to the tab numbers?</td>
<td>Lack of numbering, incorrect or confusing numbering can make the checklist unusable. Recommend numbering each page in correspondence with the tab number or other logical manner.</td>
</tr>
<tr>
<td>Is the number clearly identified on the page?</td>
<td>Lack of a page number can make the checklist unusable. Recommend putting the number at the bottom or top of the page. Large font size is recommended.</td>
</tr>
<tr>
<td>Are actions consecutively numbered in the drill?</td>
<td>Research has shown that numbering actions assists in place keeping. Recommend consideration be given to numbering actions.</td>
</tr>
</tbody>
</table>

### Checklist Content

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.1 Structure</strong></td>
<td>Have the number of action items been minimised to take account of time available to complete the drill? For example, landing gear problems are likely to be discovered when fuel is low.</td>
</tr>
<tr>
<td></td>
<td>It is essential that the minimum number of actions be carried out to establish a safe aircraft state. Consider carefully whether diagnostic actions that attempt to eliminate the source of the problem are essential when there are likely to be time constraints.</td>
</tr>
</tbody>
</table>

| **2.2 Checklist Instructions** | Is a set of notes outlining the checklist coding philosophy contained in the checklist? |
| | The notes should detail the coding and presentation philosophy used throughout the checklist. Recommend including instructions in the checklist or providing easy access to the instructions in the documentation suite. |
| | Do they adequately describe the presentation and philosophy principles used in the checklist? |
| | The notes should provide explicit details on how to interpret the information contained within the checklist. They should also define terminology such as *land as soon as possible* and *land as soon as practicable*. |

| **2.3 Title** | Is a title prominently displayed at the start of each drill? |
| | Lack of a title will make the checklist unusable. The drill must have a title (see CAP 676 Appendix 3, Examples 2 and 4). |
| | Does the title fully reflect the failure condition? |
| | A misleading title could result in the incorrect drill being carried out. An unambiguous and practical title should be used (see CAP 676 Appendix 3, Examples 2 and 4). |
| | Is the title completely distinguishable from the rest of the drill? |
| | The title must stand out from the action items and notes on the drill. Recommend using a method like boxing and/or bold font (see CAP 676 Appendix, 3 Examples 2 and 4). |
### 2.4 Failure condition

<table>
<thead>
<tr>
<th>Does the checklist contain a description of the failure Condition(s)?</th>
<th>A repeat of the warning captions and failure states provides a useful confirmation that the correct checklist has been selected. Recommend including a description of the failure conditions (see CAP 676 Appendix 3, Examples 2 and 4).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the checklist contain an illustration of the alerting trigger captions?</td>
<td>A repeat of the warning captions in the checklist (using the same colour as it appears on the flight deck) provides a useful confirmation that the correct checklist has been selected. Recommend including an illustration of the relevant warning captions (see CAP 676 Appendix 3, Examples 2 and 4).</td>
</tr>
</tbody>
</table>

### 2.5 Objective

<table>
<thead>
<tr>
<th>Does the checklist contain an objective?</th>
<th>An objective statement serves as a useful confirmation that the correct checklist has been selected and the expected outcome of the drill. Recommend including an objective statement where appropriate in the checklist (see CAP 676 Appendix 3, Example 4).</th>
</tr>
</thead>
</table>

### 2.6 Memory items

<table>
<thead>
<tr>
<th>Are the memory items listed at the beginning of the drill?</th>
<th>Memory items should be carried out first and verified on the checklist. When they exist they must be the first set of action items.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are the memory items clearly distinguished from the other action items?</td>
<td>It is recommended that the memory items be distinguished in some fashion – boxing, shading, line marking, numbering (M1, M2), etc.</td>
</tr>
</tbody>
</table>

### 2.7 Cautionary Notes

<table>
<thead>
<tr>
<th>Are cautionary notes clearly discriminated on the checklist?</th>
<th>Cautionary notes highlight resultant performance constraints and should be differentiated from ordinary explanatory notes. It is recommended that appropriate colour shading highlights caution notes. Ideally they should be accompanied by the word 'caution'.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are the cautionary notes printed above the action item that they relate to?</td>
<td>It is essential that the crew are aware of the implications of any action item before they carry it out. Recommend moving the cautionary note to precede the action that it relates to.</td>
</tr>
</tbody>
</table>

### 2.8 Action items

<p>| Are the action items distinguishable from the notes in the checklist? | It is important to identify the ‘do’ list items in the list. Recommend that they are distinguished from other items in checklist (e.g. text font size, font type or bold font are potential candidates). |</p>
<table>
<thead>
<tr>
<th><strong>2.9 Explanatory Notes</strong></th>
<th><strong>Are the explanatory notes clearly distinguished from action items?</strong></th>
<th>The notes should not clutter the action items. It is recommended that they are visually distinguishable.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Are the notes complete in terms of providing all the operating Instructions necessary to perform the action item?</strong></td>
<td>Missing information relating to control operation (e.g., force required or number of detents) has caused problems in the past. It is recommended that all necessary information associated with control operation be provided.</td>
</tr>
<tr>
<td></td>
<td><strong>Are the notes linked to the action item that they relate to?</strong></td>
<td>It is essential that the notes either precede or follow the action item. It is recommended that notes are Consistently placed close to the action items that they refer to.</td>
</tr>
</tbody>
</table>

| **2.10 Decision items** | **Are conditional steps clearly laid out?** | An error – prone situation exists with complicated conditional statements particularly when action items are embedded within them. It is recommended that decision items are discriminated either by using special bullets or line marking or choice directives (see CAP676 Appendix 3, Examples 2 and 4). |

| **2.11 Review of System status** | **Is a review of system status and operational capability provided on the checklist?** | A system status review provides the crew with diagnostic information regarding system capability. They are useful in dealing with a failure situation, which cannot be rectified. It is recommended that consideration be given to including a table or list detailing system failures and alternate operational capability in the checklist (see CAP 676 Appendix 3, Example 5). |

<p>| <strong>Are the ‘read’ and ‘do’ items clearly linked?</strong> | The items should be linked to avoid the possibility of associating the wrong challenge and response. Recommend using dots or dashes to link challenge and response items (see CAP 676 Appendix 3, Examples 2 and 4). |
| <strong>Are the critical items (e.g., actions resulting in the de-activation of the flight controls) discriminated?</strong> | Critical items which could create a hazardous situation require positive verification by the monitoring crew-member and therefore it is important that these actions are clearly Discriminated from other action items. Recommend changing presentation of critical items to provide discrimination. |</p>
<table>
<thead>
<tr>
<th><strong>2.12 Deferred items</strong></th>
<th>Are deferred items clearly identified?</th>
<th>Actions, which will be carried out at a later phase of flight, should be at the end of the checklist and should be clearly labelled. It is recommended that a label such as ‘deferred item’ precede the final deferred action items (see CAP 676 Appendix 3, Example 5).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Are they grouped accordingly?</td>
<td>Deferred items are easier to use if they are clearly grouped according to phase of flight or an environmental condition. It is recommended that grouping techniques are used.</td>
</tr>
<tr>
<td></td>
<td>Is there sufficient information to carry out the deferred step?</td>
<td>When returning to a checklist to carry out items that have been deferred it is necessary to recall the system deficiencies and carry out the actions correctly. To aid recall it is recommended that ‘do’ actions be spelt out explicitly.</td>
</tr>
<tr>
<td><strong>2.13 Crew responsible</strong></td>
<td>Where appropriate does the checklist indicate who is responsible for carrying out the drill?</td>
<td>The instructions should indicate who is responsible for carrying out the drill but if this changes for any of the drills it should be specifically stated as to who is responsible for specific actions.</td>
</tr>
</tbody>
</table>

### Layout and Format

<table>
<thead>
<tr>
<th><strong>3.1 Drills per page</strong></th>
<th>If the drill runs onto a second page is it split at a logical place in the drill?</th>
<th>Drills should be split into logical sections and the logical sections should not be split at a page break as it impacts continuity of the drill.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.2 Start and finish</strong></td>
<td>Does the drill have a clearly defined start?</td>
<td>The drill will be unusable if it is not clear where the drill starts. It must have a clearly defined start.</td>
</tr>
<tr>
<td></td>
<td>Does the drill have a defined end?</td>
<td>The end of drill must be indicated with an ‘end of xxx drill’ indication or graphical equivalent (see CAP 676 Appendix 3, Examples 2 and 4).</td>
</tr>
<tr>
<td></td>
<td>Are the end of drill indications provided in every place on the drill where it is complete, including decision steps?</td>
<td>The end of drill must be included at all places in the drill when it is complete (see CAP 676 Appendix 3, Example 2).</td>
</tr>
<tr>
<td><strong>3.3 Continuation pages</strong></td>
<td>Is it clear when the drill continues onto another page?</td>
<td>The drill may not be completed if it is not clear that it continues onto another page. It is recommended that a clear indication be provided at the bottom of the page and top of the continuing page (see CAP 676 Appendix 3, Examples 4 and 5).</td>
</tr>
<tr>
<td><strong>3.4 Order</strong></td>
<td>Does the order of the action items ensure that the failure is fixed at the earliest opportunity?</td>
<td>The design of the drill must ensure that priority items, i.e. those that will deal with the fault in the most time-efficient way, are in the appropriate order.</td>
</tr>
</tbody>
</table>
### 3.5 Cross-referencing

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where cross-referencing is used within a drill is it clear as to which step should be carried out?</td>
<td>An error-prone situation exits with internal cross-referencing if it is not clear which step it refers to. It is recommended that the use of cross-referencing is minimised and that steps are numbered when cross-referencing is used.</td>
</tr>
<tr>
<td>Where cross-referencing to other material is it clear which page and document it refers to?</td>
<td>It is not ideal to have to refer to other documents because it could result in the crew losing their place. However if it is necessary it is recommended that a place keeper symbol be used to aid return to the right place in the drill. It is also recommended that the document and page number if possible are clearly referenced.</td>
</tr>
</tbody>
</table>

### 3.6 Figures and tables

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are the figures and tables clearly linked to the drills they are associated with?</td>
<td>Errors will occur if the wrong figures or tables are referred to. It is recommended that the figures and tables should be clearly labelled to allow correct referencing.</td>
</tr>
<tr>
<td>Are the figures legible and usable?</td>
<td>Performance data contained in graphs will not be usable if the presentation is too small particularly in low visibility situations. Ensure that performance data is legible under operational conditions.</td>
</tr>
</tbody>
</table>

### 3.7 Abbreviations and consistency

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do all captions and labels used in the drill correspond exactly to the labels used on the flight deck?</td>
<td>It is essential that exact correspondence is achieved and any differences must be corrected.</td>
</tr>
<tr>
<td>Does the checklist identify clearly aircraft type, model, variant and modification state?</td>
<td>This could result in the wrong checklist or wrong drill being used. It is recommended that all checklists visually highlight any differences in variants relating to the drills. It is recommended that the checklist relate to the individual aircraft tail.</td>
</tr>
</tbody>
</table>

### 3.8 Special cases

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the emergency evacuation drill easy to locate?</td>
<td>It should be on the cover of the Emergency Checklist and/or on a separate quick access card.</td>
</tr>
<tr>
<td>Are the rejected take-off and overrun drills easy to locate?</td>
<td>They should be located on a cover of the Emergency Checklist.</td>
</tr>
</tbody>
</table>

### END of CAP 676 RECOMMENDATIONS

<table>
<thead>
<tr>
<th>Special cases</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are necessary follow-on drills clearly identified and referred to in primary drills used after an ‘event’?</td>
<td>Drills that need to be run after the one for a particular failure or situation, must be named clearly. The page on which a particular checklist can be found, has to be clearly stated at the relevant point or end of the primary drill.</td>
</tr>
<tr>
<td>Sometimes one or two additional drills need to be carried-out after an abnormal situation checklist is run, to deal with consequential matters.</td>
<td></td>
</tr>
</tbody>
</table>
NASA REPORT ON THE TYPOGRAPHY OF FLIGHT-DECK DOCUMENTATION,

by Asaf Degani of the San Jose State University Foundation, San Jose, California. This NASA document was prepared in December 1992 for the National Aeronautics and Space Administration, Ames Research Center, Moffett Field, California 94035-1000, under Contract NCC2-327.

List of Design Recommendations (Extract)

This section lists together all the design recommendations from the previous sub-sections. These recommendations are not specifications. They only form a baseline, which is based exclusively on the author’s subjective interpretation of the data. Each recommendation should be carefully evaluated by the designer based on the type of documentation, usage, criticality, and the target population. The recommendations are listed according to the order of sections in the report (subsection numbers are given in parenthesis):

1. Sans-serif fonts are usually more legible than fonts with serifs (3.2)
2. Avoid using a font that has characters that are too similar to one another, as this will reduce the legibility of the print. (3.2)
3. Avoid using dot matrix print for critical flight-deck documentation. (3.2)
4. Long chunks of text should be set in lower case. (3.3)
5. If upper case is required, the first letter of the word should be made larger in order to enhance the legibility of the word. (3.3)
6. When specifying font height, or accessing graphs to determine the size of a lower-case character, the distinction between "x" height and overall size should be made. (3.4)
7. As a general recommendation, the "x" height of a font used for important flight-deck documentation should not be below 0.10 inch. (3.4)
8. The recommended height-to-width ratio of a font that is viewed in front of the observer is 5:3. (3.5)
9. The vertical spacing between lines should not be smaller than 25-33% of the overall size of the font. (3.6)
10. The horizontal spacing between characters should be 25% of the overall size and not less than one stroke width. (3.6)
11. Avoid using long strings of text set in italics. (3.8)
12. Use primarily one or two typefaces for emphasis. (3.8)
13. Use black characters over a white background for most cockpit documentation. (3.9)
14. Avoid using white characters over a black background in normal line operations (3.9). However, if this is desired:
   a.. Use minimum amount of text.
   b.. Use relatively large type size.
   c. Use sans-serif to minimize the loss of legibility.
15. Black over white or yellow are recommended for cockpit documentation. (3.10)
16. Avoid using black over dark red, green, and blue. (3.10)

17. Use anti-glare plastic to laminate documents. (4.1)

18. Ensure that the quality of the print and the paper is well above normal standards. Poor quality of the print will effect legibility and readability. (4.3)

19. The designer must assess the age groups of the pilots that will be using the documentation, and take a very conservative approach in assessing information obtained from graphs and data books. (4.4)

End of NASA recommendations on typography
APPENDIX 6

UNITED KINGDOM UK CAA GUIDANCE
AERONAUTICAL INFORMATION CIRCULAR
AIC 131/199 (Pink 203)

THE NEED TO AVOID DELAY WHEN AN IMMEDIATE LANDING APPEARS NECESSARY

1 Introduction

1.1 When faced with a situation in which it is evident that a flight cannot continue as planned, the commander will first have to decide whether some delay before landing is acceptable or whether the aircraft should be landed - safely - as soon as possible.

1.2 If the circumstances are such that an immediate landing does not appear necessary, the commander will most likely have sufficient time to select an airfield that best suits his requirements and then plan for the descent, approach and landing without experiencing undue pressure. However, if the circumstances are such that an immediate landing does appear necessary, aiming to land at the nearest suitable airfield may bring with it problems that are unlikely to be faced in normal operations.

1.3 One such problem associated with a decision to land as soon as possible might be the prospect of landing overweight. For the crew, this should require little more than completing an appropriate checklist, confirming that the airfield intended to be used is suitable (having regard to the performance of the aircraft in the circumstances encountered), and taking extra care when flying the approach, landing and roll-out. Subsequently, appropriate entries will need to be made in the technical log, and an overweight inspection will have to be carried out by a person authorised to do so. The duration of the flight should not be prolonged unnecessarily by, for example, extending the track to overfly an area where the air traffic service provider would prefer excess fuel to be jettisoned.

2 Circumstances leading to early termination of the flight

2.1 In circumstances such as when there is failure of a navigation system required for entry into prescribed airspace, or when the landing gear retraction sequence is not completed after take-off, an immediate landing will almost certainly not be necessary. At times like these the commander should be able to delay starting the approach whilst taking action to reduce the all-up mass of the aircraft below that certificated as the maximum for landing.

2.2 However, in circumstances such as when on-board smoke or fires are detected and cannot be contained, or in any situation where the ability of the aircraft to remain in controlled flight is in doubt, it is more likely that the commander will decide that the aircraft should be landed without delay. Although many checklists that have been designed to address such specific emergency situations as have been foreseen begin with words like, ‘Land as soon as possible’, there will inevitably be situations that were not envisaged when an immediate landing appears to the commander to be the correct course of action to take.

2.3 In any situation where the flight cannot continue as planned, the commander retains the right to decide which course of action is most appropriate. It is probable that he or she will take into account advice or guidance available from other members of the crew, from checklists and manuals, from operations control and maintenance staff, and from ATC.

3 Actions to be taken when an immediate landing appears necessary

3.1 After having completed essential emergency or abnormal checklists, briefing the crew and preparing the flight deck and cabin areas for landing will be amongst the foremost priorities. Quite possibly the first request the crew will make of the air traffic service provider will be to adjust the aircraft's heading
towards the airfield where they now wish to land. Flight crew can expect ATC to assist, but only when a
tformal emergency has been declared and the commander's intentions have been made known.

3.2 Unless the commander considers that the nature of the emergency is likely to lead to loss of control,
he should not attempt to diagnose the cause of the problem (assuming this is not evident) until the
aircraft is tracking towards the airfield where he intends to land, and all the essential descent, approach
and landing preparations have - as far as possible - been completed. Procedures should not be rushed
to the extent that the situation is exacerbated from causes not directly related to the emergency.

3.3 The key factor to be borne in mind when an immediate return to landing appears
necessary is to prioritise requirements dictated by the situation and to avoid wasting time
carrying out non-essential tasks, aiming to get the aircraft on the ground safely - without
delay.

3.4 Full details of procedures that should be used are published in AIC 51/1999 (Pink 192), which deals
with VHF RT emergency communications, and AIC 82/1999 (Pink 199), which addresses medical
emergencies.

This Circular is issued for information, guidance and necessary action.
### ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAC</td>
<td>Army Air Corps</td>
</tr>
<tr>
<td>AAT</td>
<td>Aircrew Aptitude Test</td>
</tr>
<tr>
<td>Ab Initio</td>
<td>Latin for “From the beginning”; as relating to Elementary Flying Training.</td>
</tr>
<tr>
<td>AC</td>
<td>Advisory Circular (FAA USA)</td>
</tr>
<tr>
<td>AD</td>
<td>Airworthiness Directive (FAA USA).</td>
</tr>
<tr>
<td>AFIC</td>
<td>Arc Fault Interrupter Circuit</td>
</tr>
<tr>
<td>AIC</td>
<td>Aeronautical Information Circular (UK CAA)</td>
</tr>
<tr>
<td>ALPA</td>
<td>The Air Line Pilot Association (USA)</td>
</tr>
<tr>
<td>AMC</td>
<td>Acceptable Means of Compliance</td>
</tr>
<tr>
<td>AME</td>
<td>Aviation Medical Examiner</td>
</tr>
<tr>
<td>ASAP</td>
<td>As Soon As Possible</td>
</tr>
<tr>
<td>ASR</td>
<td>Air Safety Report</td>
</tr>
<tr>
<td>ASRS</td>
<td>Aviation Safety Reporting System</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>ATC (RAF)</td>
<td>Air Training Corps (RAF)</td>
</tr>
<tr>
<td>ATCO</td>
<td>Air Traffic Control Officer</td>
</tr>
<tr>
<td>ATPL</td>
<td>Airline Transport Pilot Licence</td>
</tr>
<tr>
<td>BAe</td>
<td>British Aerospace Systems; (a UK Aerospace equipment manufacturer)</td>
</tr>
<tr>
<td>BAC</td>
<td>British Aircraft Corporation; predecessor of BAe</td>
</tr>
<tr>
<td>BALPA</td>
<td>British Air Line Pilots Association</td>
</tr>
<tr>
<td>BCF</td>
<td>Bromo-chloro-di-fluoromethane; Fire extinguishant gas (See Halon)</td>
</tr>
<tr>
<td>CAA</td>
<td>Civil Aviation Authority. UK National Aviation Regulatory body</td>
</tr>
<tr>
<td>CAP</td>
<td>Civil Aviation Publication (UK CAA)</td>
</tr>
<tr>
<td>CAR</td>
<td>Canadian Aviation Regulations</td>
</tr>
<tr>
<td>CCF</td>
<td>Combined Cadet Force</td>
</tr>
<tr>
<td>CFIT</td>
<td>Controlled Flight Into Terrain</td>
</tr>
<tr>
<td>CFR</td>
<td>Crash Fire Rescue</td>
</tr>
<tr>
<td>C/L</td>
<td>Check List</td>
</tr>
<tr>
<td>CPL</td>
<td>Commercial Pilot Licence</td>
</tr>
<tr>
<td>CRE</td>
<td>Class Rating Examiner</td>
</tr>
<tr>
<td>CRI</td>
<td>Class Rating Instructor</td>
</tr>
<tr>
<td>CRM</td>
<td>Crew Resources Management</td>
</tr>
<tr>
<td>CS</td>
<td>Certification Standard</td>
</tr>
<tr>
<td>CVR</td>
<td>Cockpit Voice Recorder</td>
</tr>
<tr>
<td>E&amp;E</td>
<td>Electronics and Equipment (bay)</td>
</tr>
<tr>
<td>EASA</td>
<td>European Aviation Safety Agency</td>
</tr>
<tr>
<td>EASA CS</td>
<td>European Aviation Safety Agency Certification Standard</td>
</tr>
<tr>
<td>ECAM</td>
<td>Electronic Centralised Aircraft Monitoring</td>
</tr>
<tr>
<td>ECL</td>
<td>Electronic Check List</td>
</tr>
<tr>
<td>EFIS</td>
<td>Electronic Flight Information System</td>
</tr>
<tr>
<td>EICAS</td>
<td>Engine Indication and Crew Alerting System</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>EVAS</td>
<td>Emergency Vision Assurance System</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration, USA National Aviation Regulatory body</td>
</tr>
<tr>
<td>FCL</td>
<td>Flight Crew Licensing</td>
</tr>
</tbody>
</table>
SMOKE, FIRE & FUMES IN TRANSPORT AIRCRAFT

FI  Flying Instructor
FMS  Flight Management System
FOG  Flight Operations Group; Royal Aeronautical Society, London
FRaE  Fellow of the Royal Aeronautical Society
FSF  Flight Safety Foundation (USA based); pursues the continuous improvement of
global aviation safety and the prevention of accidents.
FTO  Flying Training Organisation

GA  General Aviation
GAPAN  Guild of Air Pilots and Air Navigators
GASIL  General Aviation Safety Information Leaflet (UK CAA)
GCSE  General Certificate of Secondary Education
GCSE/S  General Certificate of Secondary Education / Scotland
GID  General Information Document (UK CAA)

H  Helicopter(s)
Halon  BCF; Fire extinguishant gas (Bromo-chloro-di-fluoromethane)
Halon 1211  BCF; Fire extinguishant gas (Bromo-chloro-di-fluoromethane)
HUD  Head Up Display

IATA  International Air Transport Association
ICAO  International Civil Aviation Organisation
IFE  In Flight Entertainment
IOT  Initial Officers Training
IPA  Independent Pilots Association
I/R  Instrument Rating
IRE  Instrument Rating Examiner

JAA  Joint Aviation Authority
JAA CS  Joint Aviation Authority Certification Standard
JAR  Joint Aviation Regulations
JAR/FCL1  JAA Flight Crew Licensing Requirements for Aeroplane pilots
JAR/FCL2  JAA Flight Crew Licensing Requirements for Helicopter pilots
JAR/FCL3  JAA Flight Crew Licensing Medical Requirements

LASORS  Licensing, Administration & Standardisation, Operating Requirements & Safety
(UK CAA Publication)
Letromec  An Electro-Mechanical Company (USA)
LMC  Last Minute Change
LOC  Loss Of Control

MCC  Multi Crew Co-operation
MD  McDonnell-Douglas; aircraft manufacturer, USA
MEL  Minimum Equipment List
Mike  Microphone
MITRE  USA-based Provider of Federally-funded Research & Development centres for the
DOD, FAA (Centre for Advanced Aviation Systems Development) and the IRS. Also
assists some overseas Government Agencies.
MPA  Multi-Pilot Aeroplane

NAA  National Aviation (Regulatory) Authority
NASA  National Aeronautics and Space Administration
NPRM  Notice of Proposed Rule Making
NPPL  National Private Pilot Licence
NTSB  (The) National Transportation Safety Board

Pan Am  Pan American World Airways
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBE</td>
<td>Protective Breathing Equipment</td>
</tr>
<tr>
<td>PIC</td>
<td>Pilot In Command</td>
</tr>
<tr>
<td>PLD</td>
<td>Personnel Licensing Department</td>
</tr>
<tr>
<td>PPL</td>
<td>Private Pilot Licence</td>
</tr>
<tr>
<td>PVR</td>
<td>Premature Voluntary Retirement (from one of the Military Services)</td>
</tr>
<tr>
<td>QFI</td>
<td>Qualified Flying Instructor</td>
</tr>
<tr>
<td>QRH</td>
<td>Quick Reference Handbook</td>
</tr>
<tr>
<td>QRM</td>
<td>Quick Reference Manual</td>
</tr>
<tr>
<td>RAeS</td>
<td>The Royal Aeronautical Society</td>
</tr>
<tr>
<td>RAF</td>
<td>Royal Air Force</td>
</tr>
<tr>
<td>RN</td>
<td>Royal Navy</td>
</tr>
<tr>
<td>SAFER</td>
<td>Special Aviation Fire and Explosion Reduction Advisory Committee (USA)</td>
</tr>
<tr>
<td>SEP</td>
<td>Safety Equipment and Procedures</td>
</tr>
<tr>
<td>SFE</td>
<td>Senior Flight Engineer</td>
</tr>
<tr>
<td>SFE</td>
<td>Synthetic Flight Examiner</td>
</tr>
<tr>
<td>SFF</td>
<td>Smoke, Fire and Fumes</td>
</tr>
<tr>
<td>SFI</td>
<td>Synthetic Flight Instructor</td>
</tr>
<tr>
<td>SOP</td>
<td>Standard Operating Procedures</td>
</tr>
<tr>
<td>SPA</td>
<td>Single Pilot Aeroplanes</td>
</tr>
<tr>
<td>SSR</td>
<td>Secondary Surveillance Radar; used in conjunction with airborne Transponders for recognition by way of an assigned discrete Code ‘Squawk’ such as A2345</td>
</tr>
<tr>
<td>STC</td>
<td>Supplemental Type Certificate</td>
</tr>
<tr>
<td>STEADES</td>
<td>Safety Trend Analysis, Evaluation And Data Exchange System</td>
</tr>
<tr>
<td>TRE</td>
<td>Type Rating Examiner</td>
</tr>
<tr>
<td>TRI</td>
<td>Type Rating Instructor</td>
</tr>
<tr>
<td>TRTO</td>
<td>Type Rating Training Organisation</td>
</tr>
<tr>
<td>TSO</td>
<td>Technical Standard Order</td>
</tr>
<tr>
<td>TWA</td>
<td>Trans World Airlines</td>
</tr>
<tr>
<td>UAS</td>
<td>University Air Squadron</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>URNU</td>
<td>University Royal Naval Unit</td>
</tr>
<tr>
<td>USA</td>
<td>United States of America</td>
</tr>
<tr>
<td>V1</td>
<td>Speed up to which take-off can be discontinued on a particular runway</td>
</tr>
<tr>
<td>Vr</td>
<td>Rotation Speed; speed at which the aircraft is lifted off the ground and into the air during the take-off run</td>
</tr>
<tr>
<td>V2</td>
<td>Minimum Safety speed after becoming airborne, for a given aircraft weight</td>
</tr>
<tr>
<td>Varig</td>
<td>Defunct Brazilian Airline</td>
</tr>
</tbody>
</table>

**TERMS**

Flight Crew  In this entire document, the term Flight Crew is meant to describe the flight deck crewmembers; as against cabin crewmembers/staff (passenger flight attendants)