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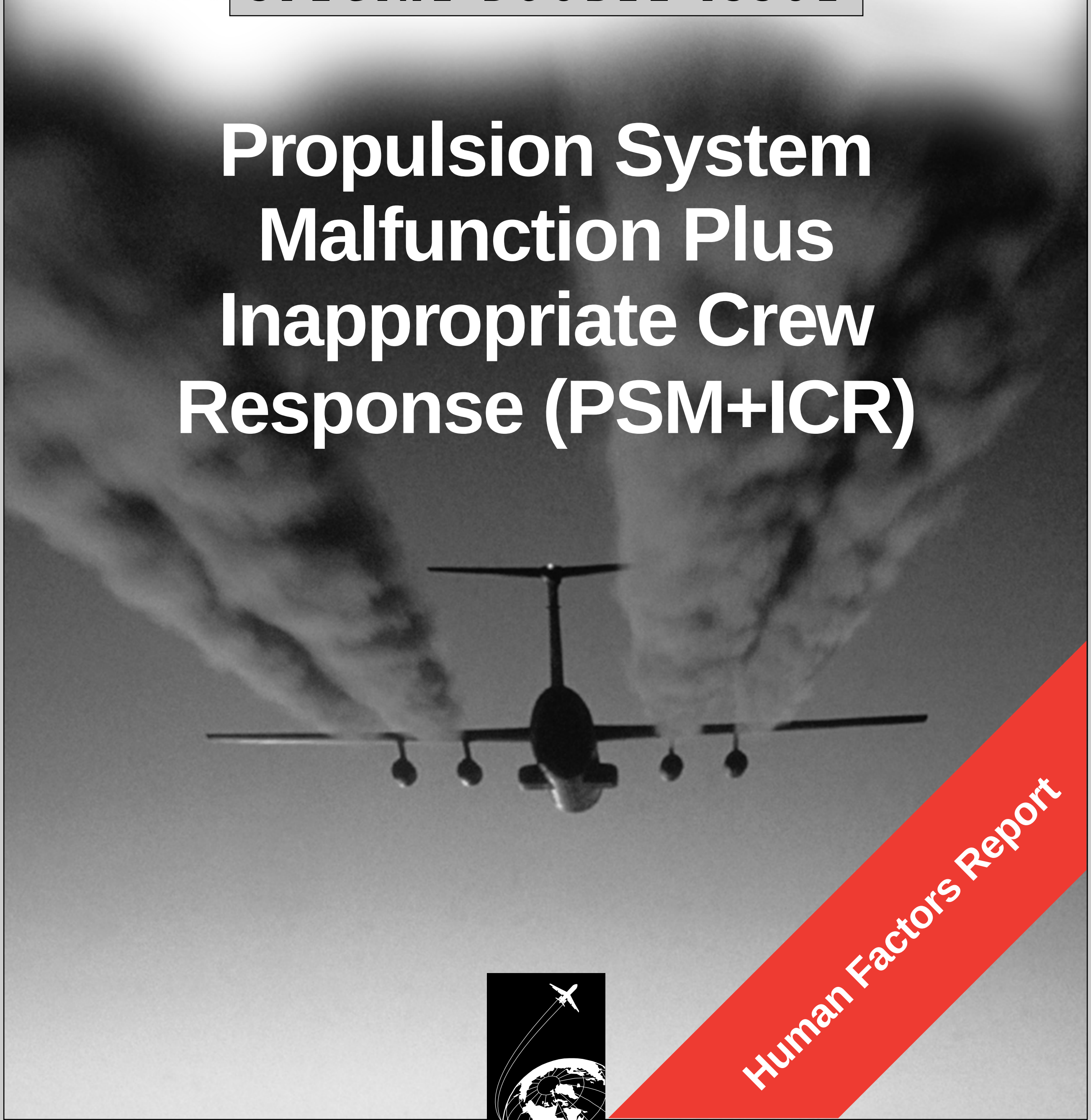

Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)

Human Factors Report

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1947–1999

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In This Issue

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Flight Safety Foundation is an international membership organization dedicated to the continuous improvement of flight safety. Nonprofit and independent, the Foundation was launched in 1947 in response to the aviation industry's need for a neutral clearinghouse to disseminate objective safety information, and for a credible and knowledgeable body that would identify threats to safety, analyze the problems and recommend practical solutions to them. Since its beginning, the Foundation has acted in the public interest to produce positive influence on aviation safety. Today, the Foundation provides leadership to more than 850 member organizations in more than 140 countries.

Foreword

This special issue of *Flight Safety Digest* presents a report on factors that have been involved in accidents and incidents when flight crews responded inappropriately to malfunctions of turbine-airplane powerplants and related systems.

The report is the result of two years of study by a multidisciplinary task group chaired by the U.S.-based Aerospace Industries Association (AIA) and The European Association of Aerospace Industries (AECMA).

The study was prompted as the result of an accident involving a twin-turboprop commuter airplane that struck the ground Dec. 13, 1994, during a missed approach at Raleigh-Durham (North Carolina, U.S.) International Airport.[1] The two pilots and 13 passengers were killed, and five passengers were seriously injured.

In its report on the accident, the U.S. National Transportation Safety Board (NTSB) said that a transient negative-torque condition caused an engine ignition light to illuminate while the crew was conducting an instrument approach. NTSB said that the captain assumed incorrectly that the engine had failed and that the captain subsequently failed to follow approved procedures for an engine failure, for a single-engine approach and go-around, and for stall recovery.

The task group assembled by AIA and AECMA studied this accident and several similar accidents and incidents that have occurred since 1959. They found that, despite improvements in propulsion systems over the years, the frequency of such accidents and incidents has not changed. Inappropriate crew response to transport-airplane propulsion system malfunctions causes an average of three accidents in revenue service and two accidents in training each year.

The propulsion system malfunctions cited in the report should not have caused accidents or incidents; the accidents and incidents were caused by flight crews who did not respond correctly to the malfunctions.

The activities of Flight Safety Foundation are focused primarily on human factors (especially flight crew error), controlled flight into terrain (CFIT),[2] approach-and-landing accidents and loss of control.

The Foundation is publishing this report in an effort to give wider distribution to useful information on factors involved in inappropriate response by flight crews to propulsion system malfunctions, and how these errors can be reduced.

— FSF Editorial Staff

1. U.S. National Transportation Safety Board. *Aircraft Accident Report: Uncontrolled Collision with Terrain, Flagship Airlines, Inc., dba American Eagle, Flight 3379, BAe Jetstream 3201, N918AE, Morrisville, North Carolina, December 13, 1994.* NTSB/AAR-95/07. October 1995. See also: Flight Safety Foundation. “Commuter Captain Fails to Follow Emergency Procedures after Suspected Engine Failure, Loses Control of the Aircraft During Instrument Approach.” *Accident Prevention* Volume 53 (April 1996): 1–12.

2. Controlled flight into terrain (CFIT) occurs when an airworthy aircraft under the control of the flight crew is flown unintentionally into terrain, obstacles or water, usually with no prior awareness by the crew. This type of accident can occur during most phases of flight, but CFIT is more common during the approach-and-landing phases, which typically comprise about 16 percent of the average flight duration of a large commercial jet.

Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)

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Contents

1.0 Executive Summary

The task report presented herewith was undertaken by Aerospace Industries Association (AIA) and The European Association of Aerospace Industries (AECMA) at the request of the U.S. Federal Aviation Administration (FAA) in response to a U.S. National Transportation Safety Board (NTSB) recommendation arising from the 13 December 1994 turboprop-airplane accident at Raleigh-Durham, North Carolina, U.S., which resulted in fatal injuries to 13 passengers and two crewmembers. The NTSB findings in this event strongly suggested that a warning light intended to indicate the activation of a recovery function was falsely interpreted as an engine failure and led to inappropriate crew action. The FAA recognized that there were additional data suggesting that this accident was one of a number of similar accidents, and that a study would be appropriate to look into all commercial transport accident histories where an inappropriate crew action may have been taken in response to what should have been a benign propulsion system malfunction.

The rate of occurrence per airplane departure for propulsion-system-malfunction-plus-inappropriate-crew-response (PSM+ICR) accidents has remained essentially constant for many years. These accidents are still occurring despite the significant improvement in propulsion system reliability over the past 20 years, suggesting an increase in the rate of inappropriate crew response to propulsion system malfunction.

At this point in time, the number of worldwide accidents for this propulsion system malfunction with inappropriate crew response "cause" is about three per year in revenue service, with an additional two per year associated with flight crew training of simulated engine-out conditions.

A project group was formed, encompassing experts from authorities; accident investigation agencies; airframe, engine and simulator manufacturers; and airline, pilot and training organizations. The group also included human factors experts from various organizations. The project group gathered extensive data from all available sources where propulsion system malfunction coupled with inappropriate crew response led to an airplane accident/incident. These data were analyzed, and conclusions and recommendations were developed based upon them.

The major conclusions from this project are:

- Although the vast majority of propulsion system malfunctions are recognized and handled appropriately, there is sufficient evidence to suggest that many pilots have difficulty identifying certain propulsion system malfunctions and reacting appropriately;

- Particularly in the turboprop arena, pilots are failing to properly control the airplane after a propulsion system malfunction which should have been within their capabilities to handle;

- While a review of instrumentation and warning systems was conducted, there is no clear evidence to link standards of engine failure/malfunction indications with the probability of inappropriate crew response. In addition, there are no human factors methodologies or human factors studies which provide clear evidence of the effects of a propulsion system failure indication on the probability of crew error. However, continued research and human factors activity in this area are strongly recommended, along with a review of the propulsion system instrumentation requirements;

- The group was unable to find any adequate training materials (books, videos, etc.) on the subject of modern propulsion system malfunction recognition;

- There are no existing regulatory requirements to train pilots on propulsion system malfunction recognition (stall/surge, severe engine failure, etc.);

- The training requirements related to "recognition and correction of in-flight malfunctions" are found in Appendix C of [U.S. Federal Aviation Regulations (FARs) Part 63, Certification: Flight Crewmembers Other than Pilots]. The disposition of the flight engineer's recognition training requirements to pilots of airplanes where no "flight engineer" position exists is not apparent. However, the expectation does exist that the pilots will perform the duties of the flight engineer;

- The simulator propulsion system malfunction models in many cases are inaccurate and/or do not have key cues of vibration and/or noise. There is also no robust process that ensures the quality and realism of simulator propulsion system malfunction models or that the malfunctions which are used in the training process are those most frequently encountered in service or those most commonly leading to inappropriate crew response. This shortfall leads, in some cases, to negative training;

- While current training programs concentrate appropriately on pilot handling of engine failure (single engine loss of thrust and resulting thrust asymmetry) at the most critical point in flight, they do not address the malfunction characteristics (auditory and vibratory cues) most likely to result in inappropriate response;

- The changing pilot population, coupled with reduced exposure to in-service events from increased propulsion system reliability, is resulting in large numbers of flight crews who have little or no prior experience with actual propulsion system failures; and,

- Data suggest that various opportunities exist for negative transfer of trained pilot behavior and experience when transitioning between different airplane types.

The major recommendations from this study are as follows:

- The requirements of [FARs] Part 61 and Part 121, and [Joint Aviation Requirements] JAR-OPS and JAR-FCL need to be enhanced for pilot training in powerplant failure recognition, the effect of powerplant failure on airplane performance and controllability, and the subsequent control of the airplane;

- The regulatory authorities should establish and implement a rigorous "process" to ensure that the following occur during the development of a pilot training program:

  - Identification of powerplant failure conditions that need to be trained;

  - Preparation of training aids (tools and methods);

  - Establishment of the appropriate means to conduct the training;

  - Assurance that each pilot receives the appropriate training for both malfunction recognition and proper response to it; and,

  - Validation of training effectiveness, along with a feedback loop to improve/update training;

- The mandatory pilot training program associated with simulated V_1 engine failures in an airplane has caused a number of hull loss/fatal accidents.[1] The value of performing this training in the airplane should be reviewed. It is the project group's belief that this specific training could be better effected in simulators. Where suitable simulators are not available, the airplane handling task could then be adequately and much more safely trained at altitude where recovery can be safely accomplished;

- The use of flight idle on turboprop airplanes for simulated engine failures or in the event of a malfunction should be reviewed by industry because of the potential association with loss-of-control events if the engine is not shut down;

- The aviation industry should undertake as a matter of high priority the development of basic generic text and video training material on turboprop and turbofan propulsion system malfunctions, recognition, procedures and airplane effects;

- The regulatory authorities should establish a means to ensure that the simulators used to support pilot training are equipped with the appropriate realistic propulsion system malfunctions for the purpose of "recognition and appropriate response training." To this end, the industry should develop specifications and standards for the simulation of propulsion system malfunctions;

- A review of propulsion system instrumentation requirements should be completed to determine if improved engine displays or methods can be found to present engine information in a manner which would better help the pilot recognize propulsion system malfunctions;

- It is recommended that the aviation industry sponsor activity to develop appropriate human factors methodologies to study both annunciation and training effectiveness for turboprop and turbofan propulsion system failures; and,

- Circumstances of negative transfer from previous training or operations should be identified, and the lessons learned should be communicated as widely as possible within the industry.

Supporting details for the above major conclusions and recommendations are included in Section 10 and Section 11 along with others drawn from the facts and data reviewed in this project.

2.0 Introduction

On 13 December 1994, a [British Aerospace] Jetstream 31 turboprop crashed at Raleigh-Durham, [North Carolina, U.S.], resulting in fatal injuries to 13 passengers and two crew. Five passengers survived the crash. The accident was investigated by NTSB, which concluded that the pilot had mistakenly assumed that an engine had failed and that the pilot subsequently failed to respond appropriately. The NTSB considered recommending that the regulations for future transport and commuter airplanes be modified to require "clear and unambiguous indication of engine failure"; however, this recommendation was not included in the final report. The final NTSB recommendations are provided in Appendix B (page 47). The FAA, partly in reaction to the NTSB investigation, requested that AIA undertake a project to identify the issues related to the accident and define any corrective actions required (see Appendix C, page 49). In response to the FAA, the AIA noted that a substantial number of serious incidents and accidents had occurred with similar links in the causal chain (based on the historical record of propulsion system related accidents presented in the AIA PC-342 committee report of May 1993).[2] At this point in time, the number of worldwide accidents for this propulsion system malfunction with inappropriate crew response "cause" is about three per year in revenue flights, with an additional two per year associated with flight crew training of simulated engine-out conditions.

The FAA request to AIA included undertaking a project to:

- Review relevant events and determine what factors influence crew errors following an engine failure;
- Define safety-significant engine malfunctions;
- Develop the guidelines for an engine failure indication system;
- Define the process and guidelines for an engine failure simulation;
- Define guidelines for engine failure recognition training; and,
- Identify the process for validating the effectiveness of these guidelines.

The FAA encouraged the AIA to invite broad participation with the expectation that the project would eventually move into an Aviation Rulemaking Advisory Committee (ARAC) activity and progress into an FAA/Joint Aviation Authorities (JAA)/Transport Canada harmonization project, if required.

The AIA responded that it would undertake the requested project and would examine the need for corrective action (see Appendix D, page 51). The initial focus of the project activity would be to assemble all:

- Relevant facts and data, including associated historical accidents and incidents;
- Experience with various mitigation approaches;
- Fixed-base and motion-based simulator capabilities and programs;
- Recommend potential improvement opportunities; and,
- Other relevant information appropriate to a thorough study of the issue.

The AIA response further stated that the AIA believed all parties would best be served by not prematurely focusing on “a solution.” An AIA-Transport Committee (AIA-TC) “project” was established, and a chairperson was selected to initiate the project. The project chairperson chose the workshop approach for the meetings of the project group as the most appropriate format for sharing relevant data, information and views. Additionally, the AIA-TC chairperson requested that AECMA co-sponsor and co-chair the activity, and assist with the collection and analysis of turboprop transport airplane event data. AECMA agreed to co-chair the project and to help the data collection and analysis tasks related to turboprop transport airplanes.

The conduct of this project required contributions from various parties with expertise in propulsion, flight crew training, airplane operations, flight deck design, simulator design and human factors. The effort involved assembling and analyzing the available data (incidents and accidents from commercial airplane operations), and understanding the contributing factors to the events of interest, as well as the relevant technologies. The military services (U.S. Air Force and U.S. Army) participated and shared relevant information and experience, including potential solutions and research on mitigating technologies. Additional information to promote a comprehensive viewpoint included operational and training flight crew experience with turboprop/turbojet/turbofan airplane propulsion system failures, the variation in propulsion system failure indicating systems currently installed, and the appropriateness of current training and simulation capabilities. Aviation human factors experts were provided by Boeing, Airbus, British Aerospace, NTSB, NASA [U.S. National Aeronautics and Space Administration] and the U.S. Army. Regulatory and accident investigation specialists participated. The simulator manufacturers and flight crew training specialists also made valuable contributions to the group’s understanding of simulation and training issues.

The project group created a number of task groups addressing specific areas of interest. The task groups covered the following:

- Turbofan data acquisition and analysis;
- Turboprop data acquisition and analysis;
- Simulation;
- Cockpit instrumentation;
- Human factors;
- Procedures and training; and,
- Regulations and advisory materials.

There are several places in the FARs and JARs related to transport category airplanes that address loss of thrust from powerplants (such as FARs/JARs 25.107, 25.109, 25.145, etc.). In summary, current regulations require airplanes to be designed to have the capability of continued safe flight after the failure of the most critical engine at the most critical point in the flight. The achievement of this outcome is obviously contingent on the flight crew’s recognition that the propulsion system has malfunctioned in order to take the appropriate action.

During the last 20 years, there has been significant improvement in propulsion system reliability, as shown in

Figure 1. Despite the significant reduction in propulsion system malfunctions, the overall PSM+ICR accident/incident rate has remained essentially constant, suggesting that the likelihood of inappropriate crew response to a propulsion system malfunction has increased. Uncontained engine failures (uncontainments) had previously been the dominant contributor to propulsion-related turbofan and turboprop airplane accidents, but with the steady effort of the industry, uncontainments have been reduced. PSM+ICR is now the dominant contributor (25 percent of hull loss and fatal accidents over the past five years) to propulsion-related turbofan and turboprop airplane accidents.

The project group analyzed accident/incident information for both turboprop and turbofan airplanes to try to establish why the improvement in propulsion system reliability has not been reflected in the accident/incident statistics. The work included examination of existing propulsion system instrumentation, pilot training programs and simulator standards, as well as an assessment of possible changes to regulatory requirements related to these fields.

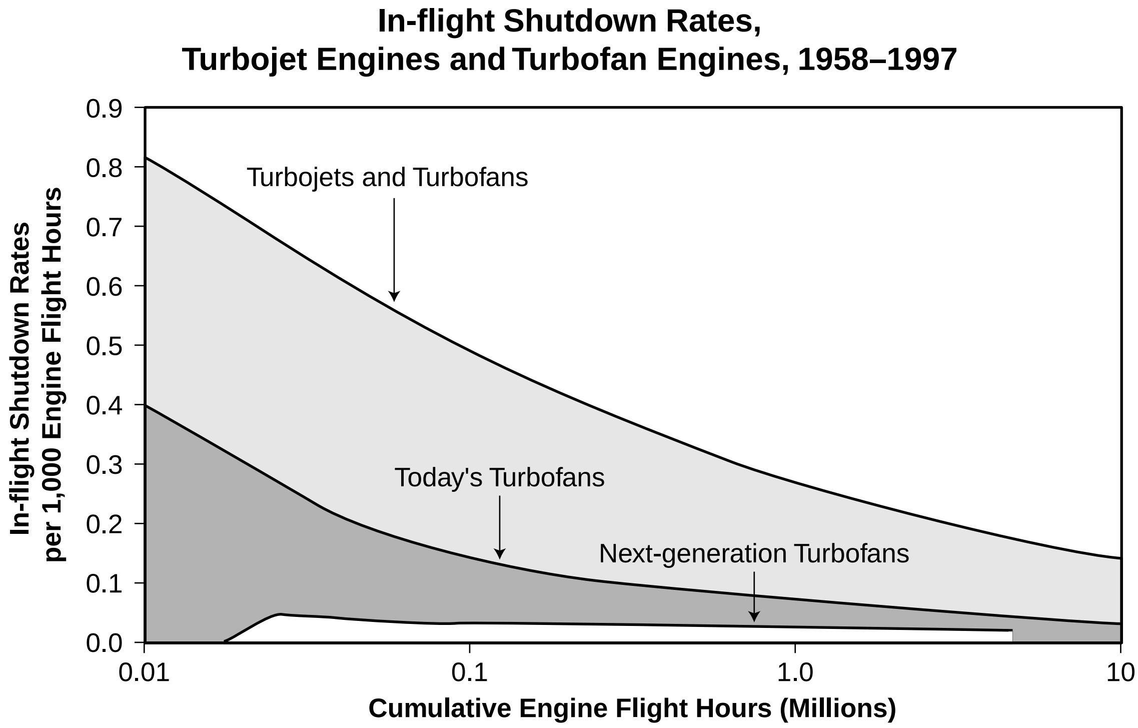
Events considered as part of this study are those which were initiated by a propulsion system malfunction on a single engine combined with an inappropriate crew response to that malfunction which then resulted in an accident or serious incident. In the process of data collection, a significant number of training accidents where crews responded inappropriately to simulated propulsion system malfunctions (e.g., V_1 engine failure) have been identified. The project group management decided it would be appropriate to offer some views in relation to these training types of accidents.

It is clear from examination of the data that some areas of difficulty encountered by flight crews are different in the turboprop and turbofan worlds. The project group recognizes that transition of crews between the airplane types will continue to occur; therefore, common solutions must be found wherever possible, while highlighting any differences.

The project group acknowledges the contributions from all the major airframe and engine manufacturers, simulator manufacturers, regulatory authorities, training organizations, pilot groups, accident investigation authorities, and participating operators (Appendix A, page 44).

3.0 Definitions

AECMA	The European Association of Aerospace Industries
AEA	Association of European Airlines
AIA	Aerospace Industries Association
ARAC	Aviation Rulemaking Advisory Committee
CAA	Civil Aviation Authority



Source: G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 1

DC&ATG	Data Collection and Analysis Task Group
DGAC	(French) Direction Generale de l'Aviation Civile
EPDB	Engine parameter display behavior
FAA	(U.S.) Federal Aviation Administration
FARs	(U.S.) Federal Aviation Regulations
HFEC	Human factors error classification
ICR	Inappropriate crew response
JAA	Joint Aviation Authorities
JARs	Joint Aviation Requirements
NTSB	(U.S.) National Transportation Safety Board
PSM	Propulsion system malfunction

Phases of flight:

Taxi	On-ground operation of the airplane prior to initiating takeoff run and following the landing roll-out from the active runway.
Rejected takeoff	A takeoff that is discontinued after takeoff thrust is set and the takeoff roll has begun.
Takeoff	The operational phase from application of takeoff power at the start of roll until the airplane is 1,500 feet above the takeoff surface, or at which the transition from takeoff speed to the en route speed (first power reduction) is completed.
Initial climb	The operational phase from 1,500 feet above ground level or at which the transition from takeoff to en route speed (first power reduction) is completed, [or from] lift-off to the flaps-retraction altitude.
Climb	The operational phase from the end of initial climb until cruising altitude is achieved.
Cruise	The operational phase from the transition from climb to assigned cruise flight altitude until the transition from cruise to descent.
Descent	The operational phase from the end of cruise until the beginning of approach at the initial navigation fix for the approach phase.
Approach	The operational phase from the end of descent at the navigation fix to wheels touchdown. The phase from the end of descent to the outer marker or five miles to the airport is often referred to as initial approach; final approach is then the phase from the end of initial approach or the outer marker to flare for touchdown of the wheels.
Landing	The operational phase from flare and touchdown of the wheels until the end of roll-out and turn off the active runway.
Go-around	An aborted approach/landing situation where the airplane is commanded to a takeoff/climb pitch attitude and requires the application of power to provide necessary airplane performance to abort the landing.

Compressor stall/surge — The terms "surge" and "stall" are used interchangeably within this report to describe the breakdown of engine airflow within the engine. Compressor stall/surge occurs when the stability limit of a compressor is violated. A single surge event may occur, or several may occur which are typically spaced less than one second apart. A high-power surge is accompanied by an audible report from the engine, which may be accompanied by tangible structure-borne vibration and/or flames from the inlet and/or exhaust. Within the engine, airflow reverses, leading to vibratory thrust pulsation and loud acoustic noises, along with "flames" out the inlet and/or exhaust. The symptoms associated with compressor surge are dependent on the level of thrust or power at which the engine is being operated. At high power levels, the thrust oscillations will be large and the noise will be extremely loud — akin to a cannon or a shotgun blast at 10 feet. At low power, the thrust oscillation may not be noticed and the sound will be muted; the only cues may be the effect on engine displays. Compressor stall/surge may or may not be the result of a mechanical malfunction and may or may not be recoverable.

Symptom — Symptom is defined in this report as a cue perceived by the pilot. Symptoms may be auditory, visual, tactile or olfactory — i.e., loud noise, the smell of smoke, a yawing motion or onset of vibration. A symptom is what the pilot perceives as sensory input which may suggest, based on training, that something is different or wrong.

Error classification — The following error type classification definitions were identified and used in the assessment of the PSM+ICR events:[3]

- *Skill-based behavior* [occurs] when the pilot executes a very familiar task without consciously thinking about how it is executed, almost automatic;
- Two types of *skill-based errors* can be identified:
  - *Slips* [result from] doing the right thing incorrectly, i.e., if the outcome of the action is different from intended; and,
  - *Lapses* [result from] intending to do something but, because of distraction or memory failure, not completing the action;

- *Rule-based behavior* [occurs] when the pilot performs a sequence of familiar subroutines that is consciously controlled by a rule or procedure stored in long-term memory or a checklist. The rules can be in the form of *if (state) then (diagnosis)* or *if (state) then (remedial action)*. Rules can be gained through experience or communicated from other persons' know-how as an instruction;

- *Rule-based errors* are typically associated with the misclassification of situations leading to the application of the wrong rule or the incorrect recall of procedures;

- Two types of *rule-based errors* can be identified:

  - *Errors of omission* [result from] not doing something you should do; and,

  - *Errors of commission* [result from] doing the wrong thing (also called mistakes);

- *Knowledge-based behavior* comes into play when a pilot is faced with novel, unfamiliar situations, for which no procedures are available. The problem solving required in these unfamiliar situations is goal-driven. Goals are formulated based on an analysis of the environment and the overall aims of the person;

- *Knowledge-based errors* arise from any or all of the following: selecting the wrong goal; incomplete or inaccurate knowledge (of the systems and the environment); and human limitations in terms of information processing and memory required for complex problem solving. The same two types of rule-based errors can also apply to knowledge-based errors:

  - *Errors of omission* [result from] not doing something you should do; and,

  - *Errors of commission* [result from] doing the wrong thing (also called mistakes);

- James Reason[3] said that, with increasing expertise, the primary focus of control moves from the knowledge-based to the skill-based level; but all three levels can co-exist at any one time. For example:

  - Diagnosis may be knowledge-based (unfamiliar situation); and,

  - Once a diagnosis is made, a procedure is selected using rule-based behavior; and the procedure is performed in an automatic, highly practiced manner (skill-based behavior).

Propulsion system malfunction plus inappropriate crew response (PSM+ICR) — An event where the pilot(s) did not appropriately handle a single benign engine or propulsion system malfunction. Inappropriate response includes incorrect response, lack of response and unexpected or unanticipated response.

Negative training — Training effects which result in behavior that is not appropriate in real operational flight situations (e.g., display cues in engine failure training using engine fuel cuts are different from the cues experienced during real engine failure in flight).

Negative transfer (of training on different airplane) — Negative transfer [occurs] when previous training or experience on another airplane type is inappropriate or even counterproductive in the current airplane type. Negative transfer is most likely to occur during stressful, high-workload situations when pilots revert to old habits.

4.0 Data Collection, Analysis Process and Results

The objective of the data collection and analysis task groups was to examine the historical record of airplane accidents and incidents related to PSM+ICR to identify potential improvement opportunities. Experts from airframe and engine manufacturers, flight crew training organizations and regulatory agencies conducted the analysis.

Collection of relevant data for this activity focused on Western-built commercial transport airplanes. Each airframe and engine manufacturer provided the best available factual information for the events involving its respective products. It should be noted that the depth of information available for accidents/incidents varies widely and that a great deal of difficulty was encountered getting substantive data on the smaller turboprop airplane types. It is hoped that, in the future, more emphasis will be placed on recording factual findings of such events because of their importance to activities of the type undertaken here.

The data analysis teams focused on identifying the "key factors" involved in the sequence of events, including flight deck symptoms, cues, contextual variables and classification of error types. Key factors are those specific "links" in the chain or attributes of an event sequence for each accident or incident that had a significant impact on the outcome. In addition, an assessment to identify opportunities to further minimize the probability of inappropriate crew response to propulsion system malfunctions was conducted. PSM+ICR accident and incident rates with respect to time were developed to identify any trends. Accident and incident rates by worldwide regions were assessed to determine any regional differences.

The data analysis process concentrated on a small number of "data-rich" events. Care was taken to test that the conclusions drawn from these events remained appropriate for those other events where data were sparse.

The process for identifying improvement opportunities was carried out in the following manner:

- Each event was judged independently, and improvement opportunities were identified; and,
- The opportunities identified from the data-rich events were assessed in relation to those with sparse results to ensure that:
  - All potential solutions had been identified; and,
  - Identified solutions remained appropriate in all cases.

The analysis process was not intended to focus on the root cause of the initial propulsion system malfunction, but rather on the malfunction symptom(s) experienced by the flight crew and their response to the malfunction symptom(s).

4.1 Turbofan Data Analysis

This section contains the results of the data and analysis for turbofan accident/incident events from 1959 through 1996 for Western-built commercial transport airplanes that are heavier than 60,000 pounds [27,216 kilograms] maximum gross weight. There were a total of 79 events analyzed, 34 of which were accidents. A summary of each event is contained in Appendix E (page 52).

This section also includes a qualitative judgment of improvement opportunities. A summary of the conclusions reached by the group is also included.

4.1.1 Turbofan Propulsion System Malfunction Symptoms

The propulsion system malfunction symptoms present in turbofan accidents and incidents are presented in Tables 1 and 2.

4.1.2 Turbofan Event Categories

The data analysis identified four major categories for the turbofan PSM+ICR events. These categories are:

- Rejected takeoff (RTO) [Table 3, page 10] — at/above V_1 following compressor stall/surge, severe vibration or warning lights;
- Loss of control [Table 4, page 10] — resulting from:
  - Undetected thrust asymmetry due to slow, quiet engine or throttle malfunction; and,
  - Aerodynamic cues masked by autothrottle/autopilot until situation develops wherein airplane recovery becomes difficult;
- Shut down/throttled good engine [Table 5, page 11] — Inappropriate crew response to an engine malfunction (surge, severe vibration) leading to shutdown or power reduction of the wrong engine either by:
  - Incorrect diagnosis; or,
  - Incorrect action following correct diagnosis;

Table 1
Turbofan Propulsion System Malfunction Symptoms in Accidents and Incidents

Symptom	Percent of Total
Compressor stall/surge	63
Power loss	14
Stuck throttle (throttle remains fixed)	6
Fire warning	5
No response to commanded power	3
EGT [exhaust gas temperature] warning light	1
Low oil quantity	1
Severe vibrations and perceived power loss	1
Suspected power loss due to airplane deceleration	1
Temporary power loss due to standing runway-water ingestion	1
Thrust reverser “unlock” light on	1
Thrust reverser did not transition to “rev thrust”	1
Thrust reverser to “unlock” position, no power increase	1

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Table 2
Turbofan Propulsion System Malfunction Symptoms in Accidents

Symptom	Percent of Total
Compressor stall/surge	53
Power loss	16
Stuck throttle (throttle remains fixed)	6
Fire warning	6
Suspected power loss due to airplane deceleration	6
EGT [exhaust gas temperature] warning light	3
Low oil quantity	3
Temporary power loss due to standing runway-water ingestion	3
Thrust reverser did not transition to “rev thrust”	3

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Table 3
Turbofan PSM+ICR* Events Involving Rejected Takeoffs

Symptom	Number of Events	Accidents: Fatal	Accidents: Hull Loss	Accidents: Substantial Damage
RTO at or above V_1 resulting in runway overrun				
Compressor stall/surge	16	1	2	5
Power loss	4	0	1	1
Fire warning	2	0	1	1
EGT warning light	1	0	0	1
Severe vibration/perceived power loss	1	0	0	0
Perceived power loss	1	0	0	1
Thrust reverser “unlock” light, no overrun	1	0	0	0
RTO attempted after V_1				
Compressor stall/surge	1	0	0	0
RTO below V_1 resulting in runway overrun				
Compressor stall/surge	2	0	1	1
RTO below V_1 with no overrun				
Misidentified engine malfunction as tire failure	1	0	0	0
Totals	**30**	**1**	**5**	**10**

*PSM+ICR = Propulsion system malfunction plus inappropriate crew response
RTO = Rejected takeoff   EGT = Exhaust gas temperature

Note: Information on bird strikes and wet or contaminated runways was available for 28 of the 30 RTO events. Engine bird strikes played a role in eight (29 percent) of the 28 RTO events. Another eight (29 percent) of the 28 RTOs involved wet or contaminated runways.

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Table 4
Turbofan PSM+ICR* Events Involving Loss of Control

Symptom	Number of Events	Accidents: Fatal Hull Loss	Accidents: Hull Loss	Accidents: Substantial Damage
Loss of control in flight				
Power loss	4	3	0	1
Stuck throttle (throttle remains fixed)	2	2	0	0
Loud bang, power loss	1	1	0	0
Training flight (V_1 cut plus power loss)	1	0	1	0
Power loss, loss control returning to land	1	1	0	0
Loss of control on the ground				
Asymmetric thrust during landing	2	0	1	0
Uncoordinated approach and landing resulting in offside landing — with single engine-power loss	3	0	2	0
Totals	**14**	**7**	**4**	**1**

*PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Note: No horizon or ground reference was present in four of the nine in-flight loss of control accidents.

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Table 5
Turbofan PSM+ICR* Events Involving Shutdown/Throttle of Good Engine

Symptom	Number of Events	Accidents: Fatal Hull Loss	Accidents: Hull Loss	Accidents: Substantial Damage
Shut down good engine	(23)			
Compressor stall/surge	6	0	0	0
Compressor stall/surge and power loss	4	0	0	0
Stuck throttle (throttle remains fixed)	3	0	0	0
Loud noise (growling sound), EGT rise	2	0	0	0
Fire warning	2	0	0	0
Power loss	2	0	0	0
Power loss, perceived both engines failed	1	0	0	0
Noise, vibration, compressor stall/surge	1	0	0	0
Vibration, smell, compressor stall/surge	1	1	0	0
Power loss, no throttle response	1	0	0	0
Throttled good engine	(4)			
Compressor stall/surge	3	0	0	0
Loud bang, power loss	1	0	1	0
Totals	**27**	**1**	**1**	**0**

*PSM+ICR = Propulsion system malfunction plus inappropriate crew response
EGT = Exhaust gas temperature

Source: G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

- Other [Table 6]:
  - Difficulty isolating which engine is malfunctioning; and,
  - Failure to recognize the need to take action or follow established procedures (i.e., continuously surging engines).

4.1.3 Turbofan Error Type Classifications

Error classifications as defined in Section 3.0 have been used in analyzing the events. An in-depth discussion of the analytical results for error type classification is provided in Section 8.0, which provides a description of the types of events corresponding to these errors.

Table 6
Other Turbofan PSM+ICR* Events

Symptom	Number of Events	Accidents: Fatal Hull Loss	Accidents: Hull Loss	Accidents: Substantial Damage
Failure to complete procedures in engine shutdown checklist	3	1	1	0
ATC communication error resulting in shutdown of a good engine	1	0	0	0
Failure to detect asymmetric thrust (stuck throttle)	1	0	0	0
Excessive pitch attitude with power loss from single engine	1	0	0	0
Continuous surging of multiple engines	2	1	1	0
Totals	**8**	**2**	**2**	**0**

*PSM+ICR = Propulsion system malfunction plus inappropriate crew response
ATC = Air traffic control

Source: G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

(Table 7 and Table 8) summarize the results of the error classification (in many of the events, multiple errors were assessed).

4.1.4 Turbofan — Potential Areas for Improvement

A process was undertaken in an attempt to identify improvement opportunities, based on data analysis. This process proceeded event by event, using the following techniques. The conclusions offered here should not be taken literally, but rather should be used to identify a hierarchy (relative ranking) of the opportunities for improvement. Each event was judged independently and evaluated qualitatively by the analysis team of subject-matter experts.

The following definitions of areas where improvement opportunities could be found were used:

Table 7
Error Classifications in Turbofan PSM+ICR* Accidents and Incidents

Error classification	Percentage
Skill	29
Knowledge, Rule	26
Rule	21
Knowledge	10
Knowledge, Skill	7
Rule, Skill	7

*PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Table 8
Error Classifications in Turbofan PSM+ICR* Accidents

Error classification	Percentage
Knowledge, Rule	29
Knowledge, Skill	19
Knowledge	14
Rule	14
Skill	14
Rule, Skill	9

*PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

- Design;
  - Annunciation — Design and implementation of an engine or system malfunction indicating system;
  - System — Corrective design and implementation action on the cause(s) of propulsion system malfunction; and,
  - Simulation — Design and implementation of representative propulsion system failure symptomology (auditory, visual and tactile cues) in simulators;
- Training;
  - Initial — Flight crew training on the identification and proper response to failure condition symptomology/annunciation/indication;
  - Recurrent — Exposure, training and check ride testing on the identification and proper response to failure condition symptomology/annunciation/indication and current operating anomalies and problems; and,
  - Academic/system — Audio and visual training and computer-based training for recognition and training in system functions and malfunction/failure characteristics;
- Simulation;
  - Fixed-base — Capability enhancement of failure/malfunction representation for recognition and proper response training;
  - Full-flight — Capability enhancement of failure/malfunction representation for recognition and proper response training;
- Procedures;
  - New — Development of new procedures related to failure/malfunction condition; recommended action; and,
  - Modified — Enhancement of current procedure(s);
- Communication;
  - Manuals — Add material addressing the propulsion system malfunction into operating manuals as appropriate; and,
  - Awareness — Special awareness/training publications including videotape awareness

information, operating bulletins, airline publications, special briefings and/or safety symposia;

- Crew resource management (CRM);
  - – Crew coordination — Additional training, etc., with emphasis on crew coordination; and,
- Culture;
  - – Cross-culture adaptation — Refers to those learning groups (such as pilots, mechanics, et al.) who have English as a second language and a non-European language as their primary language. This refers especially to cultures which use pictographs, Cyrillic alphabet and/or a reading direction other than left to right and/or up to down. This culture adaptation need is most evident in English-labeled flight decks.

4.1.4.1 Summary of Results for Potential Areas for Improvement

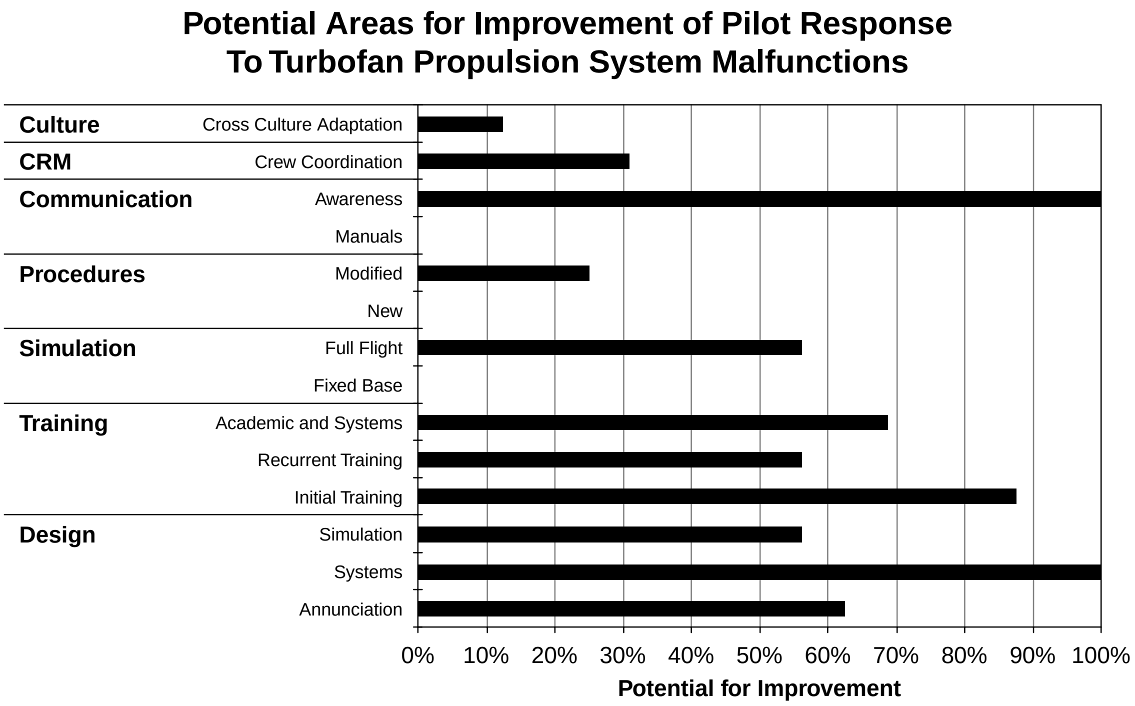
The data analysis team considered each event in the database and determined by consensus what were the potential areas for improvement based on each event. These potentials were then tabulated and are presented as percentages in Figure 2.

The areas with greatest potential improvement opportunities were those of “awareness” and “systems design.” Providing awareness information to flight crews on these types of events and the symptoms that the crew faced was judged by the team to be beneficial in all cases. Further, the team realized that reduction in the frequency of the initiating propulsion system malfunction/failures would also be effective (reduce the rate directly). However, the data team noted that such improvements (reducing the initiating propulsion system malfunction/failure rate) would be difficult to achieve, at least in the near term.

Training (initial, recurrent and academic/systems) was judged to represent good potential for improvement, particularly if the training was part of basic airmanship training. Training for malfunction recognition could be integrated into current training programs with negligible cost. Enhanced text and video material could be developed at reasonably low cost. Training in malfunction recognition was seen as an integral part of flight crew procedures training to ensure appropriate response to malfunctions.

The design areas of annunciation and simulation symptomologies were also considered to have high potential to provide improvement. Both annunciation system and simulation symptomology design action should be evaluated critically using the appropriate validity assessment techniques.

It is clear that there is no single solution. The data indicate that it will take a combination of enhanced awareness, training



CRM = Crew resource management

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 2

and simulation of a relatively few failure types to achieve an order-of-magnitude reduction in the accident rate for PSM+ICR. The enhancement of full-flight simulators with a few appropriately designed engine malfunction simulations, in conjunction with better training, was identified as having a high potential for success.

4.1.5 Turbofan — Phase of Flight for Events

Figure 3 depicts the percentage of turbofan events as a function of flight phase. The majority of events, over 70 percent, occur during the takeoff and climb phases of flight.

Figure 4 depicts the PSM+ICR annual accident rate per 10 million departures for the turbofan events. This rate was calculated using the number of hull loss and substantial damage type accidents per year divided by the total yearly commercial fleet airplane departures. The annual accident rate for PSM+ICR appears to be constant.

Figure 5 depicts the PSM+ICR annual hull-loss-only accident rate per 10 million departures for the turbofan events. This rate was calculated using the total number of hull loss accidents per year divided by total yearly commercial fleet airplane departures. The annual accident rate for PSM+ICR appears to be generally constant.

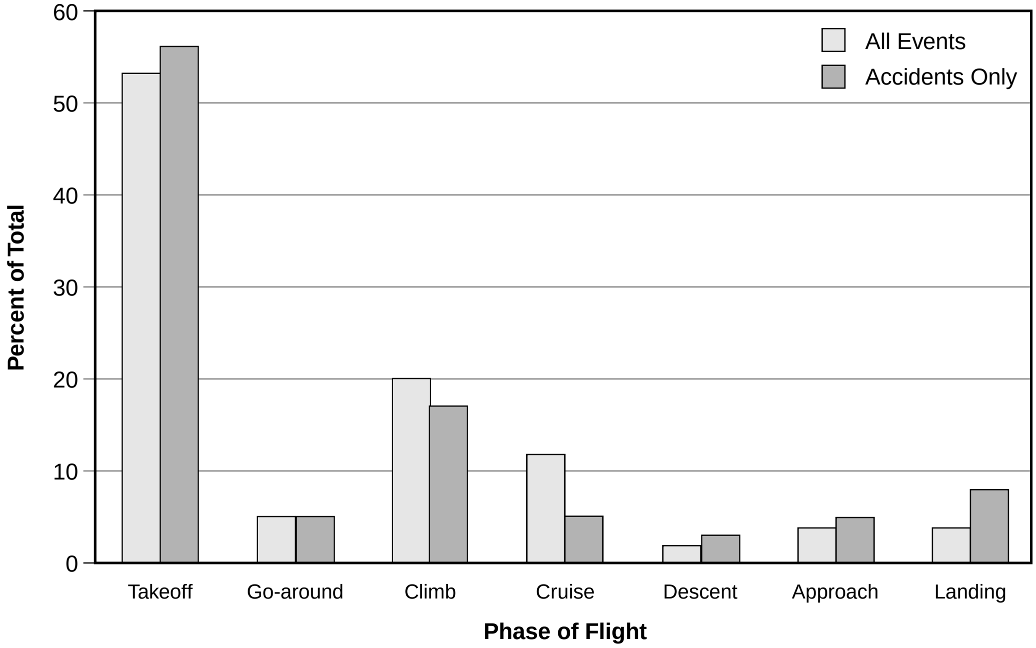
4.1.7 Turbofan Regional Data

Differences appear to exist among the airplane accident rates in different geographical and geopolitical regions. These differences have been attributed to a number of factors such as cultural differences, resource limitations, equipment used, underlying engine reliability rates, training approaches, etc. The validation of cause and effect is not clearly demonstrated by anything other than the rate difference. Appendix P (page 192) contains the charts developed to assess the statistical differences by airline regional and airplane generation aspects.

The differences in the accident rates for PSM+ICR were examined using a number of statistical significance tests. The confidence intervals suggest that some differences exist, but the statistically small number of events, the existence of multiple potential underlying causes and the lack of detailed circumstantial information make it impossible to definitively establish the reasons for the differences.

Several factors may play important roles in the rate differences. These include the training program used and the cumulative experience levels of the flight crews. When the group considers future trends — such as more pilots paying for their qualification training, improved powerplant reliability with decreased exposure to on-the-job training, lack of regulatory requirements for training beyond the V_1 cut and the general

Phase of Flight for Turbofan PSM+ICR* Events

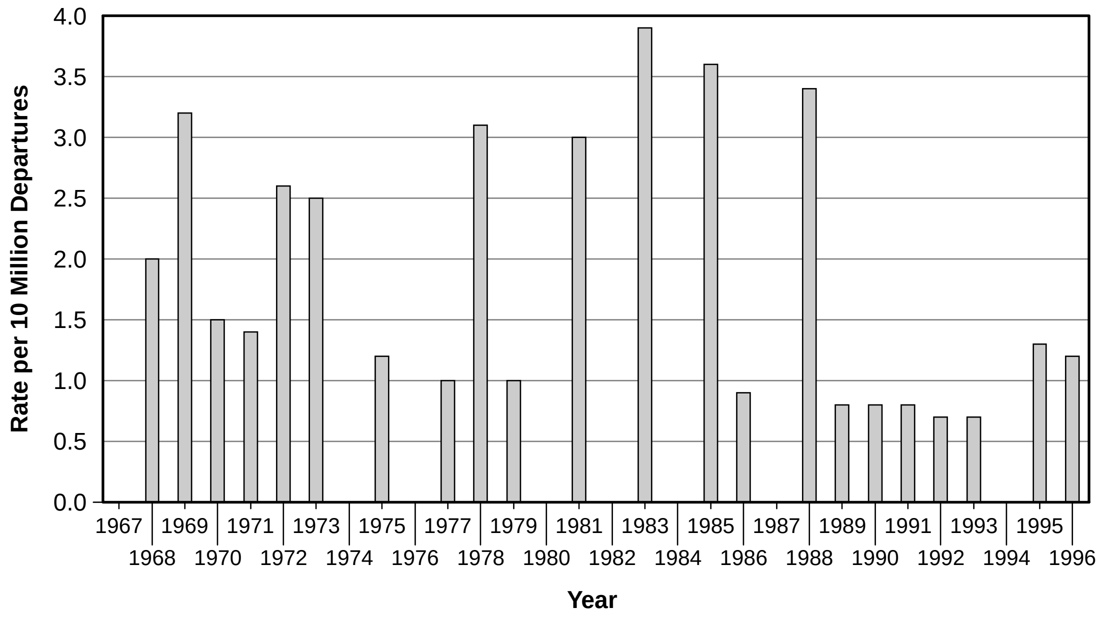


* PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 3

Turbofan PSM+ICR* Hull-loss and Substantial-damage Accident Rates

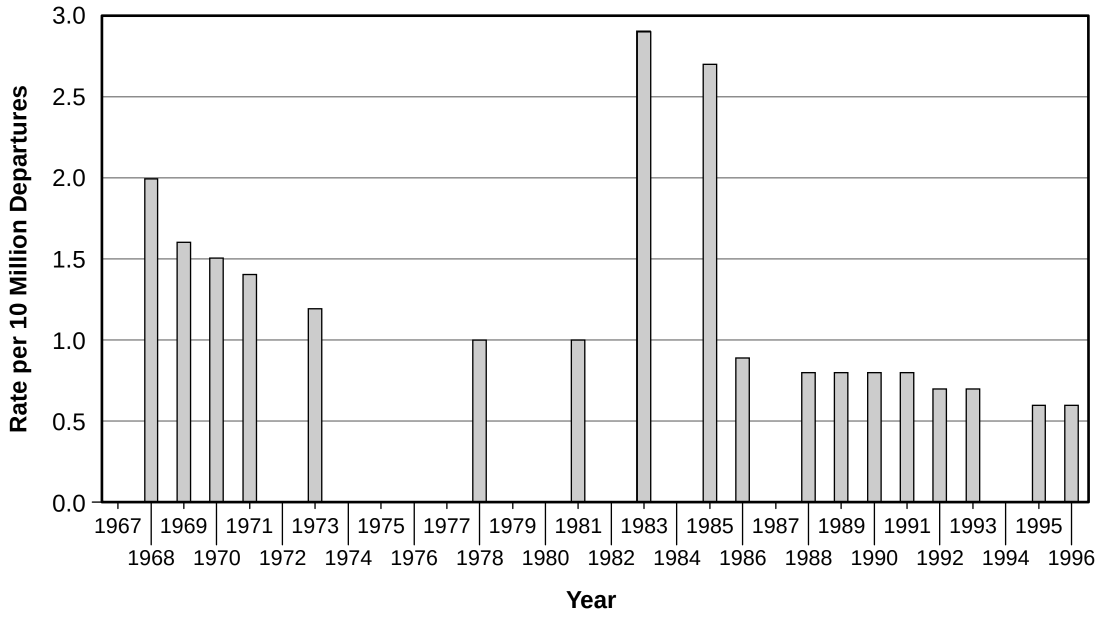


* PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 4

Turbofan PSM+ICR* Hull-loss Accident Rates



* PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 5

decrease in cumulative flight deck experience — it is unclear that the above-average historical experience in the United States and Canada will continue into the future. There is a strong possibility that differences perceived to be due to the training and experience in less-developed regions will become the future for the developed countries due to neglect of this type of training and the retirement of crews who had the experience to recognize such failure conditions and react properly. There is no reason to believe that any region is immune to these types of accidents; therefore, early action would seem to be indicated.

It would be preferable to be proactive than to wait for what is perceived to be an increased exposure to these types of accidents in future years. There is nothing in the data to suggest either that the United States and Canada are immune to these events or that their rates will continue to be better than the worldwide average.

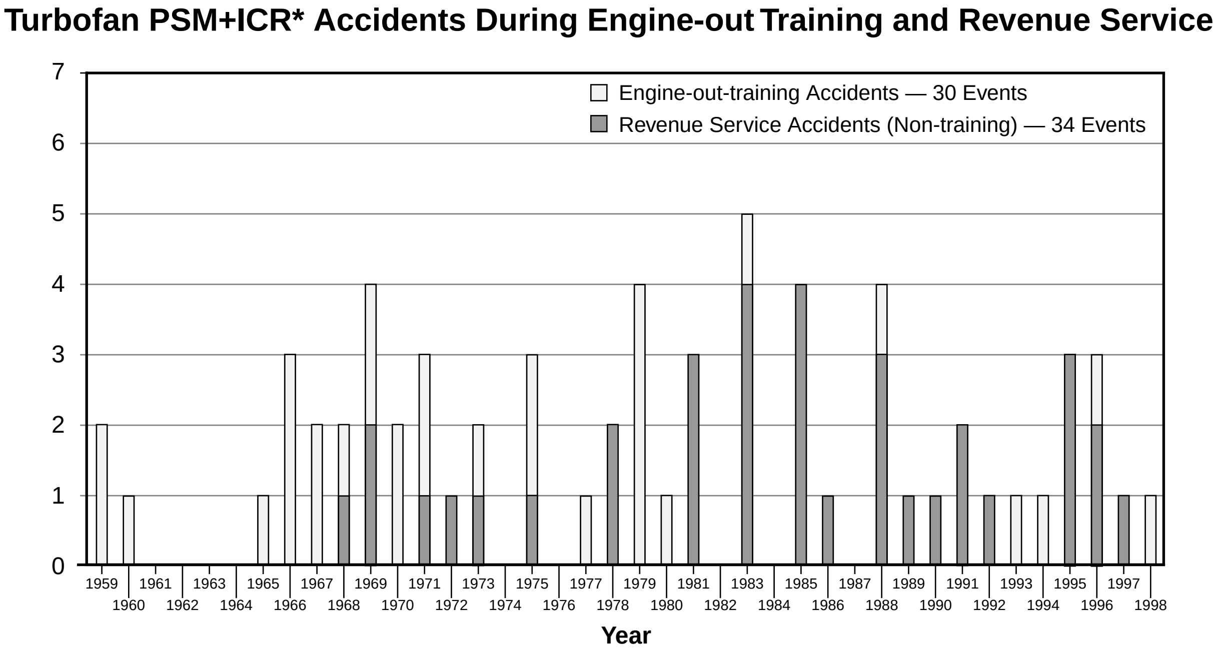
4.1.8 Turbofan Training Accidents

A review of the historical accident record for Western-built turbofan airplanes involving training accidents where either single or multiple engines were reduced to minimum thrust setting (simulated engine-out conditions) was conducted to examine relative frequency, phase of flight and geographical location of the events. Figure 6 depicts the number of simulated engine-out-training-related accidents (substantial damage, hull loss and fatal) in comparison to the PSM+ICR accidents since the beginning of commercial jet transport service.

Appendix F (page 72) provides a summary of the substantial damage, hull loss and fatal type accidents for the turbofan training-related events. Table 9 summarizes the 30 simulated engine-out-training accidents history by phase of flight and the airline geographical location. Analysis results of the simulated-engine-out-training-related events are only included in this section of the report.

4.1.9 Turbofan — Summary of Findings

- Calendar frequency of accidents is one accident per year in revenue service and one accident per year in training;
- Loud bangs (compressor stall/surges) and/or vibration-related malfunctions are influencing factors and appear to be outside most crews' experience (training and service events). This class of symptoms is a major contributor to inappropriate crew response;
- In all cases of accidents after RTOs above V_1, the airplane would have flown satisfactorily;
- Quiet malfunctions which are slow and have unobserved onset cues (masked by automatic controls) are a major contributor to inappropriate crew response;



* PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 6

Table 9
Flight Phase and Region for Turbofan PSM+ICR* Engine-out-training Accidents

Data Period: 1959–1998

Flight Phase	Events	Geographical Region	Events
Takeoff	11	United States	13
Go-around	1	Asia	5
Climb	5	South America	4
Cruise/in-flight	2	Europe	3
Final approach	4	Oceania	2
Landing	7	Canada	1
		Africa	1
		Middle East	1

Data Period: 1988–1998

Flight Phase	Events	Geographical Region	Events
Takeoff	4	United States	2
In-flight	1	Asia	2
Landing	1	Oceania	1
		South America	1

* PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

- Many flight crew members will never experience an in-service propulsion system malfunction (power loss, high-power surge, no response to commanded power) in their careers (estimate 0.7 to 0.9 events/career);
- Crews appear to have sometimes reacted inappropriately to annunciation lights (engine fail, EGT exceedance, fire warning, thrust reverser unlock) during takeoff phase at or above V_1;
- Crews sometimes had difficulty identifying which engine was malfunctioning. Modern surge recovery systems tend to eliminate an EGT exceedance as a visible cue of engine malfunction, thus making the identification of the affected engine more difficult;
- Negative transfer due to basic ADI [attitude director indicator] display philosophy differences may have been a factor in two loss-of-control accidents involving asymmetric-thrust-related events; and,
- Regional similarities across groups exist with PSM+ICR event occurrence rates. However, there is nothing in the data to suggest that any regions are immune to these events. Airplane generation rate data breakdown indicates that no significant differences exist between airplane generation types.

In addition to the main study, a more detailed study examined all engine-malfunction-related RTOs above V_1 in the General Electric/CFM International commercial fleet. The results of this specific analysis supported the conclusions of the main study given above and produced the following additional detailed conclusions:

- The number of RTOs above V_1 per calendar year is increasing in line with the increasing number of airplane departures. The rate of inappropriate crew response to an alarming engine malfunction symptom in the high-speed portion of the takeoff roll is remaining constant per opportunity or engine malfunction;
- The probability of inappropriate crew response is not affected by the number of engines on the airplane (i.e., having more instruments to watch does not increase confusion);
- Engine compressor stall/surge, flight deck warnings, vibration and yaw are relatively likely to result in a pilot decision to reject a takeoff above V_1;
- There is considerable variation between operators in the incidence of RTOs above V_1. Most geographical regions include operators with a significant incidence of these events; and,

- Crew experience alone does not appear to affect the likelihood of the event.

The very limited data available indicate that an engine stall/surge accompanied by a flight deck warning may have a higher probability of an RTO above V_1 than an engine stall/surge without a flight deck warning. The detail charts of this study are provided in Appendix G (page 75).

4.1.10 Turbofan — Potential Corrective Action Opportunities

The following are suggested as potential corrective action opportunities:

- To provide assistance to crews in identifying that an engine has malfunctioned:
  - Develop a flight crew "awareness package" to provide information to line-flying pilots to provide the following:
    1. Examples of appropriate and inappropriate crew responses (lessons learned);
    2. Types of engine malfunctions, characteristics and flight deck effects;
    3. Frequency of malfunctions; and,
    4. Impact of technology features on crew recognition and the need for no action (e.g., surge detection and recovery);
  - Enhance the crew training curriculum (expand engine events beyond V_1 throttle chops), malfunction simulation representation and training for both recognition and proper response for propulsion system malfunctions;
  - Train crews for engine surge malfunction recognition and proper response; and,
  - Provide a means to assist crews in identifying which propulsion system is malfunctioning in flight (may not be feasible for legacy hardware); and,
- Communicate the meaning of V_1 and its related performance aspects to line-flying pilots.

4.2 Turboprop Data Analysis

Regrettably, only a few turboprop airplanes have flight data recorders; therefore, the amount of data available from turboprop accidents is disproportionately small. Although the data enabled identification of loss of control as the major category to PSM+ICR accidents, insufficient data were available from the accident information to allow a meaningful analysis of the reasons for the loss of control. In an effort to understand the underlying factors in the loss-of-control events, advantage was taken of the engineering and operational expertise of the manufacturers, airline and pilot representatives participating in the data analysis task group. The participants' experience of actual incidents which involved potential loss-of-control situations both in operation and simulations was used as a basis for recommending potential improvement opportunities. Data in this report were obtained from formal accident reports and manufacturer databases. The incident experience drawn upon by the experts may not be included in these data. It has been determined that all data included in this report are in the public domain; and, therefore, the relevant data set is provided in full in Appendix H (page 77) for the PSM+ICR turboprop events. Appendix I (page 145) provides a summary of the turboprop training-related accidents.

Of the initial 114 events that were collated, only 75 met the objectives of this report. During the initial review phase, additional searches for data relating to known events were not successful. Of the final 75 events, only a few had sufficient data to elaborate on the accident cause; these were classified as data-rich events.

A significant number of events were rejected as failing to meet the task criteria. In some of these events, it was the inappropriate crew response that preceded the propulsion system malfunction; i.e., the crew actions caused the engines to fail, which subsequently led to an accident. Many of these inappropriate crew responses were associated with flight in icing conditions and crew actions in fuel system management. Although not part of this report, the crew actions (human factors) in these events should be investigated further, as they may give insight to human errors that lead to propulsion system malfunction.

Accidents involving flight training where the engine failure was simulated have been retained in the database and have been used in this analysis.

The analysis considered the following categories:

- Distribution over time;
- Phase of flight and event category;
- Error type;
- Type of malfunction, type of flight;
- Effect of autofeather; and,
- Geographical location.

Detailed analysis concentrated on data-rich accidents.

The analysis was reviewed with operators and manufacturers who participated in the study and whose opinions were sought to confirm the conclusions. Issues relating to training and airplane instrument displays were also discussed with operators, often resulting in wide-ranging differences of opinion.

Human factors analysis of the data did not show any root causes for the accidents due to insufficient data. However, several human-centered factors were identified by the operators who participated in the study which would appear to center on training and operating problems.

Subdivision of airplane accidents that did not involve FARs Part 121 operations or that involved airplanes with 19 or fewer seats failed to show any patterns that differed from the general conclusions.

Specific airplane flight deck and instrument arrangements were reviewed. Again, the lack of data prevented quantitative analysis, and many conclusions in these areas are also subjective.

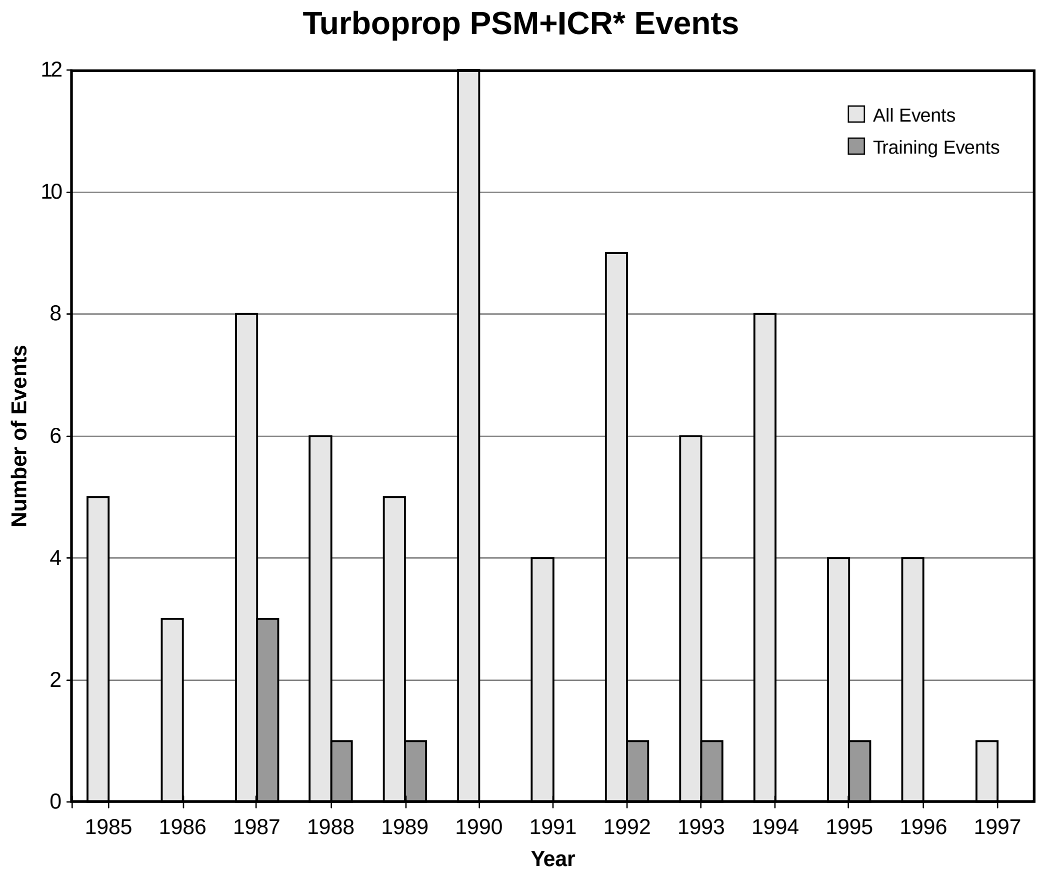
4.2.1 Distribution Over Time

The annual numbers of turboprop PSM+ICR events since 1985 are shown in Figure 7. It will be seen that there is no recognizable upward or downward trend in the annual numbers. However, the numbers show that these events continue to occur at a rate of 6 ± 3 events per year, indicating that action is required if this rate is to be reduced. The data for 1997 are only partially complete.

4.2.2 Phase of Flight

The number of propulsion system malfunction events which occurred during a particular phase of flight is shown in Figure 8 (page 20). The phases of flight are defined in Section 3.0 of this report. The dominant phase of flight for all turboprop propulsion system malfunctions is takeoff — this accounts for half of the accidents. The next highest flight phase in the rankings was approach, where there were 12 events (16 percent of the total).

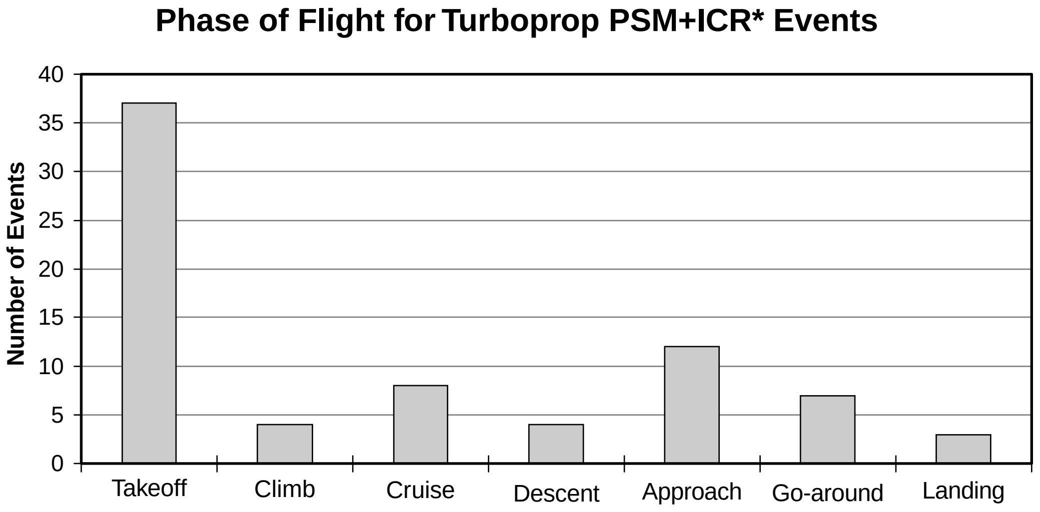
All of the takeoff events occurred once the airplanes were airborne. There was one RTO event recorded for turboprop



* PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 7



* PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 8

airplanes. This is a significant difference from turbofan events. The reason for this difference is that most turboprop operations are not conducted from runways where the accelerate-stop distance is limiting. Even at the “spoke” airfields of the typical U.S. “hub-and-spoke” operations, runways are 7,000–8,000 feet long and are more likely to be obstacle clearance limited. This forces the turboprops to reduce takeoff weights, which further improves their stopping capabilities. High-speed aborts on turboprops seldom result in overruns.

There were no data-rich events in the takeoff phase of flight.

4.2.3 Event Category

The accidents were categorized, and the results are plotted on Figure 9. The dominant event category is loss of control, accounting for 63 percent of all events.

4.2.4 Flight Phase and Event Category

Figures 8 and 9 show clearly that takeoff and loss of control individually dominate their respective analyses. Figure 10 shows that these two classifications strongly coincide. A correlation of the data by flight phase and event category shows that 70 percent of the “powerplant malfunction during takeoff” events led to loss of control, either immediately (22 events) or on the subsequent approach to re-land (four events). Or, put another way, 55 percent of the “loss of control” events occurred during the takeoff phase of flight.

It is concluded that the overwhelming majority of turboprop accidents resulting from powerplant malfunctions occur during the takeoff phase of flight and are due to the loss of control of the airplane.

4.2.5 Error Type

Each accident was evaluated to determine the specific error type associated with the inappropriate crew response. However, the assessment was based on the opinions of the experts involved. The error types are those defined in Section 3.0 of this report. Figure 11 (page 22) shows the distribution of error types.

For a given (certificated) airplane type, rule-based errors are generally addressed by training. Discussion of this data with operators supported these findings and again identified problems — in human factors, training and regulation — which are discussed later.

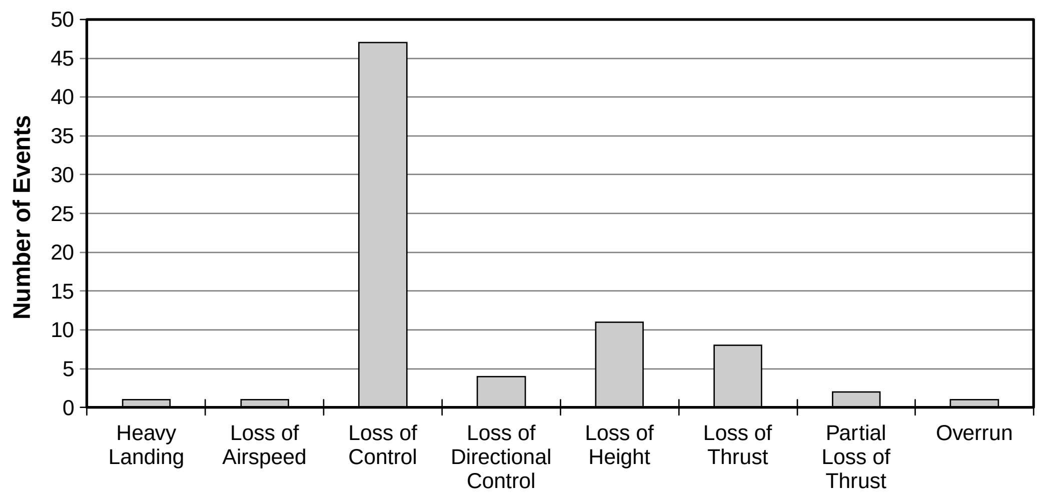
4.2.6 Type of Flight

The percentages of accidents for given types of flight are shown in Figure 12 (page 22). Revenue flights accounted for 80 percent of the events. As discussed previously, the data do not support a detailed breakdown between [FARs] Part 121 and other operations.

A disproportionately large number of events (17 percent) occurred during training or test flights.

4.2.7 Type of Powerplant Malfunction

The types of powerplant malfunctions identified as the initiating event are shown in Figure 13 (page 23). Propulsion system failures resulting in an uncommanded total power loss (“failed”) was the dominant category. Turboprop engines seldom experience compressor stall/surge. This is significantly different from the situation for turbofans. Discussion with engine manufacturers concluded that one reason for this

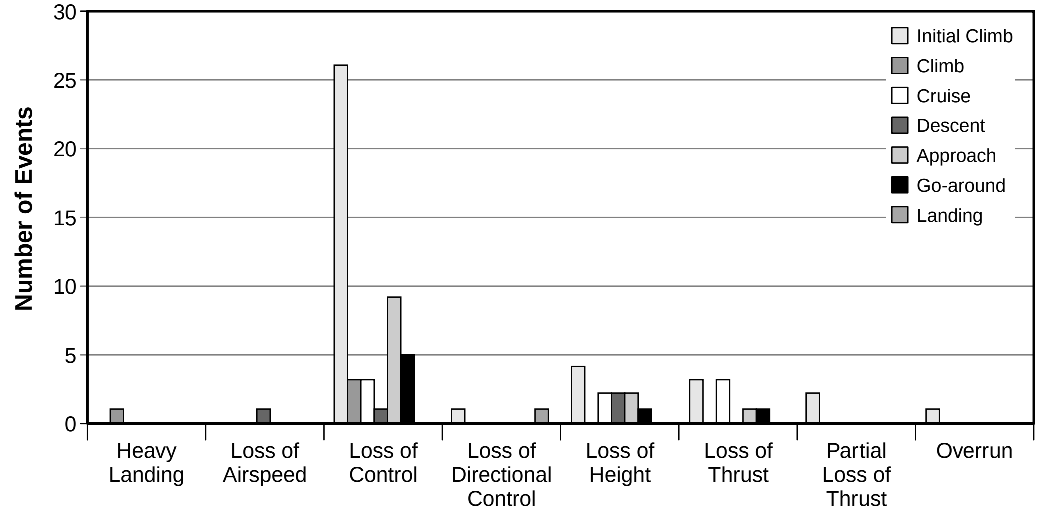


Results of Turboprop PSM+ICR* Events

* PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 9



Phase of Flight and Results of Turboprop-aircraft PSM+ICR* Events

* PSM+ICR = Propulsion system malfunction plus inappropriate crew response

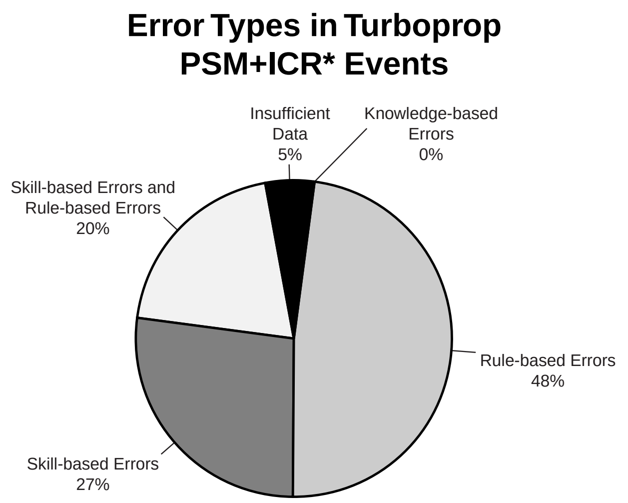
Source: G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 10

difference is that most turboprop engines (and some small turbofan engines) have a centrifugal stage in the compressor and hence are more tolerant to instability.

"Shut down by crew" events are those where either a malfunction of the engine occurred (partial power loss/torque fluctuations, etc.) and the crew then shut down that engine, or where one engine malfunctioned and the other (wrong) engine was then shut down. The distinction between "shut down by crew" and "failed" is that in the "failed" events the engine suffered a total power loss prior to any crew intervention.

There were six of the 13 "shut down by crew" events where the pilot shut down the wrong engine — three of which were on training flights where the instructor had deliberately



* PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 11

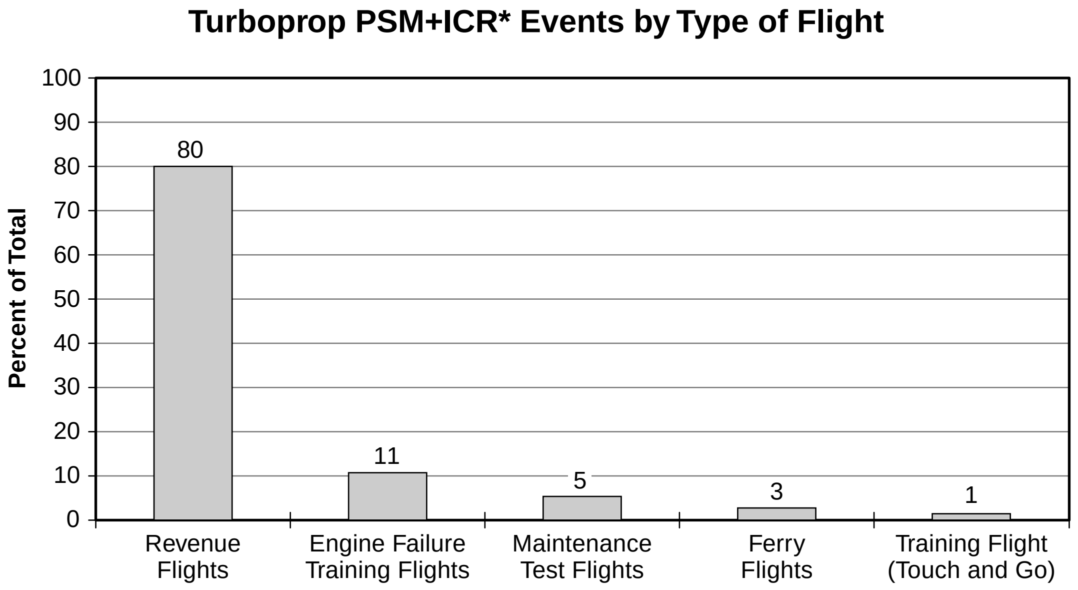
throttled one engine and the student then shut down the wrong engine. Accidents where the engine was not shut down, but maintained at flight idle, identified a category where there could have been a serious misunderstanding and lack of knowledge of turboprop operations. When an engine is at idle, the unfeathered propeller can give negative thrust, which, particularly at low airspeed, can result in a thrust asymmetry beyond that for which the airplane was certificated. Events in this category included training and deliberate “idle” selection by the crew. Each of these categories will be discussed later.

4.2.8 Failure Cues

There is little data to show which sensory cues, other than system alerts and annunciators, the crews used or failed to use in identifying the propulsion system malfunctions. Also, it is unknown whether, in fact, the crews recognized that they had a powerplant malfunction or which powerplant was malfunctioning. Unfortunately, in the turboprop accidents, few of the crewmembers survived.

4.2.9 Effect of Autofeather

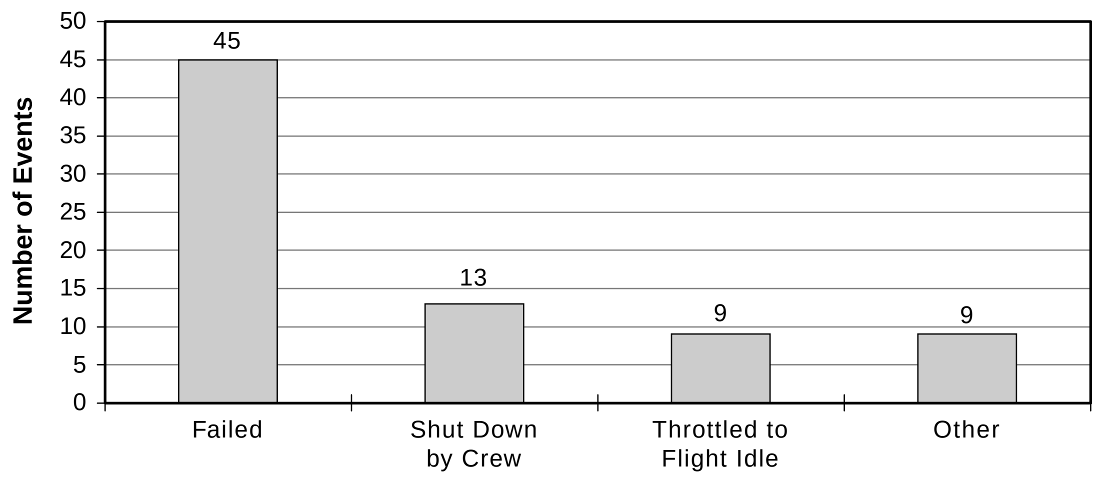
The influence of autofeather systems on the outcome of the events was examined. The “loss of control during takeoff” events were specifically addressed since this is the type of problem and flight phase for which autofeather systems are designed to aid the pilot. In 15 of the events, autofeather was fitted and armed (and is therefore assumed to have operated). In five of the events, an autofeather system was not fitted; and of the remaining six events, the autofeather status is not known. Therefore, in at least 15 out of 26 events, the presence of autofeather failed to prevent the loss of control. This suggests that, whereas autofeather is undoubtedly a benefit, control of the airplane is being lost for reasons other than excessive propeller drag.



* PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 12


Type of Powerplant Malfunction Initiating Turboprop PSM+ICR* Events

* PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 13

4.2.10 Geographical location

The analysis of the data with respect to geographical location was inconclusive. The largest number of accidents took place in North America, but this is roughly in proportion to the number of turboprop airplanes operating in the geographic regions. Additionally, the Western Hemisphere produced more consistent data.

4.2.11 Operations and Personnel

The following information was derived from discussions among the turboprop task group members, based on personal experience, and was assembled to provide some perspective on the potential differences between turboprop and turbofan powered airplane operations. In the quest to understand why pilots were losing control of their airplanes, potential contributing factors were identified. There has been no statistical analysis performed to substantiate the following information. Although the data enabled identification of loss of control as the major category in PSM+ICR accidents, insufficient data were available from the accident information to allow a meaningful analysis of the reasons for the loss of control. In an effort to understand the underlying factors in the loss-of-control events, advantage was taken of the engineering and operational expertise of the manufacturers, airline and pilot representatives participating in the data analysis task group. The participants’ experience of actual incidents which involved potential loss-of-control situations both in operation and simulations were used as a basis for recommending potential improvement opportunities.

Some turboprop operations are frequently characterized as having lower costs, less-experienced crews and airplanes which may be demanding in flight path/speed control following engine failure. The pilot associations and airline members report a decrease in the availability of experienced pilots. Training groups report that pilot candidates having less motivation or natural ability are allowed to progress through basic training. Regional airlines report a high turnover rate of pilots in the turboprop sector, particularly by advancement to jet airplanes, that further reduces the turboprop operator’s experience level, resulting in early promotion of less-experienced first officers. Some operators reported that some captains did not trust junior first officers due to the first officers’ low experience level and training.

Thus, in most in-flight emergencies, those captains not only flew the airplane and commanded the drills to be taken, but also actively participated in the drills, which detracted from the primary task of flying.

Older turboprop airplanes had a reputation as being demanding in skill and workload. A crewmember would expect to serve an apprenticeship as a first officer to acquire skills and experience of situations and diagnostic techniques. More recent airplanes utilize designs and equipment that are more error tolerant. However, as the overall crew qualifications and skill levels can easily be eroded by the high turnover rates and expectation of early promotion, those pilots now flying older airplanes are disproportionately less experienced. There should be a review of the balance of requirements between airplane certification and crew qualification, particularly for inexperienced crews flying older airplanes. It was also reported that instructors and authorized maintenance test pilots can be appointed to those positions as staff jobs, without the necessary experience or abilities. There are no requirements for specific training that must be completed before assuming an instructor's or authorized maintenance test pilot's position.

The connection between the certification basis of the airplane (the assumptions made about crew capability to recognize and handle abnormalities) and pilot training is unclear to the participants of the task group. This forms the basis for the recommendation for the development of a process to ensure that all parties have a clear understanding of the philosophies and assumptions on which the designs are based. Also, there should be formal training and qualification for instructors and maintenance test pilots.

4.2.12 Human Factors

The following major issues have been identified during the analysis of the turboprop data:

- Examples of negative training have been identified where the symptoms and modeling of propulsion system malfunctions can be inconsistent with the real operational event. In addition, with the preponderance of on-aircraft training, the only training exposure pilots see is the throttle cut to idle at V_1; again, this is inconsistent with the kinds of events most likely to be seen in service operational environments;

- Negative transfer has also been seen to occur, because initial or ab initio training is normally carried out in aircraft without autofeather systems. Major attention is placed on the need for rapid feathering of the propeller(s) in the event of engine failure. On most modern turboprop commercial transport airplanes, which are fitted with autofeather systems, this training can lead to over-concentration on the propeller condition at the expense of the more important task of flying the airplane;

- Negative training and negative transfer are most likely to occur at times of high stress, fear and surprise, such as may occur in the event of a propulsion system malfunction at or near the ground; and,

- Loss of control may be due to lack of piloting skills, or it may be that preceding inappropriate actions had rendered the airplane uncontrollable regardless of skill. It is very difficult, with just the database, to sort these two situations out. The recommended solutions (even within training) would be quite different for these two general circumstances. In the first instance, it is a matter of instilling through practice the implementation of appropriate actions without even having to think about what to do in terms of control actions. In the second instance, there is serious need for procedural practice.

  Physical and mental workload can be very high during an engine-failure event. The physical aspects are determined by the certification requirements. However, many turboprop airplanes have higher control forces than turbofan airplanes and thus may be physically more demanding. It is suggested that the certification requirements related to control forces be reconsidered in light of the above assessment.

5.0 Propulsion System Instrumentation and Failure Warning Systems

5.1 Turbofans

The indication task group was composed of members from each of the major airplane and engine manufacturers, the FAA, the NTSB and airline flight crews. The group heard presentations from several parties detailing potential problems with existing designs, proposed new methods for presenting information to the flight crew and discussed real-life experiences which had resulted in accidents.

A primary area of concern is during takeoff roll approaching and above V_1 where warning messages have influenced flight crews to abort even when the takeoff should have been continued. (It is noted that there has been much discussion and confusion concerning the flight crew decisions and actions that have to be completed at or before V_1 when aborting a takeoff. Actions have been taken by the various manufacturers and certification authorities to address this issue.)

Crews have aborted takeoffs based on lack of indications following a loud noise or heavy vibration. In at least one case, a severe engine stall or surge was thought to be a bomb, and the captain elected to abort the takeoff after V_1. It is possible to indicate the source of some surges and engine noises. Several engine manufacturers have stated that their FADEC [full authority digital engine control] systems could detect a compressor stall/surge and send a message in a timely manner to the cockpit. Tire failures, which sound like an engine surge on some airplanes, are already annunciated throughout the length of the takeoff roll (no V_1 inhibit) on at least one airplane. It would also be possible to annunciate severe engine out-of-balance conditions to the flight crew. However, the data also indicate that flight crews have inappropriately aborted takeoffs at high speed based purely on cockpit indications. Some pilots have indicated that a timely, reliable and "trained to" indication of the source of a noise or vibration could provide the necessary information for the crew to decide that an airplane is airworthy, when in the past they would have been convinced otherwise.

A further area of concern was power asymmetry resulting from a slow power loss, stuck throttle or no response to throttle coupled with automatic controls. Flying aids such as the autopilot and autothrottle can mask significant power asymmetry until a control limit is reached. At this point, the flight crew has to intervene, understand the malfunction and assume control of an airplane which may be in an upset condition. Better indications and/or annunciations of power asymmetry could warn crews in advance and allow them time to identify the problem and apply the appropriate procedures.

A separate issue of cockpit indications inducing crew error relates to the design layout of those indications, as shown in at least one event. Although the existing regulation in FARs/JARs Part 25.1321(c)(1) is explicit, the evaluation of a particular layout is subjective.[4] The layout factors should not be ignored, and the suitability of new displays for use by airline pilots should be further evaluated. Consideration of the development of additional guidance material for Part 25.1321 is recommended.

The task group discussed the issue of whether presentation of all parameters required by the FARs/JARs regulations helps or hinders in diagnosing engine malfunctions. These parameters may help in trend monitoring, but their varying relationships at different power and atmospheric conditions make them difficult for crews to use when analyzing a problem.

Improvements in cockpit indications alone may not significantly reduce crew error in handling propulsion system malfunctions. In takeoff abort situations, digital flight data recorder (DFDR) information shows that the flight crew's decision is often made and executed within two seconds of the event. In a number of instances, crews testified that the actual propulsion system malfunction they experienced was unlike anything they had ever heard or seen. They incorrectly concluded that the airplane was not airworthy.

A topic that merits further consideration is that of the use of automation to warn the crew when they may have taken an inappropriate action in response to a malfunction — e.g., a challenge regarding the selection of an engine to be shut down.

Appendix J (page 154) contains the results of a fleet survey of engine failure indications for turbofan-powered airplanes.

5.2 Turboprops

5.2.1 Instrumentation and Displays

The role of engine and flight instruments displays in accidents was considered during the analysis, and Appendix K (page 159) contains a fleet survey of turboprop airplane engine failure indications. However, the wide variation, differing applications and lack of specific data relating to displays preclude a statistical analysis.

5.2.2 Engine Instruments

There were no accidents where instruments or engine displays could be clearly identified as the root cause. There were accidents where displays may have contributed to the outcome; but, even in these instances, there were extenuating circumstances of poor maintenance or flight training. It is observed that as airplane designs have evolved, the size of the turboprop engine instruments has been reduced. While, in the past, classic, direct-drive-propeller airplanes had three large propeller gauges, modern turboprop displays may be as small as one inch [2.5 centimeters] in diameter. Additionally, parameters have been grouped within a single display and occasionally use concentric pointers.

5.2.3 Propeller Instruments

On turboprop airplanes, malfunctions of the propeller subsystem may be as critical or more critical than engine malfunctions. Although not directly supported by the accident analysis, there exists a body of incident/accident data which suggests that more-comprehensive propeller condition instrumentation may be beneficial for turboprop airplanes, particularly those with free-turbine installations. It is therefore recommended that an appropriate group within the FAA/JAA harmonization process consider additional propeller instrumentation.

5.2.4 Airplane Instruments Potentially Relevant to Loss of Control

Turboprop airplane flight instruments have improved in recent years. The three small attitude and compass displays have been replaced with five large instruments or, more recently, with an EFIS [electronic flight instrument system]. With the advent of integrated displays and redundant airplane electrical designs, turn-rate instruments are no longer fitted to modern airplanes. However, many pilots undertook their basic twin-engine flying training in airplanes using a "turn coordinator" instrument, where rate of turn is depicted in a similar manner to roll attitude. Recently, some major flight training establishments have banned the use of this instrument, as it can be misunderstood as bank angle. The more traditional turn needle and slip ball are now used. Human factors investigation has shown that well-learned responses from basic training may have a significant effect in later years. Thus, the use of the turn coordinator in basic training could result in incorrect concentration on roll control at the expense of controlling lateral acceleration in the event of an engine failure. Industry should investigate the suitability of turn coordinator instruments in training airplanes where commercial airplanes do not use these displays.

5.2.5 Lateral Acceleration

In recent years, lateral acceleration displays have decreased in size, particularly when integrated with electromechanical ADIs or EFIS. However, the requirement to control slip is still a vital parameter in controlling turboprop-powered airplanes in asymmetric flight. In turbofan-powered airplanes, slip is now not so important, as the control systems and engine locations have changed with time. Turboprop airplanes often use displays and formats developed for large jet transports, but the turbofan transport EFIS symbol size and format may be totally inappropriate for turboprop airplanes. Some of the turbofan airplanes have automatic rudder compensation or little requirement for the control of lateral acceleration in the event of an engine failure, particularly on rear-engine airplanes. These airplanes have smaller slip displays, which may be inadequate for turboprop airplanes. Thus, some turboprop airplanes have less-than-optimum instrument displays for lateral acceleration. The requirements for the clear display of lateral acceleration should be reviewed.

5.2.6 Flight Directors

Modern airplane flight instrument displays have flight-directed guidance systems. Few of these have been optimized for use following engine failure. Most control laws used in takeoff modes are based on heading/roll and pitch attitude. If this type of flight director (FD) is used when an engine fails, the resulting airplane yaw will result in a flight-directed roll command to restore the heading or a wings-level attitude. The pilot's natural instinct and trained response is to follow the FD; the command is conceptually similar to a turn coordinator instrument. The emphasis on the control of lateral acceleration by immediate use of rudder is lost, as there are no flight-directed rudders. The pitch FD command during takeoff and, in some systems, go-around is to maintain constant attitude, but the original value is almost certainly inappropriate for a climb with an engine failed. The requirement is to control speed, particularly respecting the V_{MCA} [minimum control speed in the air with the critical engine inoperative] and stall margins. Few, if any, turboprop airplanes have a takeoff/go-around FD mode with a speed command control law. A flight director display should not be used during takeoff or go-around unless it has been specifically approved for engine-failure operations.

5.2.7 Low Speed Awareness

EFIS displays with low-speed-awareness symbols may provide enhanced cues of low speed following an engine failure. If the airplane is inappropriately configured or the propeller has not been feathered, the crew does not have a display of the increased minimum control speed (V_{MCA}). The adjustment of the low-speed symbol to match the V_{MCA} for the actual airplane configuration should be considered in future designs. EFIS strip speed displays, with high values at the top, conflict with the convention of speed and attitude control; "pulling up" to the high numbers results in loss of speed. Similarly, with these displays, fast/slow indications cannot be used due to conflicting direction of error information. The exposure time of airplanes with these displays is still relatively low in comparison to the time scale of the database, and there was no conclusive evidence from the data to suggest that instrument displays caused any accidents.

5.3 Summary

1. For turbofan engines, an "engine surge" indication could be beneficial. Such an indication would be useful within one second of the event during the takeoff and go-around phases of flight, and should be engine-position specific.

2. An asymmetric thrust indication displayed to the flight crew when the thrust asymmetry exceeds a predetermined value could be beneficial.

3. An engine failure indication — e.g., "engine #_ fail" — displayed to the flight crew when the engine rolls back or runs down to a subidle condition could be beneficial.

4. A review of propeller-condition instrumentation is recommended to establish if additional instrumentation could be beneficial.

5. Manufacturers' representatives indicated that retroactive embodiment of additional engine failure/malfunction indications, particularly on non-FADEC engines, would be extremely difficult, if not impossible.

6. A tire failure indication provided to the flight crew within one second of the tire failure during both the takeoff and landing phases of operation could be beneficial.

7. A review of propulsion system parameters is recommended to determine if improved engine displays or methods can be found to present engine information in a manner that would help the flight crew recognize and handle engine malfunctions.

8. Standardization among the airplane manufacturers regarding engine caution and warning messages, and inhibit strategies during different flight phases (reference ARP 450D) is recommended.[5]

9. The locations of warnings, indicators and controls should not lead to a mistaken association with a particular engine.

10. It is evident that, where practical, all of the messages associated with systems that are affected by an engine failure should be made secondary to a primary "engine failure (subidle)" indication.

11. Consideration should be given to the use of automated systems to provide warning that a crew action may be inappropriate.

6.0 Simulator Capabilities and Realism with Respect to Propulsion System Malfunctions

6.1 Overview

The FAA and the ATA [Air Transport Association] both conducted reviews of powerplant malfunction simulation characteristics in modern simulators during the course of this project. These reviews disclosed variability (lack of standardization) and, in some cases, the lack of realism of the sound and motion for specific simulated propulsion system malfunctions. The lack of realism had previously not been considered significant, as flight simulators were primarily intended to be used for training performance and controllability issues and were not expected to be used for propulsion system malfunction recognition training. There are no standards or specifications for the design and presentation of many propulsion system malfunctions in flight simulators. The reason for the observed variability and lack of realism is due to the prior lack of industry recognition of the need for propulsion system malfunction recognition pilot training. No criticism is intended or implied by the preceding statement.

6.2 General

Appendix L (page 163) contains the results of a simulator survey conducted worldwide. There is a significantly lower number of simulators for turboprops than for turbofans. Simulators are evaluated and classified by various regulatory standards — e.g., FAA Advisory Circular (AC) 120-40B or JAR-STD. These standards address all instruments, equipment, panels, systems and controls as installed in the simulator, including the assemblage of equipment and computer software programs necessary to represent the airplane in ground and flight operations, through the range of normal operations and a number of abnormal and/or emergency situations; a visual system that provides an out-of-the-cockpit view; a motion system; a sound system for providing appropriate sounds and noises throughout the operating range of the airplane; and a control loading system to provide the pilot with proper control feel and feedback.

Throughout the development of airplane flight simulators, there has been a concerted effort to measure all performance and handling qualities of the simulator against the same parameter as measured on the airplane. It was for this reason that the criterion adopted for the basis of this measurement has been that “only (the aircraft) manufacturer’s flight test data (are) accepted for initial qualification” and that “exceptions to this policy must be submitted to appropriate regulatory authorities for review and consideration” before being accepted.

A majority of the airplane flight simulators in service at this time represent turbofan-powered transport category airplanes. However, there are a growing number of smaller business jet or commuter jet simulators coming on line. An even smaller number of simulators represent turbopropeller-powered airplanes. In fact, of the complete simulator inventory, only approximately 15 percent simulate turboprop airplanes. This disparity is primarily due to the relative cost of the airplane and its respective simulator. It may also be in part due to the current regulatory requirement to use airplanes to accomplish all of the required training and testing for all pilots, initially and recurrently — and a mere “authorization” to use simulation, if desired, to meet those same requirements. The cost of operating a turboprop airplane may well be essentially equal to what it may cost to lease time in a qualified simulator for the specific airplane type, not to mention the cost of transporting pilots from their home base to the simulator’s location and the per diem necessary during their stay. However, the use of simulators for training in place of the airplane, even for turboprop types, is increasing. In fact, in Canada, the use of a simulator is mandated for airplanes with more than 19 seats, and the United States is in the process of mandating the use of a simulator for all [FARs] Part 121 operations — i.e., 10 seats and above. Certain relief is expected for limited applications, and the change will allow the use of airplanes for the completion of training, testing and/or checking activities that cannot be supported in Level A or Level B simulators.

6.3 Overall Realism

In today’s simulators, for all airplane types, the synergistic operation of the aerodynamic programming, the visual system, the motion system (including the control loading system) and the sound system provides an excellent level of realism when compared to the operation of an airplane. The objective is that pilot behaviors that are demonstrated and reinforced in the simulator, as well as skills that are learned and polished in the simulator, are behaviors and skills that should not have to be adjusted or adapted when they are required to be used and depended upon in the airplane. Such facility provides for more complete training and more complete evaluation of pilots; and that yields a more competent and thereby safer pilot.

Currently there is an active Sound Requirements Working Group that has the objective of describing both static and dynamic cases where sounds as heard in the airplane cockpit will be developed for use in the simulator. This situation is applicable only to Level D simulators, but all simulation device levels will undoubtedly benefit from having this type of objective data available.

6.4 Realism with Respect to Engine Malfunctions or Failures

Among the current regulatory requirements for pilot training, testing and checking is one that requires that pilots be trained for and demonstrate competence in being able to handle the airplane should they experience an “engine failure” (usually a “failure” of the most critical engine or the propeller on the most critical engine) at the most critical point of flight, typically V_1. When these tasks were accomplished solely in the airplane, this engine/propeller “failure” was simulated by a rapid throttle reduction to an idle thrust position.

When training, testing and checking of pilots was moved largely from the airplane into simulators, the requirement for training and competency demonstration during “engine/propeller failures” remained unchanged. The typical malfunction represented in the simulator for training remained the rapid loss of thrust, rather than more representative failures likely to be seen in operation. Where attempts were made to include more representative malfunctions, these were often programmed, modified and "tuned" to a series of subjective descriptions related by the relatively few pilots who experienced them, rather than based on data from real events.

There is a growing quantity of information that indicates the simulations provided in pilot training, testing, and/or checking are not sufficiently realistic. Perhaps the most notable malfunction that fits this description is that of a low airspeed, high engine rpm [revolutions per minute] compressor stall/surge on a high-bypass turbofan engine. Pilots who have experienced such occurrences describe moderate to severe airframe buffeting or vibrations, a "shotgun blast" noise that startles everyone in the airplane cockpit and, at night, flames streaking forward of the engine inlet, accompanied by the airplane response to the rapidly varying thrust. Pilots who have flown simulators with malfunctions or failures programmed to simulate certain circumstances often report that buffeting or vibrations and the accompanying noise of a compressor stall/surge at high engine rpm is unrealistically low in most, if not all, simulators.

The group opinion is that, while the aerodynamic/visual/control feel/motion cueing of current advanced simulators is good, the motion system buffeting and sound system contributions do not well represent many propulsion system malfunctions, particularly high power compressor stall/surge of the turbofan engine. There is currently no basis for standardization of the propulsion system malfunction cues.

6.5 Probable Areas of Focus — Simulator Motion and Sound Systems

The simulator manufacturers have confirmed that it would be possible to modify both motion and sound systems of simulators to improve the realism of propulsion system malfunction representation. The engine and airframe manufacturers also confirm that data can be made available to produce more realistic malfunction simulations. Care is needed to ensure that increased levels of vibration and noise do not degrade the system capability.

As part of the project group's activity, a survey was initiated to establish the extent of data available from the airframe, engine and propeller manufacturers that could assist in ensuring more realistic malfunction simulations. This work is ongoing and not yet completed. However, Appendix M (page 165) contains a proposed list of propulsion system malfunction descriptions which need to be considered for incorporation into simulators for malfunction recognition training.

7.0 Flight Crew Training

7.1 General

In the days of reciprocating engines and the early generations of jet and turboprop airplanes, flight engineers were assigned the duties of recognizing and handling propulsion system anomalies. Specific training was given to flight engineers on these duties under the requirements of [FARs] Part 63, "Certification: Flight Crew Members Other than Pilots," (see Appendix N, page 168). To become a pilot, an individual progressed from flight engineer through copilot to pilot; all pilots by this practice received powerplant malfunction recognition training. In those times, the majority of pilots were likely to see several engine failures during their careers, and failures were sufficiently common to be a primary topic for discussion in the pilot fraternity. Today, it is not clear how pilots learn to recognize and cope with propulsion system malfunctions.

With the huge improvement in reliability of turbofan and turboprop engines in the last 20 years, many pilots will never experience a genuine engine failure in service. In addition, the pilot profile is changing rapidly, with a large reduction in the number of ex-military pilots in commercial service and a significantly shorter time to achieve the position of captain (approximately three to six years recently as compared with 15 to 20 years historically in the major carriers). Both the training and the flying regimes in the military provide much greater exposure to propulsion system malfunctions and the need to properly diagnose and deal with them.

At present, pilot training and checking associated with propulsion system malfunction concentrate on emergency checklist items which are normally limited, on most airplanes, to engine fire, in-flight shutdown and relight, and, probably, low oil pressure. In addition, the training and checking will cover the handling task following engine failure at or close to V_1. In order to maximize the handling task in the latter case, the most rapid loss of thrust — a fuel cut or engine seizure — is usually most appropriately used. Pilots generally are not exposed in their training to the wide range of propulsion system malfunctions that can occur.

No evidence was found of pilot training material (books, videos, etc.) on the subject of propulsion system malfunction recognition on modern engines. Nor, apart from [FARs Part] 63, was there any requirement to provide such training.

The range of propulsion system malfunctions that can occur, and the symptoms associated with those malfunctions, is wide. If the pilot community is, in general, only exposed to a very limited portion of that envelope, it is almost inevitable that the malfunctions that occur in service will be outside the experience of the pilots (flight crew). It was the view of the group that, during basic pilot training and type conversion, training in propulsion system malfunction recognition is necessary. This should be reinforced during recurrent training with exposure to the extremes of propulsion system malfunction — e.g., the loudest, most rapid, most subtle, etc. This, at least, should ensure that the malfunction is not outside the pilot's experience, as is often the case today.

Powerplant malfunctions communicate to the flight crew in multiple ways. Loud noise, onset of vibration, display behavior and smells of smoke are some cues of a malfunction. Lacking training and exposure to these cues, and with the increased reliability of modern engines and propellers, there is little chance for a pilot to gain experience as a copilot before being called upon to provide an appropriate response as the pilot-in-command. The accident and incident event data examined in this project suggest that pilots have difficulty in determining the appropriate action when confronted with a situation never before experienced.

It is beyond the charter of this project to suggest how pilot training should be conducted on propulsion system malfunction recognition. The design of modern commercial transport airplanes requires that an airplane be designed to provide the capability for continued safe flight and landing after the failure of the most critical engine at the most critical point in the flight. The realization of continued safe flight is critically dependent on the pilot recognizing and appropriately responding to powerplant malfunctions. The lack of training on the recognition aspect is seen as a significant oversight. In the future, it is suggested that designers should make note of the malfunctions that pilots are expected to recognize and handle. In addition, a process should be developed to collect this information and pass it forward to the pilot-training community to address. If designers must assume that pilots will recognize a malfunction and take appropriate action to minimize the chance of a hazardous or catastrophic effect, there should be a process that ensures that all pilots receive the appropriate training.

The industry trend is for some ab initio pilots to be required to pay for their initial training. This emerging practice puts pressure on training companies to provide training at a cost that individuals can afford. Without a regulatory requirement for propulsion system malfunction recognition training to be provided or taken, only a minimal level of training will be provided. It is recommended that a qualified group of training experts review the supporting data and material in this report, and be tasked with defining an appropriate minimum recognition-training standard. It is recommended that an attempt be made to recapture some of the training course material for flight engineers; that material should then be used as a baseline.

The lack of textbooks, videos, etc., on the subject presents a challenge.

Appendix M (page 165) contains a proposed list of simulator malfunctions that need to be considered for propulsion system malfunction recognition training.

Crews need to train to build the confidence that they can safely continue a takeoff with an engine failure past V_1. The high number of runway departures following high-speed RTOs beyond V_1 with turbofan airplanes clearly indicates that a number of factors may unduly influence captains, at 250-plus feet per second groundspeed, to make the wrong decision in not continuing the takeoff.

Although it is important to quickly identify and diagnose certain emergencies, the industry needs to effect cockpit/aircrew changes to decrease the likelihood of a too-eager crewmember shutting down the wrong engine. Many pilots today obtained their early multi-engine time and ATPs [airline transport pilot certificates] in a reciprocating twin. The standard mentality is to train to achieve lightning reflexes and decision making in the event of an engine failure during or after takeoff. With the acknowledgment that certain engine/propeller malfunctions require immediate action due to high-drag conditions, it is seldom required to identify, diagnose and secure jet and turbofan powerplants in a radically short elapsed time period; yet that is conventional thinking. Many pilots today flying jet equipment have considerable flight time on reciprocating/turboprop airplanes. The think-quick/secure-quick mentality is still there in the jet cockpit when the flight crews move up from the prop to the jet ("first learned, most retained" [law of primacy][6]). However, there are very few turbofan powerplant failure scenarios that require such immediate action. Except for four-engine airplanes, there are no "critical" engines on a jet as with a prop airplane.[7] Emphasis during training for jet crews should be placed on deliberate, considered actions during an engine failure. Habit patterns are hard to break.

7.1.1 Summary

Accident and incident events from history have similar characteristics. These characteristics suggest that the flight crew did not recognize the propulsion system malfunction occurrence from the symptoms, cues and/or indications. The symptoms and cues were, on occasion, misdiagnosed, resulting in inappropriate action. In many of the events with inappropriate action, the symptoms and cues were totally outside of the pilot's experience base (operational and training). The symptoms and cues, common to the majority of turbofan transport events, were very loud noise (similar to a shotgun blast at 10 feet) and/or the onset of extreme vibration. The levels of these symptoms and the airplane's reaction to them had not been previously encountered by the flight crew. Loud noises and vibration cues were occasionally misidentified (e.g., tire failures) as powerplant failures, and also have led to inappropriate response.

Any assumption that engine failure recognition training will occur in service is not currently valid with modern engine reliability. The onset of aural and tactile cues in powerplant failure in modern simulators is still inadequate and misleading relative to the accident and incident cases assessed. To recognize powerplant failures, the entry condition symptoms and cues need to be presented during flight crew training as realistically as possible. When these symptoms and cues cannot be presented accurately, training via some other means should be considered. Care should be exercised to avoid the chance of negative training. The need to accomplish failure recognition emerges from analysis of accidents and incidents that initiated with single powerplant failures which should have been, but were not, recognized and responded to in an appropriate manner.

Flight departments, from ab initio upward to the largest flight training departments, need to develop unique and innovative methodologies to better educate and train aircrews in the basics of powerplant operations and aerodynamics. All pilots need solid understanding of the performance factors that drive V_X [airspeed for best angle of climb], V_Y [airspeed for best rate of climb], V_2 [takeoff safety speed] and other important airspeed requirements. Special attention should be devoted to pilots who are transitioning from a high-time background in another airplane, because habit patterns will be deeply ingrained. Transition and even upgrade pilots should be afforded some amount of free play time during simulator sessions to experiment with engine-out flying qualities, the special combination of indications and warning/advisory lights, and as many variations of engine/system anomalies as possible.

7.2 Turboprop Training

7.2.1 Training for Engine Failure Recognition

Training for engine failure or malfunction recognition is varied. It is feasible that a pilot throughout training will never have had to identify a failed engine. Engines are shut down to practice restart drills. During these demonstrations, the pilot does not have to evaluate the condition of the gas generator or propeller system by reference to the instruments; "the fuel is off, so it must have stopped." This is indicative of a reaction to a single piece of data (one instrument or a single engine parameter), as opposed to assessing several data sources to gain information about the total propulsion system.

During in-flight engine failure training (for the purpose of practicing airplane handling), the engine is only simulated failed. Again, the pilot gains no experience of actual engine failure recognition. The propulsion system instruments show a normal, healthy engine being operated at low power. The dominant datum is the instructor retarding the power lever. An additional negative aspect of simulated in-flight training is that during a go-around, only the live-engine power lever is advanced. For those accidents where one engine was at idle as a precaution, the crew is not predisposed to using the idling engine.

Operators reported that there is little or no training given on how to identify a propulsion system failure or malfunction. Often, audio identification predominates due to the awareness of propeller pitch change, but this is only a single data source which could represent either a propulsion system failure or a minor engine control system malfunction. A cross-check of propulsion system parameters between engines is taught as a quick reference to identify which engine has a problem. However, this technique does not always give sufficient information about a particular engine or necessarily the correct answer. Industry should provide training guidelines on how to recognize and diagnose the engine problem by using all available data in order to provide the complete information state of the propulsion system.

7.2.2 Operational Training

Generally, flight or simulator training is procedure-based. Many operators only train to the minimum standard — i.e., to pass the takeoff V_1 cut check ride and, where applicable, fly a single-engine go-around.

There are few specific requirements for propulsion system failure recognition or malfunction diagnosis.

Airplane flight handling policy is often decided at operator level, either by the management and training staff or by local-authority inspectors. Surprisingly, operators reported varying opinions on whether to control the yaw before roll or vice versa as the correct immediate action for an engine failure. The airframe manufacturer normally gives this advice, but where it is not explicit, or there is no textbook to refer to, folklore and partially understood aerodynamic theories are used to justify procedures.

Basic and recurrent training should include a consistent and in-depth explanation of asymmetric thrust flight and the flight control techniques to be used. Industry should consider the provision of training aid material to support the identification of propulsion system failure or malfunction and to standardize training for asymmetric flight. For example, many training schools and operators teach the necessity to trim the airplane in yaw at V_2 to reduce the high foot loads due to asymmetric thrust. However, they may also fail to teach or demonstrate that, as the airplane subsequently accelerates, the requirement for rudder decreases. From the new trimmed state, the rudder force and position lessen as airspeed increases; these can appear to the pilot to be in the opposite sense to that required to control the initial failure. This potential confusion, together with the stress of the situation, may adversely affect the crew's performance. Some manufacturers recommend that, following a propulsion system failure, yaw trim should not be used or applied fully until the airplane has reached the final takeoff speed.

7.2.3 Stall Recovery Training

The recommended procedure for stall recovery training should be reviewed by industry, as it is believed to be a source of negative transfer between turboprops and turbofans. Maintaining adequate speed is essential to controlling the airplane. The small performance margins in turboprop airplanes result in low climb rates during single-engine operations; thus, the crew may be reluctant to lower the pitch attitude in order to accelerate. Furthermore, the basic stall warning recovery training could compound this situation. If training teaches to hold a constant attitude, apply power and achieve minimum height loss, there is little or no applicability of this technique to the problems of low-speed flight following engine failure. Classic stall recovery training concentrates on the low-power and approach-and-landing scenarios, where power can be applied to restore speed without attitude change. Stalls with an engine failed during takeoff or go-around are not taught due to the problems of V_{MCA}. With an engine failed, speed can only be controlled by adjusting attitude, as power is already at the maximum. This technique is in conflict with the basic stall recovery training and, therefore, may cause confusion during low-speed flight with an engine failure.

7.2.4 Use of Flight Idle

It is concluded from review of the accidents that occurred during training, where one engine was deliberately set to flight idle, that either the check pilot did not understand the flight mechanics of turboprop airplanes at flight-idle power or failed to maintain the conditions simulating an engine failure. At flight idle, the unfeathered propeller will give negative thrust at low airspeed. For zero thrust, a particular value of torque must be set and maintained with changing airspeed. During training or a check flight, it is possible that, since the instructor has to act as both the nonflying pilot as well as the check and safety pilot, the attention to power resetting can be overlooked.

The use of flight idle in training has two further negative aspects: Firstly, retarding an engine to idle is of little value for the recognition of a true engine failure by reference to instruments. In some cases (free-turbine engines), the core engine is running normally and the propeller speed or torque is artificially set to a false value. The propeller torque is adjusted, or should be set, to give zero thrust. This is similar to day-to-day conditions during a descent and, thus, gives the crew a feeling of normality. Secondly, once a crew has been given training with an engine at flight idle, they then could be predisposed to use the technique as a precaution for a partially diagnosed or minor powerplant malfunction. The use of flight idle for training during simulated engine failures and as a precautionary action in the event of a propulsion system malfunction should be reviewed by industry.

7.2.5 Negative Thrust

When given a choice between shutting down an engine or selecting idle, the crew often opts for idle. This is due to a situation where it may be better to maintain an engine at idle with the propeller feathered for electrical or hydraulic services as a precaution against a further problem rather than shutting the engine down. This debate applies for free-turbine installations only, as in the case of single-shaft [direct-drive] engines, the engine must be shut down to feather the propeller. This issue is another potential source of negative transfer. If, with an engine at idle and with an unfeathered propeller, the crew fails to recognize the problem of negative thrust at low airspeed or, conversely, fails to appreciate the higher effective V_{MCA} (which the manufacturer does not have to publish), loss of control is probable. Although most manufacturers advise the correct propulsion system setting for zero thrust, there is no mandated training for this operation, nor for any demonstration of the increased V_{MCA}.

Abnormal flight operations with the engine at idle (zero thrust) resulted in an accident recorded by one of the data-rich events. The airplane deviated from the flight path during the approach due to negative thrust; during the subsequent go-around, the handling pilot lost control of the airplane. This type of behavior occurs in other events, particularly during go-arounds where the crew does not use the precautionary engine for power and the handling pilot fails to recognize the negative thrust and then loses control. Modern airplane certification standards are such that an airplane can be flown safely with an engine shut down and that a failure of the remaining engine is very much less likely than the requirement to fly a go-around. Most manufacturers recommend that for an engine malfunction, the engine should be shut down with the propeller feathered. However, where there is choice, pilots appear to have developed closely held assumptions regarding the need for additional redundancy. This issue should be reviewed by industry, but training should clearly indicate the manufacturer's recommendations and the logic behind them.

8.0 Human Factors

8.1 Background

8.1.1 Human Factors Role in the Workshop

Human factors specialists participating in the AIA workshop on PSM+ICR had three important functions to perform:

- Provide real-time inputs on the human factors perspective to issues under discussion by the various task groups during workshop sessions;

- Develop and implement a process to validate the recommendations made by the workshop task groups using error data derived from human factors analyses of the accident/incident databases of the Data Collection and Analysis Task Groups — Turbofan and Turboprop; and,

- Develop human factors-based recommendations related to methods for validating the effectiveness of proposed corrective actions when implemented.

The human factors (HF) specialists involved in the workshop process and HF Task Group came from Airbus, Boeing, British Aerospace, FAA, NASA, NTSB and the U.S. Army. The human factors specialists, knowledgeable in commercial air transport issues, are a limited resource. The project group wishes to express their thanks for the help provided.

8.1.2 Databases

There are three databases involved in the development and validation of the recommendations produced by the workshop. These are:

- The Data Collection and Analysis Task Group (DC&ATG) – Turbofan summary database (Appendix E, page 52) and results for turbofan events described in Section 3.1 of this report;
- A human factors error classification database derived from the summary event data of the DC&ATG – Turbofan database (Appendix O, page 172); and,
- The DC&ATG – Turboprop database (Appendix H, page 77) and results for turboprop events described in Section 4.2 of this report.

The first two of these three databases served as the primary sources for recommendations and for the development of the validation process to support those recommendations. The related research to be described below served as secondary sources for the validation process.

8.1.3 Related Research

Human factors research related to the efforts of the workshop is of two types: research dealing with the classification of errors and inappropriate responses of aircrews in the presence of system malfunctions; and basic applied research on flight crew/system interface design.

A review of research on flight deck design, especially as related to propulsion systems and as conducted at NASA Langley Research Center, was presented at the initial AIA/AECMA Workshop on PSM+ICR in Seattle, Washington, U.S., in January 1997.[8] This material contains recommendations on top-level conceptual issues and specific research results. Additional relevant research references were made available as an addendum to the presentation. This material will be particularly useful in support of efforts to validate any proposed design solutions that may be derived from workshop recommendations.

The work of several authors on the classification of errors in aviation accidents was also reviewed. Research directly relevant to workshop issues, as well as relevant error classification work, are discussed in more detail in Section 8.4.2.7. The relationship of the results of this related work to the results of the human factors error classification (HFEC) model and the error classification database generated in support of the workshop activities is discussed as well.

8.2 Database Development and Analysis

8.2.1 Turbofan Database

The development of the PSM+ICR database and analysis of the data for turbofan events are discussed in Section 4.1 of this report. A member of the Human Factors Task Group participated in an initial detailed analysis of the events in the summary version of this database. Conclusions and recommendations resulting from the activities of the DC&ATG – Turbofan are to be found in the above-mentioned section. The summary data on which the results and recommendations from the DC&ATG – Turbofan are based were used in developing the HFEC database. The validity of the workshop recommendations will be addressed using this latter database.

8.2.2 Turboprop Database

For various reasons, the turboprop database has such a paucity of context data that no validation of the turboprop recommendations based on HFEC data could be included in the workshop final report. However, a large number of human factors issues are dealt with, and recommendations are made based on the data available. These are summarized in Section 4.2 and other sections of the report related to the analysis of turboprop accident/incident data.

8.3 Overview of Human Factors Analysis

A detailed summary of the results of and rationale for applying the HFEC model to the DC&ATG-Turbofan summary database can be found in Appendix O (page 172). Also included in this appendix are the complete HFEC database and the error classification model used in deriving the database. Table 10 provides an overview of the data summarized in Appendix O and permits comparison of the results with other studies of flight crew error to be discussed in Section 8.4.2.7. A total of

Table 10
Summary of Turbofan PSM+ICR* Error Data

Category	Number of Errors	Percent of Total
Detection	**18**	**8%**
Interpretation	**81**	**37%**
Processing	55	68%
Knowledge	26	32%
Strategy/Procedure	**47**	**22%**
Execution	**72**	**33%**
Slips/Lapses	18	25%
Other skill-based errors (execution, coordination, piloting skills, timing, etc.)	54	75%
Totals	**218**	**100%**

* PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

218 cognitive errors were identified within the 79 events of the turbofan summary database. The average number of errors per event was 2.8, with a range of errors per event of 1–9. There were only two events in which only one cognitive error was identified. This finding of multiple cognitive errors per event precluded an attempt to achieve a simple mapping of recommendations to events and thus dictated the approach taken in relating the human factors recommendations to the overall workshop recommendations.

The error classification data in Table 10 are organized by error category, number of events in which the error occurred and percent of error total. Within some of the categories, a further breakdown is shown with headings that help to relate the data to other research efforts to be discussed later. The percentage values shown for these generic subcategories represent percentages within the category.

The numbers set in bold type under the "Number of Errors" column in Table 10 represent the total number of times errors in each category occurred in the database. It is interesting to note that when the number of events in which a major category of error occurred are counted, the pattern of frequency across error categories is the same. That is, *detection* errors occurred in 18 events, *interpretation* errors occurred in 58 events, *strategy/procedure* errors occurred in 44 events, and *execution* errors occurred in 47 events. As can be seen, multiple interpretation and execution type errors within an event were more likely than detection or strategy/procedure errors. The former two categories of error had the greatest number of subcategories and thus provide greater opportunity to develop more detailed bases for the recommendations. This greater potential is reflected in the level of detail that could be provided for the workshop recommendations related to errors of interpretation and execution.

8.4 Validating Recommendations

8.4.1 General

The term "validation" as used here refers to the process of determining:

- That there is a direct and documented link between the human behavior in PSM+ICR events and the workshop recommendations;
- That the human factors analyses of the types of errors observed or inferred in the PSM+ICR events not only substantiate the recommendations but also provide sufficient guidance for specific actions which may be taken to implement the recommendations; and,
- That there are at least generic, if not specific, guidelines for human-performance testing to assess the effectiveness of implemented recommendations in both training and design.

Accomplishing this validation process was the major task confronting the Human Factors Task Group. Toward this end, an error model was developed and applied to the turbofan summary database (Appendix O, page 172). The error classification database developed from this application goes beyond the error classification work already done by the DC&ATG. The purpose of obtaining this additional detail in error classification was to provide needed insight into the cognitive aspects of PSM+ICR as a basis for detailed recommendations in training and design. Application of the error classification database to the recommendations of the project group is presented below.

8.4.2 Support for Workshop Recommendations

Taken together, the error classification data illustrated in Table 10 and summarized in Appendix O show strong support from several perspectives for the workshop recommendations which relate to crew training and design. A detailed discussion follows of the error data as they can be applied to specific aspects of flight crew training. No specific recommendations are made at this time regarding flight deck design. However, the generic recommendations for how flight deck design issues should be addressed (e.g., the need to validate the effectiveness of current and future system malfunction annunciations) are included later, as are generic recommendations on the validation of training solutions which may grow out of workshop recommendations. A detailed mapping of error category data to the workshop recommendations follows. Also included here is a discussion of related applied research and error classification efforts. This related research tends to verify the appropriateness of the workshop error classification work in that the pattern of results obtained here fits quite well in general with patterns obtained with other error models and pilot populations.

8.4.2.1 Detect

Most of the errors identified across events within this category were monitoring errors; that is, failure to monitor ("note") control position (e.g., throttles, switches, levers) or engine instrument behavior, either as noting deviations from normal in a detect sense or failure to monitor these deviations over time. Recommendations here can focus on both training and design. Because of the differences in the details in type of engine parameter display behavior (EPDB) to be noted and differences in the root cause producing the abnormal EPDB, emphasis on detection and interpretation should be addressed in training. Throttle position — or, more generally, thrust asymmetry — can perhaps best be addressed with alerts. This design recommendation recognizes the role of very high workload, very low workload and distractions as major contributing factors to this type of error.

8.4.2.2 Interpret

Errors in integrating and interpreting the data produced by propulsion system malfunctions were the most prevalent and varied in substance of all error types across events. This might be expected given the task pilots have in propulsion system malfunction (PSM) events of having to integrate[9] and interpret data both between or among engines and over time in order to arrive at the information that determines what is happening and where (i.e., to which component). The error data clearly indicate that additional training, both event specific and on system interactions, is required. This training theme is to be found throughout the conclusions of the DC&ATG – Turbofan and overall recommendations of the workshop.

In 22 events, crews reacted inappropriately on the basis of one or two very salient cues (e.g., loud bangs, yaw, vibration), thus failing to integrate all the data relevant to understanding what was happening and where. It should be possible to modify this behavior through training, given improved representation of PSMs in simulators during initial training, recurrent training and proficiency checks. This same failure to integrate relevant data resulted in seven instances where action was taken on the wrong engine. These failures to integrate data occurred both when EPDB was changing quickly (and thus more saliently), as well as when it was changing more slowly over time. Training in turbofan airplanes needs to continually emphasize the necessity of taking the time to integrate all data relevant to a PSM in order to interpret the situation correctly and enhance the likelihood that appropriate action will be taken. There is anecdotal evidence to suggest that some operators may consciously or unconsciously establish training environments that tend to promote too-rapid response to PSMs. There is also potential for negative transfer of training and experience from turboprop to turbofan airplanes (e.g., in certain turboprop airplane engine malfunctions, immediate action is required in order not to lose control of the airplane). Negative transfer issues such as this should be considered in detail in the development of training programs.

A second subcategory of errors related to interpretation involved erroneous assumptions about the relationship between or among airplane systems and/or the misidentification of specific cues during the integration/interpretation process. Errors related to erroneous assumptions should be amenable to reduction, if not elimination, through the types of training recommended by the workshop. Errors due to misidentification of cues need to be evaluated carefully for the potential for design solutions.

A third (and major) subcategory of errors leading to inappropriate crew responses under "interpret" was that of misinterpretation of the pattern of data (cues) available to the crew for understanding what was happening and where, in order to take appropriate action. Errors of this type may be directly linked to failures to properly integrate cue data because of incomplete or inaccurate mental models at the system and airplane levels, as well as misidentification of cues. A number of the events included in this subcategory involved misinterpretation of the pattern of cues because of the similarity of cue patterns between malfunctions with very different root causes; in some cases, the root cause was not even in the propulsion system (e.g., blown tire interpreted as surge, or vice versa). This type of error behavior should be particularly amenable to modification through training of the types recommended by the project group.

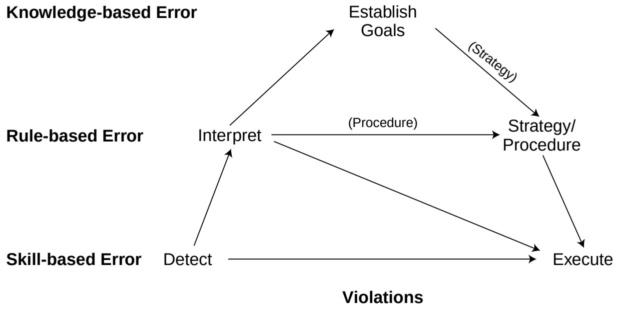
A fourth subcategory here pertains to errors involving failure to obtain relevant data from crewmembers. Errors classified under this category might also be classified as being of the "partially or poorly integrated data" type. However, the separate call-out of failing to integrate input from crewmembers into the pattern of cues is considered important for developing recommendations regarding crew coordination. It also highlights the fact that inputs to the process of developing a complete picture of relevant cues for understanding what is happening and where can and often must come from other crewmembers as well as from an individual's cue-seeking activity. Understanding the crew-coordination aspects of this fact should lead to specific impact on training programs when dealing with how to handle PSMs. These errors are different from "not attending to inputs from crewmembers," which would be classified as detection errors.

A fifth subcategory entitled "knowledge of system operation under abnormal conditions lacking or incomplete" was included apart from the "misinterpretation" subcategory because the evidence from the events in the DC&ATG – Turbofan summary database clearly supported the analysis, indicating that these errors were based on erroneous or incomplete mental models of system performance under abnormal conditions. The inappropriate crew responses were based on errors produced by faulty mental models at either the system or airplane level. Reduction in errors of this type can be achieved through more complete training on system operation and systems interaction during PSMs.

8.4.2.3 Strategy/Procedure[10]

The rationale for using both the "strategy" and "procedure" terms is illustrated in Figure 14 and Appendix O, Figure 1 (page 172). The term "procedure" is used to refer to those situations where a formal, written procedure or widely accepted "best practice" exists, or should exist, for dealing with a PSM which has been appropriately identified. The term "strategy" is used to infer the plan of action selected by a crew when no formal procedure or best practice existed or, at least, was known to the crew. Implementation of an inappropriate strategy would be classified as a knowledge-based error, whereas selecting the wrong procedure to use with a particular PSM would be a rule-based error. For the purpose of supporting workshop recommendations, the error classification model breaks down the types of errors leading to inappropriate crew response in the strategy/procedure category well beyond the rule-based/ knowledge-based error classification. By doing so, the relationship between the error classification data and the recommendations of the workshop is much clearer.

Classification of Errors That Led To Inappropriate Crew Response to Propulsion System Malfunction



Notes: The error classifications were adapted from Rasmussen's (1982) and Reason's (1990) taxonomies for classifying information processing failures and interpreted within the framework of Shontz's (1997) concept of the data-transformation process.

Sources: G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998 [from: Rasmussen, J. "Human Errors: A Taxonomy for Describing Human Malfunctions in Industrial Installations." *Journal of Occupational Accidents* (No. 4, 1982): 311–333; Reason, James. *Human Error.* Cambridge, England: Cambridge University Press, 1990; and, Shontz, W.D. "Crew Information Requirements Analysis (CIRA)." Boeing Document D6-82110. 1997].

Figure 14

By far, the greatest number of errors, in terms of number of events involved, were attributed to the selection of an improper strategy/procedure given the conditions under which the event occurred. There were a total of 43 events in which an improper procedure or strategy was chosen given the conditions. This category was divided into three subcategories that can be used to support different aspects of the workshop recommendations. These subcategories were:

- Choosing to execute an RTO above V_1 speed (21 events);
- Choosing to reduce power on one or both engines below a safe operating altitude (five events); and,
- Selecting other strategies which deviate from "best practice" (17 events).

The number and nature of the errors in the first subcategory definitely validate the need for Recommendation 5 and Recommendation 7 of the overall workshop recommendations (see Section 11.0), as well as several points made by the DC&ATG – Turbofan in their list of "potential corrective action opportunities." Those events in the second subcategory support the need for Recommendations 5 and 7 as well. The events containing errors relevant to strategy/procedure that have been placed in the third subcategory are so diverse in nature that they represent something of an "other" category. This diversity defied efforts to aggregate the data in a way that would focus on particular recommendations. One might consider the errors represented as pertaining to poor airmanship if this could be considered as referring to the use of poor judgment over very diverse circumstances while flying airplanes.

Other subcategories under strategy/procedure contained too few events to warrant an interpretation of their relevance to the recommendations of the workshop.

8.4.2.4 Execute

The errors classified under this general heading produced inappropriate crew responses (ICRs) that were inappropriate because of errors in execution as opposed to ICRs which resulted from errors made in the processing and/or interpretation of data or those made in the selection of action to be taken. As such, the subcategories are quite diverse and are therefore dealt with independently for the most part with respect to recommendations.

The first two subcategories represent the classic slip and lapse errors. These are "carry out unintended action" and "failure to complete action." There were 18 events in which errors of these types occurred. They represent instances in which switches or throttles affecting normally operating engines were inadvertently thrown, closed, activated, etc., or situations in which steps in a procedure were omitted with very serious consequences. Errors of these types do not lend themselves to elimination through training. They must be addressed through error-tolerant design or designs that preclude the slip from happening, or through the use of designs that support the execution of procedures which preclude the inadvertent omission of procedure steps. These skill-based errors are the most frequent in occurrence but are also the most likely to be caught and recovered. This relationship also held in the HFEC database.

Errors that involved poor execution of action are much more amenable to training as a corrective action. There were 13 events containing errors of this type. They represent errors in technique rather than omission. For the most part, they represent the need to concentrate on the development and maintenance of the ability to properly execute abnormal procedures.

Events in which there was poor/no crew coordination in carrying out action were included here. There was some ambivalence as to whether this was an error type or contributing factor. A "poor/no crew coordination" category was also included under contributing factors. The event lists do overlap to some extent, but the distinction is between poor/no crew coordination in executing a particular action (execute error) versus lack of crew coordination in general (contributing factor). A total of 21 events were classified as having errors involving lack of crew coordination in the action taken. These errors indicate the need for increased focus on the training of crews to coordinate their actions during PSM events. This recommendation is much more narrowly focused than one dealing with CRM in general.

A subcategory of poor piloting skills was also included to classify skill-based errors of this sort that were related to PSM events. A problem when including an error category of this nature is that of defining the error itself. This problem can best be understood by reviewing the items in this category as found in Appendix O. If PSM events are represented more realistically and become a regular part of training and testing of pilots, perhaps potential for this type of error will be dealt with both specifically and more systematically.

A final subcategory under execution was failure to initiate action in a timely manner. This category was included in an attempt to capture the timing aspect of errors. Nine events were identified as containing this type of error. Timing errors have a tendency to exacerbate other errors that are occurring during a PSM event. The issue of timing needs to be addressed as a part of training to deal with all PSM events. It is more complex than simple admonishments to take one's time in dealing with abnormal events. Crews need at least initial guidance on effective timing of actions and the variations in such timing as a function of specific PSM events.

8.4.2.5 Violations

Violations as errors are very different from the types of error described thus far. The difference is in intent. The types of inappropriate crew responses classified as violations during the error classification process involved specific violations of company policy or procedures. Needless to say this was very rare; at least, evidence of it was very scarce in the DC&ATG – Turbofan summary database. Dealing with violations of this sort requires:

- The very clear, concise statement of company policies and procedures;
- Their dissemination to all flight crews; and,
- An evaluation of the process which insures that flight crews have access to, understand and abide by these policies and procedures.

8.4.2.6 Contributing Factors

These aspects of the events were identified and categorized for the purpose of providing "context" for the events. Relating contributing factors to the error data offers the possibility of understanding at least some of the conditions which have relevance to or seriously impact human performance, and may provide a framework for better understanding the "why" of human error; particularly, the cognitive errors. Unfortunately, the resources were not available to develop the relational database that would be necessary to exploit the potential contribution of these data to our understanding of the whys of at least some of the errors contained in the database. Such a relational structure should be a critical component of any further efforts with the error classification database.

8.4.2.7 Relationship of Data to Related Research

There are several research efforts (Shontz, 1997[11]; Wiegmann and Shappell, 1997[12]; Shappell and Wiegmann, 1997[13]; Wildzunas, R.M., 1997[14]; O'Hare et al., 1994[15]) in which the results relate to the error classification work done for the workshop. The patterns of error classification across these studies are remarkably similar even though the pilot populations are very different — i.e., Army helicopter pilots, general aviation pilots, military pilots (U.S. Navy), transport pilots and instructor pilots (transport). The differences in patterns may be explained largely in terms of differences in definitions for similar categories of errors, as well as differences in the criteria investigators used in assigning errors to categories.

Wildzunas (1997) investigated wrong-engine shutdowns in Army helicopters using both a survey and a simulator study. The pattern of errors by cognitive function was very similar to the PSM+ICR error data. The functions contributing the greatest number of errors were diagnostic (here, "interpretation") and action (here, "execute") as they were in the HFEC database. The largest difference was in the major contribution of strategy/procedure errors in the HFEC database, whereas there were very few goal, strategy and procedure errors in Wildzunas' simulator study. His survey data showed that pilots felt that improper diagnosis and lack of training were major factors affecting their actions on the wrong engine. This supports the recommendations of the workshop with regard to the need for enhanced training to improve crew performance in determining what is happening and where.

Wiegmann and Shappell (1997) compared several models of human error, including that of Rasmussen (1982),[16] to parse error data from mishaps involving U.S. Navy and U.S. Marine Corps pilots. Their database included 3,293 mishaps attributed at least in part to human causes. The pattern of errors classified using the Rasmussen model was very similar to those shown in Table 10 for the HFEC database. When allowances are made for model differences and definitions, the patterns of error classification using the other models (including Reason's) were also similar to those of the HFEC database.

O'Hare et al. (1994) also used the Rasmussen model (1982) for error classification in one of the two studies reported. The pattern of errors by cognitive function was again similar to that obtained in the HFEC database. The exception was the very high proportion of serious accidents associated with errors in goal setting in their data. The HFEC database had no errors in this classification because there were no data on which to base inferences about goal setting in the DC&ATG – Turbofan Summary Database. Further comparisons between the O'Hare et al. data and the HFEC database with regard to the relationship between error category and seriousness of the accident were not possible with the limited resources available to support the workshop effort; however, this might be of interest if there is support for further analyses in the future.

Shappell and Wiegmann (1997) have proposed yet another approach to human error analysis in airplane accident investigations which includes many categories of data not included in the models discussed above. The “contributing factors” of the HFEC database overlap somewhat with the Shappell and Wiegmann set of “unsafe conditions of the operator” and less with their “unsafe supervision” set. However, there is complete overlap of the HFEC database and their set called “unsafe acts of the operator.”

Shontz (1997) conducted a study of pilot reactions to high-power compressor stall/surges under conditions where the pilots were not expecting the event. (The pilots assumed they were only participating in a CFIT [controlled flight into terrain] procedure validation process.) No inappropriate actions were taken on wrong engines during the event, but the interpretations of what was happening varied widely across pilots, as did the procedures called for and executed. Thus, the errors and inappropriate response categories for this study matched those of the HFEC database with the exception of execution errors.

This review of related research indicates that the HFEC model and analysis has produced results which are similar to those of both research studies (Wildzunas, 1997; Shontz, 1997) and error classification efforts (Wiegmann and Shappell, 1997; O’Hare et al., 1994) with regard to the cognitive function categories used and the pattern of errors within these categories. The HFEC analysis and classification results can be improved with additional reliability and validity checks; but the basic findings appear to be on target, and the workshop recommendations appear to be relevant.

8.5 Generic Human Factors Recommendations for Validating Recommended Training and Design Solutions

8.5.1 Recommendations for Training

- Eventually, current training scenarios should be analyzed to avoid redundancy in the initiating PSM events used (especially V_1 cuts) so that recommendations for realistic PSM event recognition and recovery training can be implemented without increasing overall training time. Some preliminary efforts in this area are a part of the process of developing recommendations (see, for example, Appendix M, page 165).

- Cooperation of a selected set of airlines should be sought for the purpose of evaluating the effectiveness of training recommendations. Proficiency checks and LOFT [line-oriented flight training] scenarios for individual pilots should contain PSMs which vary in both type and regularity of appearance within and across test sessions — i.e., pilots should not be able to anticipate getting the same PSMs each time they receive proficiency checks or even getting a PSM with every proficiency check. The PSM event simulation should be consistent for all pilots in the test group. Pilot behavior in the presence of unexpected PSM events should be recorded in detail and summarized to gauge effectiveness of the simulation and training. This would require de-identification of all performance behavior in terms of both individuals and airlines.

- Both the quality and extent of reporting of pilot behavior in response to PSM events that occur during revenue flights should be upgraded in order to develop the database necessary to evaluate training effectiveness. This should be a long-term effort involving as many airlines as possible. The objective would be to determine if, following training and/or dissemination of an “awareness package,” the rate of RTOs and wrong-engine actions in the presence of surges actually decreases. The process established should be kept in place long enough to determine if the “boomerang effect” occurs; this is a common occurrence following efforts to enhance pilot awareness of appropriate responses to unsafe conditions through dissemination of awareness material or with one-shot training exercises.[17]

8.5.2 Recommendations for Design

The validation of design recommendations per se may be more difficult in that it presumes that a design solution is more efficacious (at least in the long run) than a training solution. The evidence to support validation of a design recommendation typically must be stronger and more persuasive than that necessary to validate a training solution, because the former have much greater economic implications than the latter, and the evidence for greater safety impact is seldom any stronger. The exception to this is when design solutions are actually tested by gathering human performance data under carefully controlled conditions. Training solutions are typically assumed to be effective.

The validation of design recommendations should include evidence to support the contention that a design solution is in the best interests of all concerned. Generic requirements for this process are:

- Current design should have clear shortcomings in terms of information transfer capabilities that cannot readily or reliably be overcome with reasonable training and continuous testing via proficiency checks and LOFT scenarios;

- Target airplane models can be identified for the design recommendation, and potential value in terms of error reduction with the implementation of the design recommendation can be estimated;

- Credible design solutions can be generated from the recommendation(s); and,

- Credible testing procedures, metrics and equipment (especially simulator capabilities) are available to evaluate design solutions.

With respect to the last requirement, it is recommended that combined government and industry support be provided to develop test methodology (procedures, metrics and equipment) that produces results which are clearly and unequivocally valid for the civil aviation operational environment. Techniques from the research lab do not always meet this requirement. The group also needs metrics which represent system performance in terms that are meaningful for, and directly applicable to, the operational environment. Any number of efforts have attempted to achieve these objectives in venues other than the civil transport flight deck; these can provide both conceptual and technical guidance for achieving the methodological breakthroughs required. But, the requisite methodology does not yet exist — it must be developed, and should be, in a timely manner.

9.0 Regulatory Requirements

Commercial transport airplanes designed and certified under FARs/JARs Part 23 or Part 25 are required to be capable of continued safe flight following the failure of the most critical powerplant at the most critical point of the flight. From the analysis carried out by the group, it has been identified that a primary cause of the powerplant-related accidents and incidents has been the fundamental inability of the flight crew to correctly identify and/or respond to the initial powerplant malfunction. Review of the regulatory requirements has shown that the requirements to train flight crews for abnormal propulsion system behavior are assigned to flight engineers under [FARs] Part 63. Also, although training on handling thrust loss is assigned to pilots under [FARs] Part 61, there are no references to Part 63 in Part 61. The industry adoption of two-person flight crews as a standard has left the issue of propulsion system malfunction recognition training essentially not addressed. A similar situation exists in both Transport Canada and JAA regulations, based on preliminary reviews.

The task group considers that regulatory action may be appropriate in a number of areas to address this issue. The areas of consideration for regulatory review are threefold: first, a need to include both generic and type-specific engine malfunction recognition training at appropriate points in the training and checking curricula; second, the inclusion of specific requirements for realistic training-simulator modeling of engine malfunction, including audio and tactile modeling; and, third, possible changes to the powerplant instrument requirements contained in the airplane design codes.

9.1 Propulsion System Malfunction Recognition Training

With the significant increase in engine reliability, it is likely that many pilots will go through their entire careers without experiencing a serious propulsion system malfunction. The existing [FARs] Part 61 training requirements concentrate on ensuring that the pilot can handle the airplane in the event of an engine failure (thrust loss). This training is normally accomplished, either in a simulator or on the airplane, with a power cut and rapid loss of thrust at the critical point of flight (V_1). This is not representative of the most probable failures actually seen in operation, such as high-power stall/surge or unidentified loss of thrust from a low-power situation.

The task group therefore proposes that ARAC be tasked to consider amending the training requirements to include engine failure recognition training at appropriate points in the syllabus. The following FARs are recommended for review to include engine failure recognition training:

- Part 61 — Certification: Pilots and Flight Instructors;
    - Subpart E, Paragraphs 125 and 127;
    - Subpart E, Paragraphs 153, 155 and 157; and,
    - Appendix A and Appendix B; and,
- Part 121 — Operating Requirements: Domestic, Flag and Supplemental Operations;
    - Subpart N, Paragraphs 403(a)(3), 419(a)(1) and (2), and 439(b)(2);
    - Subpart O; and,
    - Appendix E and Appendix F.

Appropriate changes to equivalent sections of [FARs] Part 135 — Operating Requirements: Commuter and On-demand Operations — are also recommended.

Where training is carried out in the airplane, rather than in a training device, it is recommended that specific engine failure recognition ground training should be mandated. This is particularly relevant to Part 135 operations.

Equivalent changes to JAR–FCL 1, Subparts D, E and F, to require inclusion of engine failure recognition training as both generic and type-specific training are also recommended. Again, revision to JAR–OPS 1, Subpart N, Appendixes 1 through 1.965, should be reviewed for inclusion of specific engine failure recognition ground training where use of the airplane, rather than a training device, is permitted.

9.2 Simulator Modeling

It has been established that engine failure models incorporated in training simulators, which in some cases cover a wide range of failures, are often of questionable realism. Only the rapid thrust loss after a fuel cut used for V_1 engine failure handling training was found to be generally accurate. This lack of accuracy may not only lead to a lack of awareness of actual engine failures, but may actually provide negative training that could lead flight crews to misinterpret symptoms of genuine engine failures.

It is recommended that the following regulations be reviewed with the intention of incorporating requirements that ensure engine failure modeling is properly representative of the failures likely to occur in service, particularly for the audio and tactile (vibration) aspects of such failures/malfunctions: [FARs] Part 21, Subpart N, Paragraphs 407, 424, 425 and 441(c); and Part 21, Appendix H.

FAA Advisory Circular (AC) 120-40 (as amended) and AC 120-45 (as amended) will require review to include the need for accurate simulation of engine failures.

It is also recommended that Part 21, Appendix H include a requirement that the simulator model be based on data provided by the engine manufacturer. A method should be found to ensure that the models of propulsion system malfunctions provided by the simulator manufacturers are based on data for the most-probable malfunctions, as provided by the airframe and engine manufacturers.

Equivalent changes to JAR–STD and other affected regulations are also recommended.

9.3 Powerplant Instrumentation

A wide range of powerplant instrumentation is provided on multi-engine commercial airplanes. Some evidence is available regarding the effectiveness of the different ways in which powerplant information is presented to flight crews. It is proposed that ARAC be tasked with reviewing the requirements of FARs/JARs Parts 23 and 25, Paragraphs 1305, 1321, 1337 and 1585, in order to produce an updated standard for powerplant instrumentation based on the information available. At this time, it is not expected that retrospective application of a revised standard of instrumentation will be justified.

10.0 Conclusions

1. The purpose of flight training programs is aimed primarily at ensuring that the pilot can exhibit the flying skills necessary to control the airplane satisfactorily at all times, including in the event of an engine failure. The pilot's ability to handle engine failures is dependent on the sum of his or her training and service experience. With the significant increase in powerplant reliability, a pilot's general exposure to in-service powerplant malfunctions can no longer be assumed to always be sufficient to ensure that the malfunction is properly identified and appropriately handled.

2. The information developed in this study indicates that there is a shortfall in some pilots' abilities to recognize and/or handle propulsion system malfunctions. The shortfall from initial expectation is due to improved modern engine reliability, changing propulsion system failure characteristics (symptoms), changes in flight crew experience levels and related shortcomings in flight crew training practices and training equipment.

3. Industry has not provided adequate pilot training processes or material to ensure that pilots are provided with training for powerplant malfunction recognition. This shortcoming needs urgent action to develop suitable text and video training material which can be used during training and checking of all pilots for both turboprop-powered and turbofan-powered airplanes.

4. The training requirements related to recognition and correction of in-flight malfunctions are found in [FARs] Part 63, Appendix C, for flight engineers. The disposition of the flight engineer's recognition training requirements to pilots of airplanes where no flight engineer position exists is not apparent. However, the expectation does exist that the pilots will perform the duties of the flight engineer.

5. Concerns were also identified with the published propulsion system malfunction procedures and the methods used for the validation of their correctness.

6. A substantial number of the turbofan accidents reviewed are related to propulsion system malfunctions resulting in high-speed aborts, including above V_1 and V_R [rotation speed]. Accordingly, current pilot training may be deficient in addressing the symptoms of the malfunctions, particularly loud noises and the importance of V_1 and V_R speeds. There was only one RTO-related accident identified on a turboprop airplane in the database.

7. A significant number of turboprop and turbofan accidents have been identified where training of propulsion system malfunctions on or near the runway was taking place.

8. The dominant cause of turboprop PSM+ICR accidents is loss of control. The largest number of events occur during the takeoff phase of flight. There was only one turboprop RTO accident; this is a significant difference from the turbofan airplane accident data.

9. The review of simulator capabilities shows that the technology exists to better produce realistic propulsion system malfunction scenarios. However, at the moment, realistic scenarios are often not properly defined or based on airframe or powerplant manufacturers' data. Rather, the scenarios are often based on the customers' perceptions of the failure scenario. There is generally no airframe or powerplant manufacturers' input into realistic engine failure/malfunction scenarios as represented in simulators. Furthermore, the engine failures currently addressed in most training do not cover loud noises and the onset of heavy vibration. Complete and rapid loss of thrust is currently being trained and is probably the most critical from an airplane handling perspective; however, this failure

is not necessarily representative of the malfunctions most likely to be encountered in service. There is also evidence that this lack of realism in current simulations of turbofan propulsion system malfunctions can lead to negative training, increasing the likelihood of inappropriate crew response. Review of current simulators indicates that the tactile and auditory representation of airplane response to engine compressor stall/surge is very misleading.

10. Considerable effort was undertaken to review existing engine failure indication systems and their differences and similarities between airplane manufacturers. All airframe manufacturers of later turbofan-powered airplanes inhibit alerts as a function of phase of flight, but at somewhat different phases of flight. The group believes that standardization of the flight-phase inhibit points is desirable. In general, the propulsion system malfunction alerts are not inhibited on turboprop-powered airplanes. The group also believes that a review of powerplant instrumentation requirements could be beneficial. In particular, engine surge, asymmetric thrust, engine failure and tire failure annunciations were thought to be worthy of consideration to assist the crew in determining what malfunction had occurred. However, there is currently no clear indication substantiated by review of service experience or human factors testing that establishes whether the propulsion system malfunction warning systems installed on current airplanes are either beneficial, neutral or detrimental. Research on the issue is desirable.

11. Adequate data could not be found to link standards of engine failure/malfunction indications with the probability of inappropriate crew response. Design evaluation suggests that retrospective embodiment of engine failure/malfunction indications, particularly on non-FADEC engines, would be extremely difficult, if not impossible. There have been no human factors studies performed to determine if a link exists between engine failure/malfunction warnings and a reduced level of engine failure/malfunction plus crew error accidents/incidents. There are arguments that real or false warnings may exacerbate the problem in certain circumstances, particularly during the takeoff phase of flight. Clearly, training would still be required.

12. The group agreed that, unless propulsion system malfunction recognition training was an actual requirement, such training would likely not take place consistently across the industry. The group further agreed that requirements for better realism of simulator reproductions of powerplant malfunction/failure scenarios should also be mandated. The affected sections of the JARs and FARs which are recommended for review are identified in Section 9. This regulatory activity should be conducted under the ARAC umbrella and should be included in the harmonization work program. The review of the requirements should cover the following points:

    - Identification of propulsion system malfunctions to be trained;
    - The design and use of flight crew training equipment;
    - The inclusion of propulsion system malfunction recognition training in both training and checking programs; and,
    - Powerplant instrumentation requirements.

13. Data suggest that various opportunities exist for negative transfer of trained pilot behavior and experience when transitioning between different airplane types.

14. Since the turboprop database is not data rich, many of the following specific conclusions are based on limited incident information received from manufacturers and operators represented in the group. The participants' experience of actual incidents in both operation and simulations was used as a basis for reaching these conclusions:

    - Current constant attitude airplane stall recovery training may be detrimental to the pilot's low airspeed control during engine-failure operations. The assessment of error types indicates that training and regulation could reduce skill-based errors and rule-based errors by pilots;
    - The assessments of error types suggest that skill-based errors and rule-based errors predominate;
    - Flight-idle and zero thrust are generally not the same. The use of flight-idle power settings in simulated engine-out training or as a precautionary power setting may result in negative thrust (increased drag) with an unfeathered propeller and expose the crew to an increased hazard;
    - The use of throttle chops to flight idle to simulate real engine failures has little training value in relation to training pilots to identify real propulsion system malfunctions or failures. This practice is of benefit to train airplane handling;
    - During one-engine-inoperative operations, priority should be placed on airspeed control. With an engine failed, speed can only be controlled by adjusting attitude, as power is already at the maximum. This technique may be in conflict with the basic stall recovery training and may therefore cause confusion during low-speed flight with an engine failure; and,
    - Turboprop flight instrument displays are evolving. There appear to be weaknesses in the display of lateral acceleration (slip). Flight director systems that are not specifically designed for takeoff and go-around

could give inappropriate commands following propulsion system malfunction or failure.

11.0 Recommendations

1. The requirements need to be enhanced to recognize the need for pilot training in powerplant failure recognition. It is recommended that [FARs] Parts 61 and 121, JAR–OPS and JAR–FCL be amended to require inclusion of engine failure/malfunction recognition in pilot training syllabi.

2. Regulatory authorities should review the requirements and content of pilot training for propulsion system malfunction or failure and the control of the airplane immediately after takeoff.

3. The regulatory authorities should establish and implement a rigorous process to ensure that the following occur during the development of a training program:

   - Identification of powerplant failure conditions that need to be trained;

   - Preparation of the training aids (tools and methods);

   - Establishment of the appropriate means to conduct the training;

   - Assurance that each flight crewmember receives the appropriate training for both malfunction recognition and proper response to it; and,

   - Validation of effectiveness, along with a feedback loop to improve/update training.

4. The performance of V_1 thrust cut training in the airplane has caused a number of hull loss/fatal accidents. The value of this training in the airplane should be scrutinized and only conducted with extreme care. It is the project group's belief that this specific training could be better effected in simulators. Where suitable simulators are not available, the airplane handling task can be adequately and much more safely trained at altitude where recovery from extreme upset conditions can be accomplished.

5. The aviation industry should undertake the development of basic generic text and video training material on turboprop and turbofan propulsion system malfunctions, recognition, procedures and airplane effects.

6. The regulatory authorities should establish a means to ensure that the simulators used to support flight crew training are equipped with the appropriate realistic propulsion system malfunctions for the purpose of "recognition and appropriate response training," and that the simulated malfunctions are consistent with the propulsion system malfunctions identified as needing to be trained. As a minimum, the airframe and engine manufacturers should be involved in the development of the simulation of propulsion system malfunctions. The scenarios that need to be included in training programs should focus on the accident/incident data produced by this group. The industry needs to ensure that propulsion system malfunctions reproduced in simulators do not produce negative training.

7. The requirements for propulsion system instrumentation should be reviewed, and requirements and advisory material related to powerplants and propellers should be established. This activity should include:

   - A review of propulsion system parameters to determine if improved engine and propeller displays or methods can be found to present information in a manner which would help the flight crew diagnose malfunctions;

   - Failure and malfunction annunciation and warnings to provide improved means for crews to identify propulsion system malfunctions. The areas for consideration include the types of annunciation and warnings (visual, aural, tactile, etc.), introduction of annunciations for engine surge, asymmetric thrust, engine failure, tire failure, and standardization of warning and annunciation inhibits; and,

   - Standardization among the airplane manufacturers regarding engine caution and warning messages, and inhibit strategies during different flight phases (reference ARP 450D).

8. The retroactive embodiment of additional engine failure warning on existing airplanes would be both difficult and costly. Therefore, research and development are required prior to any possible recommendation for retroactive installation of such equipment. Methodologies are not yet available that would allow evaluation of the benefits or detriments of the introduction of additional annunciations of propulsion system malfunctions to existing airplane types. These must also be developed (see Recommendation 10).

9. Flight training departments should enhance training methodologies to educate and train pilots in propulsion system malfunction effects on airplane performance. This relates to both the frequency and quality of training given in this area. All pilots need solid understanding of the performance factors that drive V_1, V_R, V_2 and other important performance and handling requirements. It is essential that the specialized training materials developed in areas such as propulsion system malfunction are properly communicated to the line-flying pilots.

   - Industry should provide training guidelines of how to recognize and diagnose the engine problem by using all available data in order to form the best possible information about the state of the propulsion system.

- Circumstances of negative transfer from previous training or operations should be identified, and their lessons learned should be communicated as widely as possible within the industry.

10. The aviation industry should sponsor activity to develop appropriate human factors methodologies to address both annunciation and training effectiveness for turboprop and turbofan propulsion system failures.

11. The following recommendations are specific to turboprop airplanes:

    - The use of flight idle on turboprop airplanes for simulated engine failures or in the event of a malfunction should be reviewed by industry because of the potential association with loss-of-control events if the engine is not shut down.

    - Stall recovery training should be reviewed by industry and regulatory authorities for possible negative training effects in one-engine-inoperative situations.

    - Industry should investigate the suitability of turn coordinator instruments in training airplanes where commercial airplanes do not use these displays.

    - There should be formal training and qualification requirements for instructors and maintenance test pilots.

    - In terms of loss of control in turboprop airplanes, the certification requirements for the clear display of lateral acceleration should be reviewed.

    - The use of a flight director display should not be allowed during takeoff or go-around, unless it has been specifically approved for one-engine-inoperative takeoffs and landings, because of possible incorrect pitch guidance.♦

Notes and References

1. V_1, formerly called takeoff decision speed, is defined by the U.S. Federal Aviation Regulations (FARs) and the Joint Aviation Requirements (JARs) as: "the maximum speed in the takeoff at which the pilot must take the first action (e.g., apply brakes, reduce thrust, deploy speed brakes) to stop the airplane within the accelerate-stop distance. V_1 also means the minimum speed in the takeoff, following a failure of the critical engine at V_{EF}, at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance." Critical engine is defined in reference 7 below. V_{EF} is defined as "the speed at which the critical engine is assumed to fail during takeoff."

2. Aerospace Industries Association (AIA). *Initial Report on Propulsion System and APU Related Aircraft Safety Hazards, 1982 through 1991*. A special report prepared at the request of the U.S. Federal Aviation Administration. May 1993.

3. Reason, James. *Human Error*. Cambridge, England: Cambridge University Press, 1990.

4. FARs Part 25.1321 and JARs 25.1321 state: "(c) Required powerplant instruments must be closely grouped on the instrument panel. In addition — (1) the location of identical powerplant instruments for the engines must prevent confusion as to which engine each instrument relates."

5. SAE [Society of Automotive Engineers] International Aerospace Recommended Practices (ARP) 450D is superseded by ARP 4102/4, *Flight Deck Alerting System (FAS)*. April 1999.

6. U.S. Federal Aviation Administration Advisory Circular 60-14, *Aviation Instructor's Handbook*, said, "Primacy, the state of being first, often creates a strong, almost unshakable, impression. For the instructor, this means that what is taught must be right the first time. For the student, it means that learning must be right."

7. FARs Part 1 defines critical engine as "the engine whose failure would most adversely affect the performance or handling qualities of an aircraft."

8. Trujillo, Anna C. "Propulsion System Malfunction Plus Inappropriate Crew Response." Paper presented at AIA/AECMA Workshop on Propulsion System Malfunction Plus Inappropriate Crew Response, Seattle, Washington, United States, January 1997.

9. In this context, "integrate" is taken to mean the process of gathering data that are relevant to the problem at hand in order to develop an accurate "picture" (individual data points plus the relationships among them) of the propulsion system malfunction.

10. No errors pertaining to the "establish goals" category could be inferred because of the very limited nature of the data in the DC&ATG–Turbofan summary database necessary to appropriately make such inferences.

11. Shontz, W.D. "Crew Information Requirements Analysis (CIRA)." Boeing Document D6-82110. 1997.

12. Wiegmann, D.A.; Shappell, S.A. "Human Factors Analysis of Postaccident Data: Applying Theoretical Taxonomies." *The International Journal of Aviation Psychology* Volume 7 (1997): 67–81.

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15. O'Hare, D.; Wiggins, M; Batt, P.; Morrison, D. "Cognitive Failure Analysis for Aircraft Accident Investigation." *Ergonomics* Volume 37 (November 1994): 1855–1869.

16. Rasmussen, J. "Human Errors: A Taxonomy for Describing Human Malfunctions in Industrial Installations." *Journal of Occupational Accidents* (No. 4, 1982): 311–333.

17. Accidents and incidents related to a particular unsafe condition appear to be reduced for a period of time following dissemination of "awareness" material but eventually return to or near the pre-dissemination rate of occurrence.

[FSF editorial note: This report is adapted from the Aerospace Industries Association/The European Association of Aerospace Industries' "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Nov. 1, 1998. FSF editorial staff worked with the report's authors, and some changes were made for clarity and style.]

Further Reading From FSF Publications

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FSF Editorial Staff. "Ice Ingestion Causes Both Engines to Flame Out During Air-taxi Turboprop's Final Approach." *Accident Prevention* Volume 56 (February 1999): 1–8.

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Appendix A

Contributing Organizations and Individuals

Aero International (Regional)
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- Michael Shelton
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- Capt. John Sciera
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Association of European Airlines
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Atlantic Coast Airlines
- Ken Latour

Atlantic Southeast Airlines (Regional Airline Association)
- Dean Karnatz

Bombardier Aerospace
- Jim Donnelly
- David Lamb

British Aerospace
- Tim Allen
- Mike Bayley
- Paul Emmerson
- Dave Gibbons
- Daniel Gurney
- Len Houston
- Colin Irvine
- Martin Maltby
- Rene Nibbelke

CAE Electronics
- Capt. Kip Caudrey

Canadian Airline Pilots Association
- Al Murray

Canadian Airlines International
- Peter Howe
- Capt. Jack Tucker

Cessna Aircraft Co.
    Doug Hazelwood
    Donald Mallonee

CHIRP
    Peter Tait

Cranfield University
    Helen Muir

Embry-Riddle Aeronautical University
    Marco Pizer

European Regional Airlines Association
    Roy Humphreyson
    Ian Wigmore

(U.S.) Federal Aviation Administration
    Kathy Abbott
    Donald Armstrong
    Anne Azevedo
    Tom Boudreau
    Martin Buckman
    Tom Clinton
    Ed Cook
    Michael Dostert
    William Emmerling
    Steven Kolb
    Hals Larsen
    Dy Le
    George Lyddane
    Lee Nguyen
    Lanny Pinkstaff
    Robert Pursel
    Thomas Toula
    James Treacy

Federal Express Corp.
    Capt. Ryan Swah

Fokker Services B.V.
    Wim Overmars

General Aviation Manufacturers Association
    William Schultz

General Electric Aircraft Engines
    Roland Crandall
    Tony Freck
    Sarah Knife
    Joseph Marksteiner

Gulfstream Aerospace Corp.
    Ted Mendenhall
    William Shira

Hartzell Propeller
    Roger Stallkamp

Independent Consultant
    Tony Wassell

International Air Transport Association
    Tore Granaas

International Federation of Air Line Pilots Associations
    Capt. Steve Last

Joint Aviation Authorities
    Robin Boning
    Hazel Courtney
    David Lambourne
    Rex Riddington
    Laurent Gruz

KLM
    Desiree Van Leeuwen

KLM — IFALPA
    Wynand Moonan

Lockheed Martin Aero and Naval Systems
    Richard Trusis

NASA Langley Research Center
    Paul Schutte
    Anna Trujillo

NASA Lewis Research Center
    Sanjay Garg
    Carol Russo
    Donald Simon

(U.S.) National Transportation Safety Board
    Kenneth Egge
    Jerome Frechette
    Douglas Wiegmann

Pratt & Whitney Canada
    Mark Feeney

Pratt & Whitney
    Dick Parker
    Al Weaver

Raytheon Aircraft
- Eric Griffin
- Conrad Jackson

Reflectone
- Capt. Bruce Anderson

Regional Airline Association
- David Lotterer

Rolls Royce
- John Chambers
- Michael Cooper
- David Gibbons

Securite' de Vols — Aviation Safety
- Pierre Mouton

Smiths Industries Aerospace
- Alison Starr

SNECMA—Villaroche
- Gerard Clergeot
- Yves Halin

The Boeing Co.
- David Carbaugh
- James Johnson
- Pam Rosnik
- G. Philip Sallee
- William Shontz
- Jerry Swain
- Dennis Tilzey
- Van Winters

The Boeing Co. — Douglas Products Division
- Steven Lund
- Alan Macias
- Paul Oldale

Tompson Training and Simulation
- Michael Brookes
- Mark Dransfield

Transport Canada
- Andrew Chan
- Len Cormier
- Michel Gaudreau
- Larry Green
- Merlin Preuss

Transportation Safety Board of Canada
- Nick Stoss

U.K. Flight Safety Committee
- Peter Richards

U.S. Air Force
- Ken Burke
- Major Jeff Thomas

U.S. Army
- Lawrence Katz
- Robert Wildzunas

United Airlines
- Steve Ferro
- Chuck Ferrari
- Capt. Bill Yantiss♦

CHIRP = U.K. Confidential Human Factors Incident Reporting Programme
IFALPA = International Federation of Air Line Pilots Associations
NASA = U.S. National Aeronautics and Space Administration

Appendix B

U.S. National Transportation Safety Board Final Recommendations From Investigation of Jetstream 31 Accident, 13 Dec. 1994

Findings:

1. The flight crew was properly certificated in accordance with U.S. Federal Aviation Regulations [FARs] and company procedures.

2. The airplane was certificated and maintained in accordance with existing regulations, except for the improper installation of the FPA-80 [Collins flight profile advisory system] as a substitute for a GPWS [ground-proximity warning system].

3. Air traffic control services were properly performed.

4. Weather was not a factor in the accident.

5. The captain associated the illumination of the left engine IGN [ignition] light with an engine failure.

6. The left engine IGN light illuminated as a result of a momentary negative torque condition when the propeller speed levers were advanced to 100 percent and the power levers were at flight idle.

7. There was no evidence of an engine failure. The CVR [cockpit voice recorder] sound spectrum analysis revealed that both propellers operated at approximately 100 percent rpm until impact, and examination of both engines revealed that they were operating under power at impact.

8. The captain failed to follow established procedures for engine failure identification, single-engine approach, single-engine go-around, and stall recovery.

9. The flight crew failed to manage resources adequately; specifically, the captain did not designate a pilot to ensure aircraft control, did not invite discussion of the situation, and did not brief his intended actions; and the first officer did not assert himself in a timely and effective manner and did not correct the captain's erroneous statement about engine failure.

10. Although the first officer did perform a supportive role to the captain, his delayed assertiveness precluded an opportunity to avoid the accident.

11. Flight 3379 did not encounter any wake turbulence during the approach to Runway 5L or during the departure from controlled flight.

12. AMR Eagle training did not adequately address the recognition of engine failure at low power, the aerodynamic effects of asymmetric thrust from a "windmilling" propeller, and high thrust on the other engine.

13. AMR Eagle provided "negative simulator training" to pilots by associating the IGN light with engine failure and by not instructing pilots to advance both power levers during single-engine go-arounds as required by the operation manual.

14. AMR Eagle and Flagship Airlines crew training records do not provide sufficient detail for management to track performance.

15. Flagship Airlines management was deficient in its knowledge of the types of crew records available and in the content and use of such records.

16. Flagship Airlines did not obtain any training records on the accident captain from Comair. Further, Comair's standard response for employment history would not, had it been obtained, have included meaningful information on training and flight proficiency, despite the availability of such data.

17. The FAA [U.S. Federal Aviation Administration] did not provide adequate guidance for, or ensure proper installation of, the FPA-80 as a substitute for a GPWS on Flagship's fleet.

18. The structure of the FAA's oversight of AMR Eagle did not provide for adequate interaction between POIs [FAA principal operations inspectors] and AMR Eagle management personnel who initiated changes in flight operations by the individual Eagle carriers.

Probable Cause:

The National Transportation Safety Board determines that the probable causes of this accident were: 1) the captain's improper assumption that an engine had failed, and 2) the captain's subsequent failure to follow approved procedures for engine failure, single-engine approach and go-around, and stall recovery. Contributing to the cause of the accident was the failure of AMR Eagle/Flagship management to identify, document, monitor and remedy deficiencies in pilot performance and training.

Recommendations:

As a result of the investigation of this accident, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

- Publish advisory material that encourages air carriers to train flight crews in the identification of and proper response to engine failures that occur in reduced power conditions, and in other situations that are similarly less clear than the traditional engine failure at takeoff decision speed. (Class II, Priority Action) (A-95-98);

- Review the organizational structure of the FAA surveillance of AMR Eagle and its carriers with particular emphasis on the positions and responsibilities of the focal point coordinator and principal inspectors, as they relate to the respective carriers. (Class II, Priority Action) (A-95-99);

- Ensure that all airplanes (other than the AMR Eagle J3201 fleet) that currently use a Collins FPA-80 in lieu of GPWS, under the provisions of [FARs Part] 135.153, have installations that comply with Federal regulations. (Class II, Priority Action) (A-95-100);

- Require all airlines operating under Parts 121 and 135 and independent facilities that train pilots for the airlines to maintain pertinent standardized information on the quality of pilot performance in activities that assess skills, abilities, knowledge and judgment during training, check flights, initial operating experience and line checks, and to use this information in quality assurance of individual performance and of the training program. (Class II, Priority Action) (A-95-116);

- Require all airlines operating under Parts 121 and 135 and independent facilities that train pilots for the airlines to provide the FAA, for incorporation into a storage and retrieval system, pertinent standardized information on the quality of pilot performance in activities that assess skills, abilities, knowledge and judgment during training, check flights, initial operating experience and line checks. (Class II, Priority Action) (A-95-117);

- Maintain a storage and retrieval system that contains pertinent standardized information on the quality of Parts 121 and 135 airlines pilot performance during training in activities that assess skills, abilities, knowledge and judgment during training, check flights, initial operating experience and line checks. (Class II, Priority Action) (A-95-118); [and,]

- Require all airlines operating under Parts 121 and 135 to obtain information, from the FAA's storage and retrieval system that contains pertinent standardized pilot training and performance information, for the purpose of evaluating applicants for pilot positions during the pilot selection and hiring process. The system should have appropriate privacy protections, should require the permission of the applicant before release of the information, and should provide for sufficient access to the records by an applicant to ensure accuracy of the records. (Class II, Priority Action) A-95-119)♦

Appendix C

Letter from U.S. Federal Aviation Administration (FAA) To Aerospace Industries Association (AIA)

U.S. Department
of Transportation
**Federal Aviation
Administration**

Transport Airplane Directorate
Aircraft Certification Service

1601 Lind Avenue, S.W.
Renton, Washington 98055-4056

06 March 1996

Mr. Howard Aylesworth, Jr.
Director, Airworthiness and Regulations
Aerospace Industries Association of America, Inc.
1250 Eye St. N. W.
Washington, D.C. 20005-3922

Dear Mr. Aylesworth:

The purpose of this letter is to encourage the Aerospace Industries Association of America (AIA) to utilize data from previous AIA activity and a recent accident as a basis for initiating development of guidelines for an engine failure indication system.

On December 13, 1994, an American Eagle Jetstream Super 31 crashed near Morrisville, North Carolina. The National Transportation Safety Board investigation indicates that contributing causes of the accident were:

a. The captain’s improper assumption that an engine had failed.

b. The captain’s subsequent failure to follow approved procedures for engine failure, single-engine approach and go-around, and stall recovery.

Studies conducted by the AIA under the Continued Airworthiness Assessment Methodology, PC 345 Committee, previously identified that inappropriate flightcrew response to an engine malfunction is a leading cause of propulsion system related accidents. The data showed that crew error related accidents following an engine failure on airplanes with three engines (which incorporate cockpit indication of engine failure) are roughly 1 accident in 7,500 engine failure/shutdowns. Data for two-engine airplanes that do not incorporate an engine failure indication show 1 accident in roughly 700 engine failure/shutdowns. Discussion of this data with members of the AIA indicates that further review of the accident history should be undertaken to better understand the factors that result in flightcrew error following an engine failure. The review would include identification of any deficiencies in current simulations available for flight crew training. This review may result in a recommendation that [U.S. Federal Aviation Regulations] Parts 25 and 23 should be amended to require new airplane designs to provide pilots with an unambiguous indication of engine failure.

The FAA believes that there may be a number of contributing factors involved in these historical events that should be investigated, such as:

a. Heightened crew concern following an engine failure on a two-engine airplane.

b. Reduced flightcrew response times needed to maintain directional control on airplanes with two wing-mounted engines, which necessitate rapid response to an engine-out event.

c. Lack of guidance that establishes standards for engine manufacturers to provide a clear indication of “engine failure.”

d. Reduced experience level of flightcrew operating airplane types involved in these accidents.

e. The absence of engine failure recognition training.

f. The absence of realistic engine failure or malfunction simulations for training.

The FAA encourages that the AIA undertake a project to:

a. Review relevant events and determine what factors influence crew error following an engine failure.

b. Define safety-significant engine malfunctions.

c. Develop the guidelines for an appropriate engine failure indication system.

d. Define the process and guidelines for engine failure simulation.

e. Define guidelines for engine failure recognition training, and.

f. Identify the process for validating the effectiveness of these guidelines.

If the AIA study resulted in a finding [for] development of new regulatory requirements and/or guidance, these new requirements/guidance would apply to all new and possibly re-engined multi-engine FARs Part 25 and Part 23 (commuter category) aircraft, and embrace all types of propulsion systems. It is envisioned that this project would be started as an industry project that would be transferred to the appropriate Aviation Rulemaking Advisory Committee working group and involve harmonization with the other civil aviation authorities.. To ease the transition of the recommendations into the regulatory processes, we encourage broad participation by all elements of the aerospace industry, including human factors specialists, engine manufacturers, airplane manufacturers and flightcrew training specialists.

Sincerely,

Original signed by Darrell M. Pederson

Ronald T. Wojnar
Manager, Transport Airplane Directorate
Aircraft Certification Service

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Appendix D

Letter from Aerospace Industries Association (AIA) To the U.S. Federal Aviation Administration (FAA)

March 7, 1997

Mr. Ronald T. Wojnar
Manager
Transport Airplane Directorate
Federal Aviation Administration
1601 Lind Avenue S.W.
Renton WA 98055-4056

Dear Mr. Wojnar:

My letter of June 19, 1996 indicated that the AIA would undertake the activity you requested in your letter of March 6, 1996. The AIA planned to review accident and incident data associated with engine failures, coupled with inappropriate crew response, and examine the potential need for corrective action. The initial focus of the activity would be to assemble all relevant facts and data associated with historical accidents and incidents, experience with various mitigation approaches, fixed-base and motion-based simulator capabilities and programs, and other relevant information appropriate to a thorough study of engine failures coupled with inappropriate crew response. Once this had been accomplished, a follow-on phase would analyze and synthesize these data in order to draw appropriate conclusion.

Last June AIA had anticipated this project would be initiated before mid-September and would be completed by August of 1997. The phase identifying causal factors and engine malfunctions would begin in January 1997 and be completed by October of 1997. It was recommended that G. P. Sallee of Boeing chair this activity. Your concurrence was requested before initiating the project as outlined.

Lacking a formal FAA response to my June 1996 letter, yet with encouragement from the FAA staff, AIA launched the TC [Transport Committee] Project with a Workshop on “Propulsion System Malfunction Plus Inappropriate Crew Response” on January 14-16, 1997 at the SeaTac Red Lion Hotel in Seattle. A copy of the attendance roster is included herewith and shows participation from the FAA, [Joint Aviation Authorities], [U.S. National Transportation Safety Board], U.S. Air Force, [U.S. National Aeronautics and Space Administration Langley Research Center], [Air Line Pilots Association, International], and U.S., Canadian and European manufacturers.

The success of the workshop and the depth of material presented will minimize any schedule slippage due to a late start. The AIA TC Project chairman has requested that AIA ask AECMA [The European Association of Aerospace Industries] to jointly sponsor, co-chair and provide the focal point with respect to data collection and analysis of turboprop aircraft related events. This request is under active AIA review and I anticipate it will be positively received.

Based on the overall reaction to the workshop, AIA presumes that the TC Project plan meets the FAA’s need and has your approval. AIA will continue to report periodically on project status.

Sincerely,

Original signed by Howard Aylesworth, Jr.

Howard Aylesworth, Jr.
Director, Airworthiness and Regulations

HA:mps

Appendix E

Summary of Turbofan PSM+ICR* Events

* Propulsion system malfunction plus inappropriate crew response

Glossary

AGL = Above ground level

APU = Auxiliary power unit

ATC = Air traffic control

AVM = Airborne vibration monitor

CAA = Civil aviation authority

CAS = Calibrated airspeed

CB = Circuit breaker

c.g. = Center of gravity

CMC = Central maintenance computer

CVR = Cockpit voice recorder

DFDR = Digital flight data recorder

ECAM = Electronic centralized aircraft monitor

EDT = Eastern daylight time

EGT = Exhaust gas temperature

EICAS = Engine indicating and crew alerting system

EPR = Engine pressure ratio

FAA = U.S. Federal Aviation Administration

FDR = Flight data recorder

FL = Flight level

F/O = First officer

FOD = Foreign-object damage

GMT = Greenwich mean time

HPC = High-pressure compressor

HPT = High-pressure turbine

IAS = Indicated airspeed

ISA = International standard atmosphere

ICAO ARB = International Civil Aviation Organization Air Research Bureau

LPT = Low-pressure turbine

MAC = Mean aerodynamic chord

MCT = Maximum continuous thrust

MLG = Main landing gear

MTW = Maximum takeoff weight

N_1 = Low-pressure-compressor shaft speed

N_2 = High-pressure-compressor shaft speed

NLG = Nose landing gear

NTSB = U.S. National Transportation Safety Board

PIC = Pilot-in-command

PNF = Pilot not flying

RTO = Rejected takeoff

TLA = Thrust lever angle

TOGW = Takeoff gross weight

V_{MCG} = Minimum control speed on the ground with the critical engine inoperative

VMC = Visual meteorological conditions

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
10	73/1ST/2/HF	Loss of control	Final approach, go-around	Power loss

Summary of Event:

Power loss, go-around executed + loss of control (stall)

Summary of Narrative:

The aircraft was on final approach and cleared to land by the tower. When it reached 90 meters (300 feet) high, it initiated a go-around with full power. The aircraft pitched up in excess, stalled, banking to the right, and hit the ground about 2,500 feet to the right of the runway. No. 1 engine hit the ground with no power. No. 2 engine hit the ground with full power. Probable cause: pilot factor — failure to maintain flying speed. Contributing factor — powerplant failure/loss of thrust from one engine.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
39	*85/EWB/4/S	Loss of control	Cruise	Power loss

Summary of Event:

Power loss + failure to correct for thrust loss resulting in airplane stall

Summary of Narrative:

During cruise at 41,000 feet the airplane experienced a horizontal wind shear condition causing a gradual increase in airspeed and a response by the autothrottle system, which was in the mach mode and the autopilot was in the altitude-hold mode. The autothrottle system retarded the power levers gradually to idle (50 seconds elapsed time). As airspeed decreased power levers advanced slowly to MCT (40 seconds elapsed time) and engine no. 4 went into a sub-idle condition during the acceleration. The airplane began to roll off due to thrust asymmetry with the autopilot maintaining heading hold. The pilot then disengaged the autopilot and the airplane immediately rolled to the right and entered a near vertical dive into the clouds. The crew recovered control below 11,000 feet after exiting the clouds and regaining a visual horizon. Recovery was completed at 9,500 feet. The airplane experienced negative load factor and in excess of 5.0 Gs positive load factor. The crew managed to relight the no. 4 engine and landed uneventfully. The recommended procedure following a power loss is to disconnect the autopilot and/or re-trim with the autopilot engaged. Inspection of the airplane revealed substantial damage. NTSB probable cause: the captain’s preoccupation with an in-flight malfunction and his failure to monitor properly the airplane’s flight instruments, which resulted in his losing control of the airplane.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
77	95/2ND/2/HF	Loss of control	Go-around	Vibration and bang (low power surge), thrust loss

Summary of Event:

Single engine power loss (fan blade fracture) + go-around and loss of control

Summary of Narrative:

The airplane was cleared for the approach to runway 30 at approximately 200 feet above ground level when the crew initiated a go-around (reported to the tower as some kind of a problem) and subsequently lost control of the airplane. The investigation revealed that the engine suffered a fan blade fracture which ultimately resulted in a power loss. Witnesses and ATC indicate the airplane initiated a go-around but never gained altitude and rolled over and impacted the ground. The accident investigation report included the following findings: The probable cause of the accident is loss of control of the airplane over the course of attempt at restarting fuel (initiating go-around thrust) during landing with low power. Contributing causes to this situation: (1) the structural failure of the first-stage compressor blade from engine one, which led to a loss of power and a deviation from the landing trajectory; (2) the slow or late execution of the fuel restarting (go-around) procedure while operating on a single engine, unknown to the crew, which led to an irreversible loss of speed. The commission holds that the crew initiated a fuel restarting (go-around) procedure too late, thinking that it always had available power to its two engines.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
37	83/1ST/4/HF	Loss of control – asymmetric thrust	Takeoff	Power loss suspected

Summary of Event:

Power loss + loss of control

Summary of Narrative:

Airplane aborted takeoff and returned to hangar for engine maintenance. No. 4 engine was producing popping sounds at power level above 1.7 EPR. Cargo was unloaded prior to an attempted flight. It was reported that operating normally and one engine was set at reduced thrust. Just after takeoff the airplane veered to the right and impacted in an industrial neighborhood. Three crewmembers were fatally injured as well as 11 persons on the ground.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
50	88/EWB/3/I	Loss of control on ground	Landing	Thrust reverser to unlock position

Summary of Event:

Asymmetric thrust during landing due to forward thrust + failure to recognize

Summary of Narrative:

As the captain was deploying thrust reversers during landing, the no. 2 and no. 3 reversers unlocked and deployed (green-light condition), but the no. 1 reverser was binding and only moved to the unlock position (amber-light condition). Captain was not warned of this condition, though second officer should have monitored lights. Captain said he reached to check the no. 1 lever; at about that time, aircraft yawed right. Despite immediate action by the captain, directional control of the aircraft was lost due to yawing caused by inoperative thrust reverser. Aircraft continued off runway, crossed two taxiways and nose gear collapsed. Investigation revealed that after touchdown no. 1 engine accelerated with forward thrust as the no. 2 and no. 3 engine provided reverse thrust. At about the same time, the aircraft's nose lifted off the runway to a four-degree attitude and the aircraft went off the runway. An exam of the throttle quadrant revealed the S1-847 SW was curled/twisted and two support shafts (holding the SWs) were bent causing intermittent open of the no. 1 thrust reverser.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
44	85/EWB/4/H	Loss of control on ground – asymmetric reverse thrust; throttle cable failed	Landing	Thrust reverser (no. 1) did not transition to "rev thrust," yaw right, thrust increase to full

Summary of Event:

Asymmetric thrust + failure to recognize

Summary of Narrative:

During landing rollout, the airplane veered off right side of runway. Airplane passed through a drainage ditch, went over a grassy area, then onto a concrete ramp where the left outboard wing struck an illumination standard. This caused the airplane to spin around, coming to a stop on a 360 degree heading 250 meters to the right of runway 14 centerline. Weather was not considered a factor in the accident. All landing gear folded aft. The body gear is embedded in the fuselage to Station 1660, nose gear in electronics and equipment compartment, left wing gear separated. All nacelles resting on ground. Both inboard struts buckled upward. The fuselage is badly buckled and bent just aft of the wing between doors 3 and 4. Lower body is significantly damaged. Wing leading edges are damaged as are wing trailing edges which were struck by gear. It has been concluded that before the engines were placed in reverse, the no. 1 engine thrust control cable separated. If the cable parted before the reverse thrust lever signaled "open" to the solenoid controlling the air valve, the entire mechanical part of the cable, quadrant, directional valve, push pull cable and fuel control would be driven toward full forward thrust by the tension in the companion T1A cable. The pilot had no immediate means to control the no. 1 engine thrust, except to cut off fuel, and the airplane departed the runway before it could be stopped. The FAA issued an airworthiness directive for repetitive inspections until the bracket is replaced per the service bulletin. The airplane is considered uneconomical to repair and is declared a hull loss.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
34	83/1ST/2/HF	Loss of control – return to landing	Climb	Power loss (unrecoverable)

Summary of Event:

Power loss + returning to landing and loss of control – crash

Summary of Narrative:

Shortly after takeoff, engine no. 1 failed and the airplane turned back to the airport. While banking to the final approach, a wing tip contacted the ground inside airport boundaries. The fuselage fractured into three sections. Additional data: Flight was normal until transition from takeoff to climb at which time the no. 1 engine failed. The crew had not completed emergency procedures training. The crew did not apply procedures adequate to the emergency presented; they selected runway 3 (downwind) given that they should have returned to runway 21 or continued ahead. The final approach configuration, which was accomplished simultaneously (gear and flaps down), caused a reduction in airspeed; crew did not immediately select takeoff power, tried to land downwind on runway 3 instead of climbing out in the best configuration, then making a landing approach to runway 21 as advised by tower.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
61	*92/MNB/2/H	Loss of control	Descent	Stuck throttle

Summary of Event:

Asymmetric thrust (stuck throttle) + failure to recognize – control loss

Summary of Narrative:

The airplane impacted a mountain 630 meters high 32 kilometers from the airport during descent. DFDR data indicate with the autothrottle and autopilot engaged, the right thrust lever was responding intermittently to autothrottle commands. On level-off at 7,200 feet the left thrust lever responded normally but the right thrust lever did not respond and remained at idle. The autopilot attempted to compensate for asymmetric thrust by commanding left aileron. The heading started to drift right, and as the left engine approached 80 percent thrust, the airplane began to bank to the right. Heading select was activated on the mode control panel for 14 seconds and then deselected. The airplane was now passing 50 degrees bank. Control wheel steering was activated with a right-wing-down input opposite to that which the autopilot was holding. The right thrust lever was now advanced. and the right bank and nose pitch angle rapidly went to 78 degrees nose low. The airspeed increased through 300 knots with the engine thrust now nearly symmetric at 88 percent. Last bank angle was approximately 155 degrees right roll, pitch 78 degrees nose low, airspeed 413 knots.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
74	*95/EWB/2/H	Loss of control	Climb	No response to commanded power

Summary of Event:

Asymmetric thrust (stuck throttle) + crew failed to recognize – control loss

Summary of Narrative:

The first officer was manually flying the airplane, the autothrottle and flight directors were engaged, and profile mode was used. Soon after takeoff, the first officer started a left turn to go direct to the second waypoint which was northwest of the airport. After passing thrust-reduction altitude (at 1,500 feet AGL), the flaps were retracted to position 15/0 (the slats were still extended). At this point, the CAS was about 190 knots and the bank angle was initially stabilized near 20 degrees left. About 30 seconds later, the bank angle increased, the aircraft went inverted, the pitch decreased to 80 degrees nose down, and the aircraft crashed with a CAS in excess of 300 knots. No one survived the impact; 49 passengers and 11 crewmembers were on board. The preliminary investigation shows that the aircraft took off with a gross weight of 105 metric tons with a thrust setting that was equal to maximum takeoff thrust. Soon after takeoff, the aircraft was cleared to proceed to the second waypoint and the first officer started a left turn. After passing thrust-reduction altitude, the autothrust system transitioned to climb mode. However, the right throttle lever did not retard normally; it remained above climb power for about 55 seconds. This caused the left throttle lever to move (over 42 seconds) to the idle position. The most probable cause for this malfunction was excessive friction (binding) in the right throttle. This airplane, like most modern conventional airplanes, uses a single servo motor to move the throttle levers during autothrottle operations. In these systems, the autothrust system sends a signal to the servo motor to attempt to move both throttles until the EPR/N_1 of the engine which is producing the highest power reaches the new limit. In an apparent attempt to counteract the overbanking tendency, which was due to the thrust asymmetry, the first officer made a right roll input to the control wheel to stabilize the bank angle near 20 degrees. However, about 28 seconds later and for unexplained reasons, the first officer briefly made a large left roll input to the control wheel (an input into the turn and toward the engine that was at idle). This input apparently caused the bank angle to increase from about 30 degrees to 45 degrees. At this point, the first officer asked the captain to engage autopilot 1. The autopilot engaged for about one second; it then disengaged due to the pilot applying a pitch input force greater than 33 pounds to the control wheel. It is significant to note that, prior to losing control of the flight path, the roll inputs to the control wheel never exceeded 50 percent of the deflection that was available. Also, there is no evidence of any input to the rudder pedals throughout this event.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
43	*85/2ND/2/H	Loss of control – incorrect rudder	Climb	Compressor surge and power loss

Summary of Event:

Loud bang, compressor surge (power loss) + incorrect flight control input – control loss

Summary of Narrative:

Witness reported that soon after takeoff smoke and fire was coming from the right engine. The aircraft climbed to 700 feet AGL, (167 knots) then rolled into a steep right bank and crashed on airport property one-fourth of a mile from the runway in a nose-down attitude. Investigation showed that a right engine compressor blade and spacer exited through a 4-inch by 4-inch hole in the engine casing at the 11 o'clock position. Analysis of the voice and crash recorder showed that the airplane yawed right, was pulled up to 2 Gs and stalled before rolling right, possibly inverted, and crashing. NTSB probable cause: The flight crew's improper use of flight controls in response to the catastrophic failure of the right engine during a critical phase of flight, which led to an accelerated stall and loss of control of the airplane. Contributing to the loss of control was the lack of crew coordination in response to the emergency. The right engine failed from the rupture of the 9th to 10th stage removable sleeve spacer in the high pressure compressor because of the spacer's vulnerability to cracks. The crew applied incorrect rudder 4–5 seconds after the engine malfunction; initially the rudder was deflected in the correct direction. Both crewmembers were relatively inexperienced in the airplane.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
6	71/1ST/4/H	Loss of control – training	Takeoff	Power loss

Summary of Event:

Training flight – simulated engine-out + continued takeoff – loss of control – impacted ground

Summary of Narrative:

Aircraft was accomplishing a simulated heavy-weight takeoff. After brake release acceleration was satisfactory at 80 knots and at V_1 (115 knots). After V_1 no. 4 engine was throttled back to idle and at about this point the engineer noticed power loss on no. 3 engine. The aircraft started to veer to the right and the pilot rotated in an attempt to complete the takeoff. As the aircraft took a high nose-up position, the ventral fin contacted the runway and the aircraft departed the runway at a 30 degree angle. Aircraft traveled about 4,000 feet in a straight line across rough terrain, shedding engines and landing gear. The tail section of the fuselage separated just before the aircraft came to a stop. Fire spread rapidly and consumed the aircraft. The forward main door was found to be jammed shut, so the crew of five evacuated through the cockpit sliding windows. Probable cause established from ICAO ARB summary: Pilot factor– loss of control due to failure to follow correct procedures.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
68	94/2ND/3/I	Other – ATC communication error resulting in shutdown of good engine	Takeoff	Compressor surge

Summary of Event:

Vibration, power loss + RTO and shut down good engine (tower incorrectly identified)

Summary of Narrative:

Soon after beginning takeoff roll, tower called and told captain they saw flames out what they thought was the no. 1 engine. At the same time, aircraft began to vibrate and no. 1 engine was shut down. Takeoff was aborted and during taxi vibration continued until the no. 2 engine shut itself down. One C1 blade was found to be completely liberated from the hub and missing. Heavy damage to Bellmouth; inlet case struts broken from outer casing and twisted. No. 1 fan blade event was contained. Damage to no. 1 engine was previous FOD which was found during borescope required prior to ferry flight.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
35	83/1ST/2/H	Other – failure to complete shutdown procedures	Takeoff	Compressor surge

Summary of Event:

Loud bang, disintegration + failure to complete shutdown procedures – on runway

Summary of Narrative:

The aircraft sustained an uncontained failure of the no. 2 engine during takeoff roll. The aircraft was stopped on the runway and the passengers and crew evacuated via the emergency slides. Subsequent fire seriously damaged (hull loss) the aft portion of the airplane before airport emergency crews were able to bring it under control. It was reported that the crew neglected to activate the fire extinguishing system. Probable cause: improper shutdown procedure following an uncontained engine failure.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
81	96/1ST/4/Hf	Other – forced landing	Takeoff	Compressor surge – power loss

Summary of Event:

Compressor surge before V_1 + shutdown (fire warning) of another engine resulting in forced landing

Summary of Narrative:

Initial report: After takeoff at night the airplane failed to gain altitude and reportedly hit a church bell tower five miles from the runway and crashed into neighborhood houses. Reportedly, there were three crewmembers and about 27 local people fatally injured. The airplane reportedly contained cargo. The aircraft was destroyed by impact and postimpact fire when it crashed among buildings shortly after takeoff. The accident happened in darkness (2245 local) but in clear weather with unlimited visibility and a full moon. The aircraft had taken off from runway 23 but then apparently failed to climb. It subsequently struck a radio mast on rising ground about 4.5 miles beyond the end of the runway. The point of initial impact was some 125 feet above the airfield elevation (255 feet). At takeoff the aircraft's weight was understood to be 305,183 pounds. (MTW 322,200 pounds). It is reported that the aircraft's no. 2 engine experienced a surging condition during the takeoff roll before V_1. It is believed the crew reduced power on no. 2 during the surging condition and continued the takeoff. Additionally it is understood that the crew shut down no. 3 engine shortly after liftoff due to a fire warning and the side cowl from the no. 3 engine was found on the runway. Limited information.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
57	91/2ND/3/I	Other – RTO – misidentified malfunction	Takeoff	Heavy noise and vibration, compressor surge

Summary of Event:

Heavy noise and shaking, compressor surge + RTO, crew misidentified as tire failure

Summary of Narrative:

During takeoff roll at approximately 70 knots heavy noise and shaking was experienced. The aircraft began to veer toward the right side of the runway. Because the engine readings were normal the crew suspected a right main wheel puncture. The takeoff was aborted. The airplane turned off the runway and stopped for inspection. The nose dome on the right engine had departed its mountings and fallen down into the inlet. The nose dome, accessory drive housing and a fan blade were damaged. The cause of the nose dome coming loose is strongly suspected to be overtorquing of the nose dome.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
59	92/MWB/2/I	Other – asymmetric thrust, stuck throttle	Cruise	No response to commanded power

Summary of Event:

Asymmetric thrust (stuck throttle) + failed to detect asymmetry – airplane rolled, recovered

Summary of Narrative:

After level-off at a cruising altitude of FL390, airspeed slightly exceeded the desired value, and the autothrottles reduced the power to bring the airspeed back to the proper setting. However, when power was automatically reapplied, the left engine did not respond but remained at 0.98 EPR, this caused the right engine to reach a maximum cruise thrust of 1.54 EPR as the automatic system attempted to hold airspeed. The flight crew failed to detect the thrust loss on the left engine, and the airspeed bled from 250 knots to 180 knots during a period of seven minutes. The autopilot continued to hold altitude and ground track during this time, although an increasing amount of aileron deflection was required to do so. The aircraft rolled 15 degrees to the left when the autopilot was no longer able to maintain control with the asymmetric thrust condition. The crew disconnected the autopilot and took recovery action. The malfunctioning left engine was shut down and a single-engine landing was accomplished without further incident at an alternate airport.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
32	82/EWB/4/I	Other – bearing failure, crew failed to secure engine	Climb	Excessive AVM warning light, vibration, compressor surge

Summary of Event:

AVM exceedance + failure to secure engine resulted in disintegration

Summary of Narrative:

The report on this incident only refers to shutdown of engine no. 2 due to low-pressure bearing failure at 6,400 feet on climb-out. The aircraft did an approach and landed with three engines operating. Engine no. 1 was shut down in error and restarted for landing and was also damaged due to ingestion of debris from the LPT of the no. 2 engine. Some damage to the leading edge of the wing and the top of the wing inboard of the no. 2 engine. Report believes the event to be a related multiple due to engine and crew. An AVM exceedance and vibration alert occurred on no. 2 engine approximately 10 seconds after liftoff. The throttle was closed and then power was restored over a period of two minutes. It remained at power until the engine failed some 5 minutes and 38 seconds after the initial warning. (Emergency procedures require throttle closure and start lever to cut-off in response to high engine vibration.) After engine failure the captain ordered shutdown of the no. 2 engine but the flight engineer pulled the no. 1 engine fire handle. On seeing the no. 1 engine fuel valve light indicate closed, he then pulled the no. 2 engine shutdown tee handle. The no. 1 engine was restarted and a three-engine landing accomplished. The no. 2 engine failure started from a low-pressure location bearing failure, followed by fan shaft failure, LPT overspeed and major engine damage.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
62	*93/MNB/2/I	Other – compressor surge, unable to isolate which engine was affected	Go-around	Compressor surge

Summary of Event:

Loud bangs, compressor surge + difficulty isolating which engine

Summary of Narrative:

The crew initiated a low approach and go-around at approximately 100 feet AGL with autothrottles and autopilot engaged, and with flaps retracted to 1 degree. Go-around airplane performance was normal (engine thrust, climb performance – OK). The airplane accelerated to 180 knots and several hard engines surges were felt; though, which engine was surging was not readily apparent. At 3,500 feet the autothrottles were tripped off and both engine throttles were retarded to 1.03 to 1.05 EPR with continuous surges still occurring. Approximately three minutes later, visual and audible surges were identified as the right hand engine, and it was reduced to idle. The surging stopped at idle. An uneventful one-engine-inoperative landing was accomplished with flaps 20 and the right engine at idle. No further surges occurred. The HPC damage was seen from about the eighth stage rearward. Crew interviews stated that after the engine surges began the instruments appeared to have EPR, N_1 and EGT had oscillations but on both engines. It was not readily apparent which engine was in surge. It kind of looks like the oscillations were greater on the right than left engine. The nature of the surge was sounding like, boom-boom, boom-boom, boom-boom, a double quality to the sound. As the crew was unable to determine positively which engine was surging, the flight analyst engineer went to the back to start looking in the lower hold, and he heard the bleed unloading on the right engine and saw the right engine oscillating (moving around relative to the wing). He then informed the flight crew, and they retarded the throttle on the right engine and surging stopped. Five minutes after the start of surging the crew landed uneventfully.

Note: Not included in event calculations, but included because of difficulty in identifying which engine surged.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
51	88/2ND/2/HF	Other – dual engine power loss, continuous surging	Takeoff	Compressor surges

Summary of Event:

Loud bangs, compressor surge, power reduction + advanced throttles resulting in total power loss resulting in forced landing

Summary of Narrative:

Shortly after liftoff a large group of pigeons was encountered, resulting in a reduction of EPR indication and surging on both engines. Captain moved the thrust levers to fully forward as the airplane appeared not to be climbing at 300 feet above the runway elevation. Runway altitude, 6,020 feet. Both engines continued surging and the aircraft was now able to climb to 1,400 feet AGL where the crew executed a turn to downwind to set up a landing approach. As the captain turned to the base leg, both engines quit running and a gear-up landing was made in a small clearing. The left engine and the 41 section separated from the otherwise intact airplane. An intense fire quickly developed from released fuel. Many passengers were unable to evacuate before being overcome by smoke and fire. It was estimated from the engine damage that the left engine had ingested 15 birds, the right engine 11. Operating the engines in continuous surge caused the final-stage compressor blades to separate, subsequently melting the turbine blades. Analysis of the engines indicated that surge-free operation was possible by retarding the throttle to clear the surge condition even with the associated engine damage.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
58	91/MNB/2/H	Other – dual engine power loss, continuous surging	Climb	Continuous compressor surges (both engines)

Summary of Event:

Low humming noise, compressor surges + throttle slightly retarded without ceasing surges – forced landing

Summary of Narrative:

Airplane crash landed in an open field 4:05 minutes after takeoff. Power was lost on both engines due to wings shedding ice during rotation. The airplane broke into three sections. No airframe fire. No. 1 engine had a fire warning 1:31 minutes after takeoff. A pilot and three passengers saw ice coming off the right wing and suspect the same for the left side. The accident investigation report is summarized as follows: Prior to takeoff the aircraft was deiced. The captain made a rolling takeoff which was normal up to the rotation. In connection with liftoff the captain heard an abnormal noise which he could not identify. The noise was recorded by the aircraft's CVR as a low humming noise. After approximately 25 seconds of flight, the right engine started to surge. The captain throttled back on that engine somewhat, but without the surging ceasing. The surges continued until the engine stopped delivering thrust 51 seconds after the surges had started. When the flight had lasted 65 seconds, the left engine also started to surge, which the pilots did not notice before this engine also lost thrust. This happened two seconds after the right engine had failed. When the engines had failed the crew prepared for an emergency landing. When the aircraft was entirely out of the cloud at a height of 300 to 250 meters, the captain elected to try and land in a field in roughly the direction of flight.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
47	88/EWB/4/I	Other – excessive pitch attitude, power loss	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + pitch attitude exceeded target by 11 degrees – recovered

Summary of Narrative:

During takeoff in conditions of squall crosswinds, as the main wheels of the aircraft left the runway the compressor of the no. 4 engine surged, resulting in a thrust loss from that engine. The aircraft banked to the right and pitched up to an attitude of 22 degrees, which was some 11 degrees greater than that recommended after an engine failure. With the stick shaker operating, the aircraft descended towards the high ground that lies due west of the airport until the commander, using maximum thrust from the three remaining engines, was able to establish a climb profile, and the aircraft then achieved a safe height. The report concludes that the incident was caused by the following: a surge-induced loss of thrust from the no. 4 engine just after rotation; the commander delaying input of down elevator until the pitch had reached 22 degrees, which was well above that recommended; and consequently the scheduled three- engine climb performance not being achieved.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
27	81/1ST/4/I	Other – power loss, air turn-back, uncoordinated approach and landing, piloting skill	Climb	Compressor surge

Summary of Event:

Loud bang, power loss + uncoordinated approach and landing, veered off side at 80 knots

Summary of Narrative:

During climb, aircraft experienced no. 3 engine compressor surge (loud bang) and power loss, and fire warning. Fire was extinguished airborne and aircraft made air turn-back, landing 25,000 kilograms overweight and 25 knots fast onto a wet runway with a 7.5-knot tailwind. Unable to stop, at 80 knots the pilot elected to veer off runway onto soft ground. All engines received FOD, and there was some damage to the MLG truck beams. The aircraft was never repaired since it was at the end of its economic life.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
1	68/1ST/4/Hf	Other – pylon shutoff valve not secured, uncontrolled fire	Climb	Compressor surge

Summary of Event:

Disintegration + crew failed to secure engine and turn off boost pumps resulting in uncontrolled fire and engine separation

Summary of Narrative:

One minute after takeoff, no. 2 engine failed. The compressor disk cut the fuel line, resulting in a fuel fire, and the crew failed to close shutoff valve in the pylon and also failed to shut off boost pumps, which continued to pump fuel onto the ramp for 20 minutes. Made an immediate returned landing; on approach the no. 3 engine fell off. Evacuation started as soon as the airplane stopped, but five occupants were overcome by heat and smoke and did not escape.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
30	81/1ST/4/H	Other – return to landing, uncoordinated approach and landing, asymmetric reverse thrust below V_{MCG}	Landing	Low oil quantity

Summary of Event:

Single engine shutdown due oil loss + uncoordinated approach and landing – control loss

Summary of Narrative:

Aircraft returned with no. 3 engine shut down due to oil loss. Landed in typhoon conditions — gusty winds, tailwind and crosswind. Landed too far down runway and initially reversed engine 1 and 4; when it looked like he might overrun, pilot brought up no. 2 engine in reverse. Airplane departed left side of runway, crossed grass, broke off NLG and ended up on high-speed turnoff. Aircraft was scrapped.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
3	69/1ST/4/S	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + RTO at V_1 resulting in overrun

Summary of Narrative:

During takeoff roll, the aircraft hit a flock of birds (sea gulls). No. 2 engine surged and the crew elected to abort at 138 knots. V_1 = 138, V_R = 145, V_2 = 162. Aircraft overran end of the runway by 560 feet into a mud swamp. No fire and no injuries. No. 1, 2 and 3 showed signs of bird ingestion with no power loss. Left main and nose landing gears collapsed, lower surface of fuselage damaged. Flaps damaged, no. 2 pylon buckled outward. Fuselage broken circumferentially from window line to window line with three- inch separation at body station 550. All engines developed reverse thrust during RTO 110 percent. The crew actions in the abandoned takeoff procedures were timely in respect of throttle closure, application of reverse thrust and actuation of speed brakes; but the evidence indicates that there may have been a delay in application of wheel brakes beyond that delay assumed in the accelerate/stop certification performance calculations. The captain was scanning the engine instruments during the takeoff (as PNF) at the time the aircraft struck the birds and loss of power from no. 2 engine occurred. He saw the no. 2 EPR drop from its setting of 1.85 to 1.55, and this initiated his decision to abandon the takeoff. The flight engineer also saw the EPR drop to 1.55 and called that there was a power loss.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
4	70/2ND/2/H	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + RTO above V_R resulting in overrun

Summary of Narrative:

The aircraft, on a scheduled passenger flight, was being operated by the copilot. Immediately after rotation for takeoff, a loud explosion was heard and the copilot detected a loss of thrust from the no. 1 engine and applied rudder to hold the heading. The copilot apparently overcorrected, causing the aircraft to yaw to the right. The captain associated the loud noise and yaw to the right with a no. 2 engine failure (and he said he saw the right engine instruments spool down) and so attempted to apply left rudder. During a brief period of uncertainty at 50 to 100 feet, the pilot elected to abort and regain the runway. The airline decided to not repair the airplane. Probable cause: Decision and action to terminate the takeoff were based on erroneous judgment that both engines had failed. Factors: No. 1 engine failed as a result of a first stage (N_2) turbine blade failure. Flight crew did not utilize the engine and aircraft instruments to determine the condition of the engines, altitude and airspeed. The company procedures and applicable flight manuals dictate that the flight crew should have continued with one engine inoperative. The captain erroneously decided power to both engines had been lost. The aircraft was airborne and above V_2 speed at the time of the engine failure. Factors leading to inappropriate response: The first officer was at the controls at the time the emergency developed and stayed on the controls with the captain throughout the abort. The captain orally took over command of the aircraft controls three seconds after the bang noise. The aircraft made a yaw to the right just after the bang sound (first officer rudder input – overcorrected). The captain stated he saw the right engine instrument indicating a malfunction.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
8	72/2ND/2/S	RTO	Takeoff	Temporary power loss due to standing-water ingestion

Summary of Event:

Power loss (temporary) due to runway water ingestion + RTO above V_1, overrun

Summary of Narrative:

During the takeoff roll in rain, the left engine appeared to lose power at about 126 knots. V_1 = 128 knots, decision to abort = 132 knots, abort speed = 135 knots. The pilot elected to abort but was unable to stop on the runway. Groundspeed was about 10 miles per hour when airplane overrun end of runway and down an incline into a shallow saltwater swamp. Only the gear and lower fuselage entered the water. Five days to remove aircraft. There was no fire. Pilot factor – improper handling of an aborted takeoff. Engine related due to apparent power loss. CAA report: Takeoff speeds calculated as V_1 = 135, V_R = 136 and V_2 = 143. The dry V_1 was correctly amended to the wet runway value of 128 knots. Having been advised by ATC of standing water at about the mid-point of the runway, takeoff was performed with water injection in use and engine ignitors on. At about 126 knots, the aircraft ran into one or both pools of standing water, which were astride the centerline and about four meters diameter and two centimeters deep. Entry into the standing water resulted in directional control problems, a hesitation in the aircraft rate of acceleration and a temporary loss of thrust probably from no. 1 engine. There was an interval of about five seconds between running through the water at 126 knots and the initiation of action to abort the takeoff. By this time the engine malfunction had ceased and it was probably accelerating again towards full thrust. The aircraft was also accelerating again and attained a maximum speed of 135 knots about two seconds after the action to abort the takeoff was taken (about 132 knots). Deceleration from the peak speed of 135 was consistent with both engines operating correctly in reverse thrust and wheel brakes functioning properly and being correctly used.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
12	75/2ND/3/S	RTO	Takeoff	Suspected power loss due to aircraft deceleration

Summary of Event:

Perceived power loss (standing runway water) + RTO above V_1 – overrun

Summary of Narrative:

At a late stage in the takeoff from runway 28 (which was very wet as a result of recent rain), the aircraft encountered an area of standing water at V_1. This resulted in a perceived "marked deceleration" and led the captain to abort the takeoff. It could not be stopped on the runway and the pilot steered it off to one side on to grass. The probable cause was determined as the pilot's decision to abort the takeoff on a wet runway at V_1. Contributory factors were the low effective braking coefficient of friction and the failure of the captain to ascertain the extent and depth of water present on the runway prior to takeoff. FDR data indicated that the highest airspeed was 127.1 knots at 1,045 meters from start of roll. The wet V_1 calculation was 117 knots. Estimated the throttles were closed at 122 knots. Nos. 1 and 2 engines suffered postaccident ingestion; all three engines performed up to specification on bench test. There was no evidence of pre-crash malfunction. The captain's decision to abandon takeoff was an instantaneous reaction to the sensation he experienced — that of a marked deceleration "compatible with a loss of engine power." However, this sensation was not supported by the engine gauges, and the FDR indicates that had the takeoff not been abandoned, the aircraft would have become airborne normally. There was no evidence of pre-mishap technical failure.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
14	76/EWB/3/I	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + RTO above V_R – overrun

Summary of Narrative:

Pilot aborted takeoff when no. 2 engine surged. Aircraft was rotating with the nose landing gear off the runway when the decision to abort was made. The aircraft went off the end of the runway about 200 feet with the main landing gear remaining on hard ground and the nose gear in mud up to the steering cylinders. Passengers were removed from the aircraft with mobile stands. Weather was bad with rain, sleet, snow and wind.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
16	*77/EWB/3/I	RTO	Takeoff	Compressor surge

Summary of Event:

Loud noise, flash of light, compressor surge + RTO above V_1 (wet runway) – overrun

Summary of Narrative:

During takeoff on runway 28 at 155 knots (V_1 = 144), the "engine failure" warning lamp came on and there was a loud noise. The crew aborted the takeoff, actioned the brakes and reversed all engines. The aircraft overran about 200 feet, last part of runway silted over. Takeoff speeds were: V_1 = 144 knots, V_R = 152 knots, V_2 = 165 knots. The stall was due to a temperature sensor cold shift.

Event #:	**ID Number:**	**PSM+ICR Category:**	**Phase of Flight:**	**Engine Symptom:**
17	77/2ND/3/I	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + RTO at V_R – overrun

Summary of Narrative:

During takeoff roll, captain heard loud bang at rotation. "Engine failure" lights and pack trip lights came on and captain aborted takeoff. Airplane continued rolling straight ahead, stopping partially off end of runway. Left MLG remained on runway. Right MLG stopped approximately two feet off end of runway, and NLG approximately 60 feet off end. There was no reported airplane damage or personnel injury. Engine was run up to takeoff power to simulate full time run to rotation. No. 2 engine had severe compressor stalls at 25 seconds into runup, at which time it shook the whole airplane. All other engines operated normally and the "engine fail" lights came on at the time of runup stalls. Airplane was ferried for unscheduled no. 2 engine change.

Event #:	**ID Number:**	**PSM+ICR Category:**	**Phase of Flight:**	**Engine Symptom:**
19	78/2ND/2/H	RTO	Touch and go	Power loss

Summary of Event:

Power loss + RTO above V_1 – overrun

Summary of Narrative:

The aircraft was on a flight crew training flight with a student pilot. A touch-and-go landing was made on runway 25. When at about the midpoint on the 8,300-foot runway, the aircraft struck a flock of pigeons. The instructor pilot took over controls and attempted to make a go-around, but his efforts were inhibited by the student pilot applying the brakes. Although thrust decay was noted on the no. 1 engine, the aircraft speed was initially adequate for a go-around. The airplane overran the end of the runway by 940 feet. The right MLG collapsed and the right engine separated. An intense fire destroyed the right wing and most of the fuselage. No injuries. Probable cause: Copilot applying braking action resulted in an abort of an attempted touch and go.

Event #:	**ID Number:**	**PSM+ICR Category:**	**Phase of Flight:**	**Engine Symptom:**
21	*78/EWB/4/S	RTO	Takeoff	Compressor surge

Summary of Event:

Loud noise, compressor surge + RTO at V_1 – overrun

Summary of Narrative:

Takeoff was delayed 15 minutes to allow brakes to cool. During takeoff run at 145 knots, the no. 3 engine surged. V_1 = 145. Aborted initiated and reverse thrust was obtained on no. 1 and no. 2 engines. The aircraft came to a stop about 200 feet past end of runway with the left main gear collapsed and separated. Investigation showed that tire pieces starting at 6,000 feet from the start of roll, and the no. 3 engine showed damage due to ingestion of the tire. Probable cause: Pilot delay in applying brakes and reverse thrust after decision to abort. Takeoff weight was 764,302 pounds. Maximum IAS was 160 knots.

Event #:	**ID Number:**	**PSM+ICR Category:**	**Phase of Flight:**	**Engine Symptom:**
22	78/EWB/3/I-2	RTO	Takeoff	Power loss

Summary of Event:

Power loss + RTO at V_1 – overrun (icy runway)

Summary of Narrative:

During takeoff on runway 22, an "engine fail light" illuminated at V_1. The takeoff was aborted and the airplane overran the runway, coming to rest about 100 feet beyond the runway end and just to the right of centerline. Although both aft slides were deployed, 59 passengers and the crew deplaned normally through the ventral stairs. Observations of the last 200 to 300 feet of runway showed that it was snow packed over patches of ice. There were no reported injuries, and the only airplane damage was a blown no. 4 tire due to a severe flat-spotting. The airplane had been steered to the right to avoid the approach lights although one light was struck by the nose wheel. The no. 2 engine had internal distress as evidenced by metal in the tailpipe. Weather: wind 220 at 20 knots; temperature 10 degrees Fahrenheit; ceiling 1,200 overcast; visibility – blowing snow with visibility at 2.5 miles; daylight at 1600 local time. No injuries with minor damage to aircraft.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
28	*81/2ND/3/S	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bang, power loss + RTO above V_R – overrun

Summary of Narrative:

At 1610 EDT, a scheduled passenger flight overran runway 9L when the captain at the controls aborted the takeoff. The abort action was initiated when the flight crew heard an explosion and observed a partial loss of power on the no. 2 engine immediately after V_R call-out and after nose gear liftoff. V_1 = 129 knots, V_2 = 144 knots. The aircraft came to rest 421 feet beyond the end of the runway surface, 215 feet to the left of the runway centerline in soft rain-soaked ground with the aircraft straddling a shallow drainage ditch. The passengers were evacuated via use of the left-side emergency chutes. Six of the passengers sustained minor injuries during the evacuation of the aircraft. The aircraft sustained substantial damage to its right main landing gear. There was no evidence of fire. Thirty ground witnesses were interviewed, and most of them described a series of loud booming sounds early in the takeoff roll. About one-third of the witnesses said that the loudest explosion occurred at or near the time that the aircraft was rotated. TOGW = 151,000 pounds. Weather at the time: 700 scattered, estimated 4,000 broken, 20,000 overcast, visibility five miles in light rain, temperature 79 degrees Fahrenheit, dew point 70 degrees F, wind 190 at 15 knots. No. 2 engine examination: Air intake duct housing interior did not reveal any signs of corrosion or failed fasteners, and all vortex generators were in place and intact. No damage to LPC and free to rotate. Visible examination of turbine did not reveal any damage or operating distress and also free to rotate. Internal borescope did not reveal any internal operating distress or discrepancies.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
36	*83/EWB/4/S	RTO	Takeoff	EGT warning (amber and red)

Summary of Event:

EGT warning light + RTO above V_1 – overrun

Summary of Narrative:

Aircraft was departing runway 13 at a gross weight of 820,000 pounds. During the takeoff acceleration, the crew gradually reduced thrust on the no. 2 engine because of high EGT, the amber warning light having come on at approximately 80 knots, and the red warning on at 120 knots. Stopping action was initiated at about 163 knots, and the airplane eventually accelerated to 166 knots. Near the end of the runway, the airplane departed the left side of the runway, breaking off all landing gear in soft ground. All four engines contacted the ground, the resulting upward forces damaging the engine struts. There was no fire and only minor fuel leak through a pulled center fuel tank fastener. Failure of the engine was determined to be separation of the first stage turbine blade retainer. Weights: TOGW 372,700 kilograms, fuel 106,000 kilograms, cargo 112,820 kilograms. Flaps 20 degrees. 20.1 percent c.g. Stabilizer trim at 6 3/4 units nose-up, mid-green band. V_i = 157 knots. V_R = 168 knots.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
38	85/EWB/4/I-1	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + RTO above V_1 – overrun

Summary of Narrative:

Pilot aborted takeoff due to apparent bird ingestion on no. 2 engine. The airplane continued off the end of runway 11 for 140 meters with all wheels buried to the rims in the grass overrun. Tires 1, 3, 5, 9, 11 and 15 deflated. No. 4 thrust reverser was inoperative, and thrust reversers 2 and 3 were used for the stop. The DFDR first indication of stopping came at a speed of 174 knots IAS 54 seconds from start of roll and six seconds beyond V_1 = 155. Gross weight unknown. No. 2 fan duct had evidence of feathers, but the fan blades showed no evidence of damage. Weather: Local area had heavy rain showers prior to event, but no rain at the time of event. DFDR analysis: Data indicated that the V_1 speed of 155 knots IAS occurred at a GMT of 1952:48, which was 48 seconds from start of takeoff roll. The first action to abort the takeoff occurred at GMT 1952:54 when the brakes were applied, which was 54 seconds from start of takeoff roll and six seconds beyond the V_1 speed.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
40	85/1ST/4/H	RTO	Takeoff	Fire warning

Summary of Event:

Fire warning + RTO – overrun

Summary of Narrative:

During the takeoff roll for the start of a ferry flight, the crew received a no. 1 engine fire warning. The crew initiated an aborted takeoff and the aircraft overran runway end and was destroyed by fire. Crew reportedly escaped injury. No additional details available.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
45	86/2ND/2/I	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + RTO at V_R – overrun

Summary of Narrative:

In heavy rain near V_1 (after initiation of rotation, according to one passenger), a flock of sea gulls was encountered. The no. 1 engine ingested at least one bird and stalled/flamed out. The takeoff was aborted and the airplane departed the runway at a point 84 feet prior to reaching the 6,000-foot runway end. The airplane came to rest in marshy terrain about 160 feet past departure end of the runway and 96 feet off of the right side. Light skid marks began 50 feet prior to the point of runway departure.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
46	*86/EWB/2/H	RTO	Takeoff	Compressor surge (power loss)

Summary of Event:

Loud bang, compressor surge + RTO above V_R (after liftoff) – overrun

Summary of Narrative:

During takeoff roll, just after rotation, loud bang was heard on the right engine. Aircraft was initiating its takeoff when crew decided to abort. Heavy lateral vibrations were felt and heard. Instruments could not be read by the crew. The captain assumed control and brought the nose back down. The aircraft was airborne for about four seconds. The captain pulled back the throttles and selected reverse thrust. Aircraft overran the end of the runway. Aircraft hit high-intensity light and other obstacles. All landing gear separated and aircraft came to rest on both engines and undercarriage. All passengers exited using slides with eight minor injuries. The flight crew reported birds on the runway during the takeoff roll, and bird debris was found in the kiss seal area of the pre-cooler fan air duct on the right engine. The takeoff was aborted after rotation. The right engine had ingested a black kite bird. Two fan blades sustained transverse fractures due to ingestion of this 2.2-pound bird.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
48	88/2ND/2/I	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + RTO above V_1 – overrun

Summary of Narrative:

At about 100 knots, a flock of birds was seen to be occupying the center of the runway. As the airplane passed through the birds, a rapid decrease in P7 was noted and the captain called stop. Copilot applied reverse thrust and brakes. The aircraft overran the end of the runway by 161 feet (49 meters) into a clearway. Decision to abort determined to be 147 knots. Crew forgot to use “lift dumpers.”

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
49	*88/EWB/4/S	RTO	Takeoff	Fire warning

Summary of Event:

Fire warning + RTO above V_1 – overrun

Summary of Narrative:

First officer aborted takeoff at 170 knots following no. 4 engine fire warning. V_1 =156 knots. The first officer removed his hands from the throttles about V_1. About two seconds later, no. 4 engine fire warning activated. The captain reached in the direction of the throttles, a move the first officer interpreted as a sign to abort. The first officer very rapidly took hold of the throttles, pulling them back to the stops, applied brakes and placed all engines in reverse. Gross weight, 778,000 pounds. Overran end of runway about 300 meters. Separated all gear. Damage to aircraft: separated all engines; NLG folded into rear of wheel well; fuel tanks punctured, no fire; underside of fuselage and all trailing-edge flaps damaged; two tires failed due to striking runway lights, other tires seem OK; brakes look OK; no. 4 engine has turbine case crack near aft flange weld, crack extends 9 through 12 to 3 o’clock. V_1 = 156, V_R = 172, V_2 =180 knots. Runway 28 is 2,500 feet long and has a paved 1,000-foot overrun.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
52	*88/MNB/2/S	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bangs, compressor surge + RTO above V_R

Summary of Narrative:

During takeoff in day VMC, after V_R, the crew felt something they interpreted to be left main landing gear tire failure. Subsequent investigation showed the left engine had a HPT blade failure (contained). The captain elected to abort, regained the controls and pushed the nose over. The NLG collapsed aft, and the aircraft was stopped on the runway with all MLG tires deflated. All crew and passengers evacuated the airplane without any reported injuries. The fuselage was fractured forward of the wing. Highlights of interview with captain and first officer showed that departure and engine-out procedures where not briefed prior to the attempted takeoff per [the airline’s] flight operations manual. First officer performed the takeoff. V_1 = 128, V_R = 133, V_2 = 140. Takeoff performed using the autothrottle. Takeoff was normal up to V_1. The aircraft came off “very smoothly” — a smooth, slow rotation. Runway length was not critical. As the nose came off the runway, there were two muffled shotgun noises. At the moment of the abnormal sounds, the first officer scanned the engine indications and EICAS. The screens indicated normal engine operation. There was a slight aircraft movement to the left, not a major movement. He had both hands on the yoke. The captain suddenly took control of the aircraft by closing the throttles. The first officer was not sure if there was verbal communication between himself and the captain regarding the change in flying responsibilities. First officer assisted the captain in the braking. During deceleration, the aircraft went from a nose-level attitude to a fierce nose-down position. Spoilers and reverse thrust operated normally during the abort. The captain said he thought he had plenty of room to stop the aircraft. It was the captain’s first aborted takeoff in an airplane, although he had received such RTO training in a flight simulator, including training on the use of maximum braking.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
54	90/1ST/4/H	RTO	Takeoff	Compressor surge, visual sighting of birds, surges on no. 2 and no. 3 engines

Summary of Event:

Compressor surge + RTO below V_1 – overrun

Summary of Narrative:

During the initial portions of the takeoff roll, the crew spotted some birds on the runway ahead and along their flight path. Thinking that the aircraft could not be stopped if aborted, the PIC continued the takeoff. However, as the aircraft continued the takeoff roll, the birds started to fly off the runway. Some of the birds collided with the aircraft and caused a momentary surge on no. 2 and 3 engines. Alarmed by the surge, the pilot made a high-speed rejected takeoff. The abort was unsuccessful. The aircraft overrun the end of the runway and fell heavily onto the lower ground and broke up. The copilot was injured seriously. Abort initiated at 118 knots, and V_1 = 131 knots.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
55	91/EWB/2/I	RTO	Takeoff	Severe vibrations and perceived power loss

Summary of Event:

Tire tread ingestion, severe vibration and perceived power loss + RTO above V_1

Summary of Narrative:

During takeoff roll, the pilot reported severe vibration from the no. 1 engine and a perceived power loss. He then elected to abort. The DFDR indicated that the calibrated airspeed reached 172 knots before the takeoff was aborted. The aircraft overran the runway end and was brought to a rest approximately 200 meters beyond the end of the runway and 60 meters to the left of runway centerline. The pilot used nose-wheel steering to avoid obstacles beyond the runway end line. There was no fire reported prior to, during or after this event, and there was no evidence of fire visible on the engine or aircraft. There was no non-containment associated with this event. Due to the tire tread ingestion, all engine-related damage was contained within the engine casing and nacelle. However, it was reported that the pilot experienced severe vibrations from the no. 1 engine and a perceived power loss. He aborted the takeoff based on the perceived power loss.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
56	91/MNB/2/I	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bangs, compressor surge + RTO at V_R

Summary of Narrative:

The aircraft was being ferried. Crew performed a takeoff abort which was initiated at V_R when the right engine surged three times and the aircraft yawed. Aircraft exited off runway 27L at turn-off T2. This location is approximately 7,500 feet from the runway start. Total length of runway is 13,002 feet. Borescope inspection of engine no. 2 revealed compressor stage 2 liner distress and bent stage 2 blades.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
60	92/EWB/4/I	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + RTO above V_1 – overrun

Summary of Narrative:

During takeoff roll at 165 knots, engine no. 1 surged with a loud bang and overtemperature. A rejected takeoff was performed at 167 knots (above V_1). The compressor surge was caused by a bird strike to the engine. The aircraft came to stop with the nose landing gear off the runway on the grass. All of the main landing gear tire fuses released. Emergency evacuation; minor injuries reported to 10 people. Maintenance crew found evidence of bird remains at the 3.0 bleed valve and precooler. No fan blades damaged.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
64	93/EWB/4/I-2	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + RTO above V_1 – overrun

Summary of Narrative:

During takeoff a bird was ingested into the engine during takeoff roll at 182 knots. A rejected takeoff was initiated and the aircraft overran the end of the runway by approximately 400 meters. There were no injuries or fatalities. The event involved two large common buzzards being ingested into the no. 2 engine with the loss of major fan blade pieces. The decision to reject the takeoff occurred several seconds after the bird strike at an airplane speed well above the target V_1 decision speed of 163 knots. The airplane overran the end of the runway by approximately 420 meters and damaged a number of light fixtures located just beyond the end of the runway. Birds were seen on the runway prior to ingestion.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
65	93/MWB/3/I	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + crew throttled good (all) engines, corrected and continued takeoff

Summary of Narrative:

During takeoff roll at, near or above V_1, one of the engines surged and the first officer (pilot flying) initiated an abort by throttling all engines; the captain then took control and readvanced throttles and continued the takeoff. The investigation showed the no. 3 engine surging, then no. 1 and no. 2 engines being commanded to reduced power, then being returned to takeoff power. It could be that the power reduction was the normal power retarded to climb power. Then the throttles for no. 1 and no. 2 appear to be readvanced to takeoff power. The no. 3 throttle must also have been advanced because EGT exceeded limits for long duration.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
75	95/MWB/2/I-1	RTO	Takeoff	Thrust reverser “rev unlk” light on

Summary of Event:

RTO at V_1, thrust reverser “rev unlk” light on, abort on runway

Summary of Narrative:

Takeoff aborted at 150 knots because engine no. 1 thrust reverser transit light came on. Wheels deflated. Decision to abort takeoff was at V_1. Actual abort occurred after V_1 due to reaction time.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
76	*95/EWB/3/S	RTO	Takeoff	Compressor surge

Summary of Event:

Loud bang, shudder, vibrations, compressor surge + RTO above V_1 – overrun

Summary of Narrative:

The aircraft was on a scheduled flight. During the takeoff run, just after the aircraft accelerated through 167 knots, the crew heard a loud bang, felt considerable vibration and airframe shudder, and rejected the takeoff. The aircraft could not be stopped on the runway, and the nose gear collapsed as the aircraft rolled through the soft ground off the end of the runway. The board determined that the engine on the left wing lost power at a critical point in the takeoff run and that the rejected takeoff was initiated at a point and speed (above V_1) where there was insufficient runway remaining to stop the aircraft on the runway. Contributing to this occurrence was the misidentification of the cause of the loud bang and lack of knowledge regarding the characteristics of engine compressor stalls. The compressor stall and loss of power, in the left engine, were the result of the failure of compressor blades in the high-pressure compressor section of the left engine.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
78	*96/EWB/3/H	RTO	Takeoff	Loud bang (compressor surge) and power loss

Summary of Event:

Loud bang, vibrations (compressor surge) power loss + RTO above V_R

Summary of Narrative:

After the airplane commenced the takeoff roll, shortly after it pitched up some 11 degrees and lifted off at a speed of 171 knots, a loud bang was heard with an accompanied power loss from the no. 3 engine. The flight crew initiated an aborted takeoff above V_R. Based on the disassembly inspection of the engine, the damage was determined to be a fracture of a HPT stage 1 blade. The V_{REF} speeds for the flight were calculated as follows: V_1 149, V_R 157, V_2 171. The airplane re-contacted the runway and departed the end of the runway. The airplane came to rest and caught fire and was destroyed. Airplane information: 211,300 kilograms with c.g. at 18.9 percent MAC (MTW = 251,744 kilograms with a c.g. range of 10.6 percent to 28.4 percent).

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
80	96/MWB/4/I	RTO	Takeoff	Power loss, deceleration stall/surge

Summary of Event:

Power loss + RTO above V_1

Summary of Narrative:

Crew rejected takeoff at 159 knots due to no. 4 engine power loss accompanied by a deceleration surge. The power loss was caused by a leaking/open engine control sense line. The airplane was stopped on the taxiway. The tower informed the crew that there was smoke coming from the underside of the airplane. All passengers and crew departed with two passengers receiving serious injuries. There was no hull damage, and 10 of the 16 main gear tires deflated due to fuse plugs blowing.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
29	*81/EWB/4/S	RTO – stop procedure	Takeoff	Compressor surge, airplane shudder, flash of light

Summary of Event:

Loud bang, compressor surge, EGT light + RTO five knots below V_1 – overrun

Summary of Narrative:

During takeoff roll, the pilot-in-command rejected the takeoff after the flight engineer called out “engine fire.” The aircraft overshot and stopped about 20 meters from the end of the runway. During the takeoff roll, approximately 20 seconds after the first officer called out 80 knots, the pilot-in-command heard a bang sound coming from the outside, immediately followed by a momentary shuddering of the aircraft. The pilot-in-command asked “what’s the matter?” A second later, the flight engineer reported “engine fire” and the commander initiated the rejected takeoff. The flight engineer based his call-out on the illumination of no. 4 EGT limit light following the bang sound, which he also heard, and on the accompanying flash of light he noted from the starboard side of the aircraft. There was no visual or aural engine fire warning. In the pre-cockpit voice recorder (CVR) playback interview, all three flight deck crew testified that the first officer called out V_1, but this call-out does not appear on the CVR playback. The DFDR readout showed that when the abort decision was made, the aircraft airspeed was 147 knots, five knots below V_1. The aircraft was within allowable gross takeoff weight.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
5	70/EWB/4/I	Shut down good engine	climb	Fire warning

Summary of Event:

Fire warning + shut down good engine, restarted engine

Summary of Narrative:

Fire warning illuminated on no. 2 engine shortly after takeoff. Crew inadvertently closed fuel cut-off lever for no. 1 engine which then had high EGT. Returned no. 1 fuel cut-off to “on” and engine returned to normal. Returned to departure airport with no. 2 shut down. Found 15th stage bleed duct was ruptured at the precooler.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
7	72/EWB/4/I-1	Shut down good engine	Climb	Fire warning

Summary of Event:

Fire warning + shut down good engine, restarted

Summary of Narrative:

During previous maintenance, a fuel flow transmitter on the no. 3 engine had been removed. When it was reinstalled, its O-rings were cut in two places. This allowed a fuel leak. During the climb-out, the leaking fuel caught fire. Subsequently the no. 3 engine was shut down. However, during the shut-down process, the flight engineer inadvertently closed the low-pressure fuel valve for the no. 2 engine, which then ran down. The captain declared an emergency, dumped fuel and returned to the departure airport. En route the no. 2 engine was restarted and a three-engine landing was accomplished.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
9	72/EWB/4/I-2	Shut down good engine	Cruise	Compressor surge

Summary of Event:

Loud bang, power loss + shut down good engine, restarted

Summary of Narrative:

Initial reports are that no. 1 engine surge with power loss due to failure of a first-stage turbine blade. No. 2 engine was apparently shut down for rising EGT from apparent surge concurrent with no. 1 surge and aircraft yaw produced by shutting down no. 1 engine. It is estimated that the shutdown of no. 2 engine was inadvertent and/or not necessary. No. 2 engine restarted.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
11	75/EWB/4/I-1	Shut down good engine	Cruise	Compressor surge

Summary of Event:

Sound heard, power loss + shut down good engine, restarted both engines

Summary of Narrative:

At FL370, a sound was heard and no. 3 engine N_1 observed to be decreasing. While no. 3 engine was being shut down, no. 4 EGT was reported as rising and no. 4 shut down. Airplane descended; no. 3 restarted at FL250, no. 4 restarted at FL230 and flight continued. Nothing found wrong. Suspect compressor deterioration and crew inadvertently shut down no. 3 — wrong engine.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
13	75/EWB/4/I-2	Shut down good engine	Cruise	High-stage bleed light, compressor surge

Summary of Event:

Loud noise, rapid rise in EGT + shut down good engine, restarted both engines

Summary of Narrative:

Several seconds after beginning cruise at FL390, the high stage bleed blue light illuminated on no. 3 engine. Immediately following there was a strong stall. EPR fell with a rapid rise in EGT. One or two seconds later all parameters fell on no. 4 engine. Restart of both engines was accomplished at FL280. Time on two engines was three minutes. Engines checked OK. No cause found. Suspect crew error — inadvertently shut down no. 4 engine when trying to shut down no. 3, or fuel management error (out of sequence).

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
15	77/EWB/4/I	Shut down good engine	Climb	Compressor surge

Summary of Event:

Loud noise, compressor surge, power loss + shut down good engine, unsuccessful restart – two-engine landing

Summary of Narrative:

During climb at FL280, engines no. 1 and 2 stalled and quit running. Both engines shut down. Attempts to relight were unsuccessful. Returned to departure airport, and overweight landing made. Metal in chip detector of no. 2 engine. No. 1, nothing found wrong. Suspect no. 1 engine shut down inadvertently.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
18	78/2ND/3/I-1	Shut down good engine	Climb	Power loss

Summary of Event:

Power loss + shut down good engine, restarted

Summary of Narrative:

During climb no. 3 engine flamed out. Suspect gear accessory shaft failure. Essential power selected to no. 1 engine, but unable to select, so switched to no. 2 engine. No. 1 engine then observed to spool down and stop. Approximately 2,000 feet lost. Restarted no. 1 engine and air turn-back. No other information. Suspect crew error associated with difficulties of no. 3 flameout.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
20	78/EWB/4/I	Shut down good engine	Cruise	Compressor surge

Summary of Event:

Noise, power loss + shut down good engine, restarted

Summary of Narrative:

After 4:55 hours of flight, no. 4 engine surged and overtemperature due to 7th stage hub broke. No. 3 engine inadvertently shut down during the restart attempt on no. 4 engine. Two engine time, 4–7 minutes. No. 3 restarted and no. 4 remained shut down during the diversion.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
23	79/EWB/4/I-1	Shut down good engine	Cruise	Compressor surge and overtemperature

Summary of Event:

Noise, compressor surge, overtemperature + shut down good engine, restarted both engines

Summary of Narrative:

During flight the no. 2 engine experienced surge and overtemperature. Approximately 40 seconds later, no. 3 engine spooled down and flamed out. Approximately 8–10 minutes since last fuel heat and fuel tank temperature at minus 20 degrees Celsius. Both engines restarted at FL280. Since no cause found for no. 3 engine, assume no. 2 engine had steady state surge due to deterioration, and no. 3 was an inadvertent shutdown.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
24	79/2ND/2/S	Shut down good engine	Cruise	Compressor surge

Summary of Event:

Loud explosion, power loss, decompression + shut down good engine, restarted engine

Summary of Narrative:

En route in cruise at FL200, the pilot reported a loud explosion from the rear of the aircraft. The cabin immediately depressurized and oxygen masks deployed. Cause of explosion was a failure of the right engine 7th and 8th stage disk spacer. Sections of the spacer penetrated the engine cowling, entering the cabin near the right lavatory and exiting through the top of the fuselage. It was reported that the pilot shut down both engines, started APU, then restarted the left engine at 5,000 feet and made an uneventful emergency landing. Ground inspection revealed the 7th to 8th stage disk spacer had failed, leaving a 5 x 7 inch hole in the engine case at 0900 position. Spacer hardware went through the apron just behind the forward engine mount and the top of the pylon, entered fuselage approximately one foot above the pylon at station 965, went through the lavatory and exited at the top of the fuselage just forward of station 965. Just above the lavatory, a wire bundle was hit, severing and damaging many wires. This bundle carries all instrument wiring to both engines, with the exception of EGT, and passes through the upper right corner of the pressure bulkhead. Engine ignition is in another bundle which goes through the pressure bulkhead in the same area. The EGT wiring passes through the bulkhead in the lower right corner.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
25	80/EWB/3/I	Shut down good engine	Descent	No response to throttle

Summary of Event:

No throttle response, power loss + shut down good engine, restarted engine

Summary of Narrative:

On descent. no. 3 engine would not respond to power lever. Engine was shut down and restarted but still no response, so engine was shut down again. As no. 3 engine ran down, a master caution light and electrical cue light came on for no. 2 engine. Autopilot disengaged. Crew noted no. 2 had flamed out. Engine restarted after 20 to 30 seconds. A three-engine landing was accomplished without further problem. Mechanical problem discussed above found on no. 3, but no cause found for no. 2 engine flameout. No. 2 engine inadvertently shut down as part of no. 3 engine problems.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
26	81/2ND/2/I	Shut down good engine	Takeoff	Power loss

Summary of Event:

Perceived both engines failed, power loss + shut down good engine – RTO

Summary of Narrative:

Aborted takeoff due to crew reported both engines failed. Maintenance found the left engine had a failed fuel pump (shaft sheared). Right engine showed no discrepancies. Suspect inadvertent shutdown by grabbing too many handles.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
31	81/EWB/4/I	Shut down good engine	Cruise	Power loss

Summary of Event:

Power loss + shut down good engine, restarted

Summary of Narrative:

Lost power on no. 1 engine and shut down no. 2 engine by mistake. Relighted no. 2 engine and continued on for a three-engine landing.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
33	82/EWB/4/I	Shut down good engine	Climb	Compressor surge

Summary of Event:

Loud bang, compressor surge (power loss) + shut down good engine, restarted

Summary of Narrative:

This incident refers to shutdown of engine no. 2 due to a low-pressure location bearing failure at 6,400 feet on climb-out. The aircraft returned to the airport and landed with three engines operating. Engine no. 1 was shut down in error and restarted for landing. Some damage to the leading edge of the wing and the top of the wing inboard of the no. 2 engine. After engine failure, the captain ordered shutdown of the no. 2 engine, but the flight engineer pulled the no. 1 engine fire handle. On seeing the no. 1 engine fuel valve light indicate closed, he then pulled the no. 2 engine shutdown tee handle. The no. 1 engine was restarted and a three-engine landing accomplished. The no. 2 engine failure started from a low-pressure location bearing failure.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
42	85/MWB/2/I	Shut down good engine	Cruise	Compressor surge

Summary of Event:

Noise (shudder), vibration, compressor surge + shut down good engine, restarted

Summary of Narrative:

During cruise at FL390, airframe began to shudder. Left throttle was retarded to idle but buffet (suspect compressor stall) continued. Left engine was shut down, but buffet continued. Made a precautionary landing. Started APU at FL350. Buffet stopped while descending through FL290. Started left engine on drift-down. Borescope of no. 1 engine and nothing found wrong. No. 2 engine borescoped and found HPC damage. Crew shut down the wrong engine.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
53	*89/MNB/2/H	Shut down good engine	Climb	Compressor surge, moderate to severe vibration, burning smell and some visible smoke

Summary of Event:

Vibration, smell, compressor surge + shut down good engine – total power loss – forced landing

Summary of Narrative:

Approaching FL290 in the climb, the crew experienced symptoms of surge, moderate to severe vibration, a burning smell and smoke due to left engine fan blade fracture. It is reported that the crew believed that smoke and vibration was from the right engine, and the right throttle was retarded 20 seconds after the onset of the vibration. The captain stated that after retarding the right throttle, the smell and signs of smoke were reduced, and he remembered no continuation of the vibration. An emergency was declared, and the right engine was shut down about 40 seconds after the vibration began. The left engine power was successfully reduced and continued to operate at "comparatively low power" but with higher-than-normal vibration in the descent. After power had been increased on the left engine for the approach to runway 27, at 900 feet AGL and 2.4 nautical miles from touchdown, with gear down and flaps 15 degrees, the left engine lost power, accompanied by high vibration levels. A left engine fire warning occurred 17 seconds after the power loss. Attempts to start and obtain thrust from the right engine before ground contact were not successful. Initial contact was on level ground, but the airplane then pitched over and impacted a major highway and its embankment, coming to rest about 900 meters from the threshold of runway 27.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
63	93/EWB/4/I-1	Shut down good engine	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + shut down good engine – two-engine landing

Summary of Narrative:

It was reported from the flight crew that during takeoff at 400 feet, the no. 2 engine surged with a peak EGT of 870 degrees Celsius. At approximately 600 feet, the no. 1 engine surged with a peak EGT of 889 degrees Celsius. Both engines were shut down sometime after 1,000 feet AGL apparently (flight crew report) due to EGT limit exceedance. EGT redline limit is 670 degrees Celsius. The aircraft continued the takeoff and dumped fuel (66,000 pounds) over the water and returned for an uneventful two-engine landing. Failure of the inlet spinner resulted in three uncontained locations (2, 6, 10 o'clock) on engine no. 2 were evident in the inlet forward of the "A" flange. One location of aircraft FOD was noted on the left air-conditioning body fairing under the left wing. Engine-manufacturer-investigation executive summary states: Probable cause of the no. 2 engine surge is attributed to the liberation of the inlet cone assembly. There is insufficient physical damage to the no. 1 engine to explain the surge (maybe a deceleration surge, from a throttle chop) and IFSD. No. 2 engine. Borescope inspection check OK; the engine was flown back to main base where the no. 1 engine was changed due to EGT overtemperature. An engine overhaul hot section was performed with negative finding and the engine was reassembled and reinstalled, and has been flying problem-free since.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
66	*93/MNB/2/I	Shut down good engine	Approach	Stuck throttle

Summary of Event:

Asymmetric thrust (stuck throttle) + shut down good engine (believed it flamed out)

Summary of Narrative:

Experienced an in-flight engine shutdown no. 2 engine during the final phase of approach at 696 feet. Initial crew reports indicated that engine no. 2 had apparently flamed out. However, the crew had apparently mistaken the retarding of engine no. 2 thrust lever by the autothrottle to be the engine winding down and so shut down the engine. A single-engine landing was accomplished without further incident.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
71	*94/MWB/4/I	Shut down good engine	Climb	Compressor surge

Summary of Event:

Loud bangs, compressor surge + shut down good engine; three-engine landing

Summary of Narrative:

Flight crew reported that 1 minute and 50 seconds after takeoff, they heard a loud bang and felt the aircraft shudder. This was followed by three loud bangs. Engine no. 2 was shut down and the aircraft returned to landing. Engine no. 2 was borescoped and no problems found. Following further review of onboard CMC messages, ground crew determined no. 3 engine had experienced surge. From DFDR data: No. 3 engine surged during power reduction from takeoff power to climb power setting (autothrottle); about 1,800 feet AGL, no. 3 surged three times then recovered; four seconds after the third surge on no. 3, the no. 2 throttle was pulled to idle; six seconds after no. 3 surge, the no. 2 engine had a surge detect flag, i.e., accelerate or decelerate surge condition.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
73	*95/MWB/2/I	Shut down good engine	Climb	Stuck throttle

Summary of Event:

Asymmetric thrust (stuck throttle) + shut down good engine

Summary of Narrative:

Crew report: After the top-of-climb power reduction, engine no. 1 had N_2 vibration of 3.0 units with associated throttle vibration. After confirmation, engine no. 1 was shut down. On return to the departure airport, engine no. 2 remained jammed at 94 percent N_1. Engine no. 1 was relighted and allowed to stabilize. Engine no. 2 was then shut down and aircraft returned uneventfully. Sequence of events: Operation of the flight was normal until top of climb. While leveling off at 12,000 feet on a short sector of 20 minutes duration, the captain noticed that the trapezoid in his primary display was displaced, the aircraft was yawing and seemed to be out of trim. He drew the F/O's attention to this, and the F/O noticed that the aileron trim was five units out and the control wheel accordingly displaced. Almost simultaneously, the captain noticed that the no. 1 throttle lever was vibrating. The captain looked at the engine parameters and saw them decreasing; he asked for the engine page on the ECAM and when selected by the F/O, both noticed an N_2 vibration of three units, with what they both thought was an increasing trend. The captain felt vibration on the no. 1 throttle, which was confirmed by the F/O. At this point, the captain concluded that the no. 1 engine might have failed. The captain decided that no. 1 engine was in distress, possibly because of a bird strike, and warranted a precautionary shutdown to avoid further damage. No. 1 throttle was not moved out of its stop at any time during the process for the same reason. The decision to turn back was made, and the engine fail checklist for the no. 1 engine was followed and the no. 1 engine was shut down with the fire handle. Upon initiating descent, the captain selected level change on the flight control unit, but it would not engage. He then realized that no. 2 throttle would not move and concluded that it was jammed. The F/O was very surprised at this and asked if he could exercise the no. 2 throttle. There was further discussion and both agreed that no. 1 throttle may have retarded to flight-idle stop so that the autoflight system could achieve the speed selected. A mutual decision was now made to start no. 1 engine. The engine start in flight checklist was followed, and the no. 1 engine was started. However, it only ran for a short period, 1 minute and 3 seconds, before stopping again. The captain asked the F/O to check all circuit breakers, which he did by getting out of his seat and examining the CB panel. While the F/O was out of his seat, the captain noticed the disagreement red light on in the no. 1 fuel lever, and both then thought that the attempt to relight the engine should be accomplished.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
79	96/MNB/2/I	Shut down good engine	Approach	Stuck throttle

Summary of Event:

Asymmetric thrust (throttle stuck at idle) + shut down good engine

Summary of Narrative:

Preliminary reports indicate that at FL230, throttle stuck at idle during descent operations. Again during the approach phase (altitude to be determined). During an autothrottle command to increase power, the right engine accelerated normally while the left engine remained at flight idle. The asymmetric thrust condition caused the aircraft to bank and yaw. The crew subsequently interpreted this as an engine flameout and closed the engine fuel shutoff lever. The engine was then successfully relighted using starter assist. The engine behaved normally until the approach when again the thrust lever failed to spool up the engine. The autopilot was disengaged, and a normal approach and landing were carried out. The autothrottle was made inoperative pending investigation. The results of the FDR printout indicated that the engine had not in fact flamed out. An autothrottle command to increase power resulted in no. 2 engine accelerating normally while the no. 1 remained at flight idle. This asymmetric thrust condition caused the aircraft to bank and yaw. The crew subsequently interpreted this as an engine flameout and closed the engine fuel shutoff lever. The engine behaved normally until the approach when again the thrust lever failed to spool up the engine. The autopilot was disengaged, and a normal approach and landing carried out. Autothrottle was made inoperative.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
41	85/EWB/4/I-2	Shut down good engine – two engines out	Climb	Compressor surge

Summary of Event:

Loud bang, compressor surge + shut down good engine – two-engine landing

Summary of Narrative:

No. 3 engine stalled at 100 feet with metal in the tailpipe. Initiated engine shutdown and air turn-back to alternate. Then the fuel flow to no. 4 engine dropped by 2,205 pounds per hour. Crew then shut down no. 4 engine and declared an emergency. The second engine shutdown apparently occurred because of a lack of crew coordination and misunderstanding, as the engine parameters dropped because the power lever had been retarded. Nothing was found wrong with the engine upon inspection.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
67	*93/EWB/2/I	Throttled good engine	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + crew throttled good engine, corrected

Summary of Narrative:

During takeoff at 100 feet AGL, no. 1 engine compressor surged. Flight crew retarded no. 2 throttle. Crew corrected no. 2 throttle (restored), continued takeoff, completed an uneventful air turn-back to the field. DFDR data indicates the following: No. 1 EPR dropped from target EPR of 1.48 to 1.05 during the surge for a period of two seconds. No. 2 EPR was reduced by the crew from a target EPR of 1.48 to 1.28 EPR then restored to 1.46 during a 10-second period. It appears that no. 2 power lever angle was retarded 13 degrees for a period of six seconds.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
69	*93/MWB/2/I-	Throttled good engine	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + throttled (all) good engines, corrected

Summary of Narrative:

During takeoff at 500 feet above ground level, the no. 2 engine compressor surged. The crew throttled both engines, then re-advanced throttles. No. 2 engine surged again and power was reduced on no. 2 engine. Takeoff was continued and resulted in an uneventful air turnback. DFDR analysis indicates the following: 1.5 seconds after the no. 2 compressor surged, the no. 1 and no. 2 throttles were reduced from 80 degrees to 50 degrees, then returned to 75 degrees over a period of four seconds. Then no. 2 engine compressor surged again, then no. 2 throttle retarded to less than 40 degrees TLA. N_1 rotor speed on no. 2 engine dropped from approximately 100 percent to 62 percent in about one second. No. 1 engine rotor speed was commanded from 100 percent to 84 percent for a period of four seconds. EGT did not exceed limit.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
70	94/MWB/2/I-2	Throttled good engine	Takeoff	Compressor surge

Summary of Event:

Loud bang, compressor surge + crew throttled good engine, corrected

Summary of Narrative:

At rotation, crew reported no. 1 engine stalled. DFDR data indicates the right engine power reduced from approximately 1.5 to 1.3 EPR during the takeoff near rotation. Analysis of the cycle deck shows at +20 ISA, the right engine lost 30 percent of commanded thrust for those conditions (12,621 pounds).

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
72	94/MWB/2/I-1	Throttled good engine	Takeoff	Compressor surge

Summary of Event:

Loud bangs, compressor surge + crew throttled good engine

Summary of Narrative:

The airplane experienced a left engine surge just after takeoff at 290 feet. After the surge, the crew retarded the throttle. The crew then advanced the throttle; no further surges and all parameters were normal. What's not stated in the report is the fact that the DFDR data indicated that the right engine was also retarded from EPR 1.55 to EPR 1.21 (48 percent of commanded thrust loss). The surged engine EPR reduced to 1.03 then recovered. The crew elected to continue the flight. An EGT exceedance was recorded on left engine with a maximum temperature of 670. EGT exceedance.

Event #:	ID Number:	PSM+ICR Category:	Phase of Flight:	Engine Symptom:
2	69/2ND/2/H	Throttled good engine – forced landing	Takeoff	Compressor surge

Summary of Event:

Power loss + throttled good engine to idle resulting in forced landing

Summary of Narrative:

Immediately after takeoff, the aircraft developed performance problems. As the aircraft rotated (117 knots) into a climb attitude, a dull bang was heard (immediately associated by the crew with the engines). After looking at the EGT gauges and observing that no. 1 engine was indicating a temperature 20 degrees Celsius higher than no. 2 engine, the pilot-in-command (jump seat) said "I think it's number 1" and, after a brief pause, said "throttle it." The pilot elected to throttle back the no. 1 engine. After closing no. 1 throttle, he reduced climb angle to six degrees from 12 degrees. At the same time, the copilot, who had reached for the checklist and was looking for the page relating to an engine emergency, became aware of the sharp reduction in acceleration, noticed the landing gear was still down and retracted it immediately. The aircraft reached a maximum height of 250 feet and then began losing speed. As ground contact became inevitable and imminent, the pilot made a controlled gear-up landing 8,200 feet from the runway threshold and slid on the snow-covered ground for 1,400 feet. Investigation revealed inadvertent displacement of no. 2 throttle and complete throttle cut on no. 1 engine. Engine tear-down of no. 2 revealed a segment of HP turbine seal caused the HP compressor surge, which was initially thought to be no. 1 engine.

Appendix F

Turbofan Training Accident Summaries

<table>
<tr><th>Date</th><th>Aircraft Type</th><th>Phase of Flight</th><th>Region</th><th>Damage</th></tr>
<tr><td>1959</td><td>Boeing 707</td><td>Cruise</td><td>United States</td><td>Substantial</td></tr>
<tr><td colspan="5">While practicing two-engine-out minimum control speed condition, at 119–120 knots (10 knots below threshold speed), aircraft entered a spin to the right. Successful recovery from spin resulted in loss of no. 4 engine and strut from wing. Aircraft landed successfully with no further incidents. Recovery was accomplished at 5,000 feet altitude after a loss of 3,000 feet.</td></tr>
<tr><td>1959</td><td>Boeing 707</td><td>Final Approach</td><td>United States</td><td>Hull Loss</td></tr>
<tr><td colspan="5">During a training flight, the crew made a no-flaps wave-off and continued around the traffic pattern with the gear extended. The crew then simulated a failure of nos. 3 and 4 engines; on final approach, the aircraft entered a severe yaw and crashed into the ground.</td></tr>
<tr><td>1960</td><td>Convair 880</td><td>Climb</td><td>United States</td><td>Hull Loss</td></tr>
<tr><td colspan="5">During takeoff, daylight training flight, no. 4 engine throttled back prior to takeoff. Airplane nosed up rapidly, stalled. Left wing dropped briefly then rolled into right vertical bank and crashed.</td></tr>
<tr><td>1965</td><td>Convair 880</td><td>Climb</td><td>United States</td><td>Hull Loss</td></tr>
<tr><td colspan="5">On takeoff for training, no. 4 throttle pulled to idle as trainee rotated; corrective rudder applied. Liftoff OK. Captain then adjusted power on nos. 1 and 2 slightly; right wing dropped and could not correct; stalled. Airplane crashed with no injuries.</td></tr>
<tr><td>1966</td><td>Douglas DC8</td><td>Climb</td><td>Oceania</td><td>Hull Loss</td></tr>
<tr><td colspan="5">Routine training takeoff; simulated no. 4 engine failure shortly after rotation; right wing dropped. Airplane failed to accelerate and slipped inward to ground, cartwheeled and disintegrated.</td></tr>
<tr><td>1966</td><td>Convair 880</td><td>Takeoff</td><td>Asia</td><td>Hull Loss</td></tr>
<tr><td colspan="5">During takeoff for a daylight, VFR training flight, no. 1 engine was throttled back to simulate engine failure. Pilot trainee lost control and allowed left wing and no. 1 engine to contact ground in nose-high attitude. Airplane then pitched over abruptly, separating landing gear and all engines. An immediate fuel fire prevented escape.</td></tr>
<tr><td>1966</td><td>Boeing 707</td><td>Landing</td><td>Europe</td><td>Substantial</td></tr>
<tr><td colspan="5">Approach for first touch and go made on ILS. No. 1 engine throttled back, trainee under the hood, screen removed at 200 feet and slightly left of centerline. Alignment correction and touched down hard and bounced on nose wheel. Found fuselage buckled.</td></tr>
<tr><td>1967</td><td>Douglas DC8</td><td>Final Approach</td><td>United States</td><td>Hull Loss</td></tr>
<tr><td colspan="5">Crashed during simulated two-engine-out landing approach. Killed 13 on ground as well as all aboard.</td></tr>
<tr><td>1967</td><td>Douglas DC8</td><td>Final Approach</td><td>Canada</td><td>Hull Loss</td></tr>
<tr><td colspan="5">Two engines out (throttle to idle) on one side; approach being practiced. Right wing dropped sharply before impact. Hit inverted.</td></tr>
<tr><td>1968</td><td>Douglas DC8</td><td>Landing</td><td>United States</td><td>Hull Loss</td></tr>
<tr><td colspan="5">Training flight simulating two engines out; allowed airspeed to drop below V_{MC}. 200 feet after touchdown, swerved off runway 3,500 feet across grass and ditch. All gear and engines separated. Fire consumed. All escaped.</td></tr>
<tr><td>1969</td><td>Convair 880</td><td>Climb</td><td>Asia</td><td>Hull Loss</td></tr>
<tr><td colspan="5">While on a training flight, the flight instructor reduced power on no. 4 engine on downwind side just after liftoff. The airplane rose to 125 feet and the right wing dropped, hitting the runway. The airplane slid 3,000 feet across open terrain stopping on taxiway and burst into flames. The pilot had not input sufficient rudder to maintain directional control with asymmetric thrust.</td></tr>
<tr><td>1969</td><td>Boeing 707</td><td>Go-around</td><td>United States</td><td>Hull Loss</td></tr>
<tr><td colspan="5">During a training flight, the airplane was making a three-engine approach with no. 4 engine in idle. The instructor called for a missed approach at decision height and the go-around was started. At this time a senior captain observer announced the loss of hydraulic system. In accordance with procedures, all hydraulic pumps were turned off. Without hydraulic rudder control, directional control could not be maintained with asymmetric thrust. The aircraft rolled to the right, lost altitude and impacted the ground, right wing low.</td></tr>
<tr><td>1970</td><td>Boeing 707</td><td>Landing</td><td>United States</td><td>Substantial</td></tr>
<tr><td colspan="5">Training flight simulated one-engine-out full-stop landing. Inboard engines reversed OK; came out of reverse at 80 knots. Deceleration with brakes only appeared marginal so again reversed. Crew could not slow for turn-off and overran at 30 miles per hour across ditches. Nose and right MLG and no. 3 engine separated.</td></tr>
<tr><td>1971</td><td>Boeing 707</td><td>Takeoff</td><td>Asia</td><td>Hull Loss</td></tr>
<tr><td colspan="5">Doing simulated heavy weight takeoff. After V_1, engine no. 4 was throttled to idle. At the same time, no. 3 engine lost power. The airplane started to veer right. Pilot rotated and ventral fin hit runway. The airplane departed the runway at 30-degree angle and went 4,000 feet across rough ground shedding parts. Fire destroyed the airplane, but no injuries were reported.</td></tr>
<tr><td>1973</td><td>Boeing 720</td><td>Final Approach</td><td>United States</td><td>Substantial</td></tr>
<tr><td colspan="5">During type-rating flight check, the airplane stayed in traffic pattern for another landing. Power on no. 1 and no. 2 engines retarded for two-engine landing. Airplane hit hard and both LH and RH main bounced and airplane bounced; nose gear collapsed. No fire.</td></tr>
<tr><td>1975</td><td>Douglas DC9</td><td>Landing</td><td>Europe</td><td>Substantial</td></tr>
<tr><td colspan="5">A trainee was being checked for captain rating. During a landing rollout in which single engine reversing was being demonstrated, directional control was lost, the airplane ran off the side of the runway, coming to rest 400 meters off the runway in a ditch. The runway was reported to have been wet.</td></tr>
</table>

Turbofan Training Accident Summaries (continued)

<table>
<tr><th>Date</th><th>Type</th><th>Phase of Flight</th><th>Region</th><th>Damage</th></tr>
<tr><td>1975</td><td>Boeing 737</td><td>Takeoff</td><td>South America</td><td>Substantial</td></tr>
<tr><td colspan="5">The aircraft was engaged in a training flight to check out three new first officers. A department of civil aviation check pilot occupied the RH seat. A company pilot was in the observer’s seat. The pilot in the LH seat was to expect an engine cut at takeoff. During the takeoff roll the check pilot cut no. 1 engine at V_1. The pilot in the LH seat rotated the aircraft to the desired attitude (14 degrees) and the gear was raised. The pilot in the center seat noticed the aircraft nose drop to about six degrees and advised the pilot in the LH seat to raise the nose. At about this time the check pilot in the RH seat took over the controls as the airplane settled onto the runway with the gear up. The airplane came to rest about 70 meters short of the far end of the runway. Time from V_1 to contact with the runway was about 11 seconds. The airplane slid parallel to the runway centerline on the left engine for 1,300 feet. At this point the forward fuselage contacted the runway and slid another 1,100 feet, and at this point the right engine contacted the runway. At this point the airplane veered to the left and came to rest after another 250-foot slide. Late in the veer the LH engine separated and rolled under the wing. A small fire occurred in the left engine but was quickly extinguished.</td></tr>
<tr><td>1977</td><td>Boeing 707</td><td>Takeoff</td><td>Europe</td><td>Hull Loss</td></tr>
<tr><td colspan="5">During a training flight, a crosswind takeoff, no. 1 engine was retarded by the instructor pilot in the left seat to simulate engine failure just as the airplane became airborne. A large yaw and left roll developed; the instructor pilot took control but was unable to recover. The airplane hit the ground and all engines and landing gear were torn off. Fire destroyed the aircraft, but all aboard evacuated, with one captain trainee suffering a broken heel.</td></tr>
<tr><td>1979</td><td>Douglas DC9</td><td>Takeoff</td><td>United States</td><td>Hull Loss</td></tr>
<tr><td colspan="5">Crashed just after airborne while practicing a takeoff with total loss of the airplane while a student pilot in the LH seat lost control and stalled during a simulated left engine out after V_1.</td></tr>
<tr><td>1979</td><td>Boeing 727</td><td>Landing</td><td>Africa</td><td>Substantial</td></tr>
<tr><td colspan="5">Airplane on a reposition flight with apparently some crew training. During approach to land, the airplane was configured with no. 1 engine intentionally shut down, ‘’A” system hydraulics isolated and all three generators off. Touched down on runway 19 about 3,600 feet beyond threshold and rolled off right side of runway into soft dirt; rolled parallel to runway, across intersecting runway 11 and made slow pivot to left, skidding across runway 19. Left main landing gear and nose gear collapsed into their wheel wells. Flaps, lower wing surface and lower fuselage were damaged severely.</td></tr>
<tr><td>1979</td><td>Boeing 707</td><td>Takeoff</td><td>Middle East</td><td>Hull Loss</td></tr>
<tr><td colspan="5">On a training flight to upgrade first officers to captain, there was a training captain, a flight engineer, and four trainee captains. On takeoff after the third touch-and-go landing, the airplane rotated normally but then yawed back and forth in a nose-high attitude and stalled. The right wing struck the ground and the airplane turned upside down and slid to a stop, on fire. The cockpit voice recorder indicates a possible simulated engine-out on takeoff with some error by the trainee pilot and confusion during relinquishing of control.</td></tr>
<tr><td>1979</td><td>Boeing 747</td><td>Landing</td><td>United States</td><td>Substantial</td></tr>
<tr><td colspan="5">On landing, all engines went into reverse normally. No. 4 EGT went to 820 degrees and throttle lever kicked back and could not be moved. No fire warning, but first officer saw fire on no. 4 engine. Engine shut down, fuel shutoff valve in wing closed and both fire bottles discharged. Airplane rolled to stop clear of runway on a taxiway, and fire extinguished by ground equipment. No evacuation was conducted. Pylon forward (firewall) bulkhead of no. 4 engine had separated allowing the forward end of the engine to drop, rupturing the main fuel line in the pylon, resulting in fuel fire.</td></tr>
<tr><td>1980</td><td>Convair 880</td><td>Takeoff</td><td>South America</td><td>Hull Loss</td></tr>
<tr><td colspan="5">On a training flight with three crew and one instructor, lost engine power on takeoff and crashed.</td></tr>
<tr><td>1983</td><td>Boeing 737</td><td>Climb</td><td>South America</td><td>Hull Loss</td></tr>
<tr><td colspan="5">A cargo flight with a crew of two was making a takeoff when the airplane failed to gain any significant altitude, and crashed. The crash site was approximately 300 meters beyond the end of the runway about 300–400 meters to the left of the runway centerline, and about 100 feet below runway elevation. Ground marks indicated that the airplane impacted in an inverted attitude and approximately 50 degrees nose down. The voice recorder transcript does not reveal any problem during the takeoff roll; however, just before the call ‘’rotate” there was a distinct sound of engine deceleration and directly after the call ‘’gear up” the landing gear warning horn began sounding. Approximately 1. 5 seconds after the warning horn sound, there was a comment, ‘’It is sinking.” About five seconds later the warning horn stopped. The first officer was in the left seat making the takeoff and was training for being upgraded to captain. Unconfirmed indications are that this was an engine cut on takeoff exercise.</td></tr>
<tr><td>1988</td><td>Boeing 737</td><td>Takeoff</td><td>Asia</td><td>Substantial</td></tr>
<tr><td colspan="5">During the takeoff, on a daylight training flight on runway 17, the instructor pilot reduced the left engine power to idle at V_1 to simulate engine failure. The takeoff was continued but the aircraft yawed and rolled to the left, dragging the left wing tip and fracturing the left wing spars at aileron mid-span. One of the pilots advanced the left engine power but the aircraft veered off the runway. The left engine contacted the ground and the landing gear was damaged. The wind was reported as 70 degrees left crosswind, 20 knots, gusting to 27 knots. No injuries were reported.</td></tr>
<tr><td>1991</td><td>Boeing 707</td><td>In Flight</td><td>Oceania</td><td>Hull Loss</td></tr>
<tr><td colspan="5">At 5,000 feet on a training flight, while demonstrating a two-engine-out V_{MCA} maneuver, control was lost and the airplane did a three-turn spin/spiral into the sea. According to Boeing analysis of the flight data and voice recorders, the maneuver was entered with power reduced on the no. 1 and no. 2 engines, rudder boost off, and at about 150 knots. The recommended speed for this maneuver is about 200 knots. The rudder effectiveness was significantly reduced with the boost off, and in combination with the low airspeed and thrust asymmetry, control was lost.</td></tr>
<tr><td>1993</td><td>Douglas DC9</td><td>Landing</td><td>United States</td><td>Substantial</td></tr>
<tr><td colspan="5">Apparent confusion during a training flight touch and go. One engine may have been in reverse. Directional control was lost and airplane departed off the runway side. Nose wheel well structure was damaged and left wing top surface skin wrinkled.</td></tr>
</table>

Turbofan Training Accident Summaries (continued)

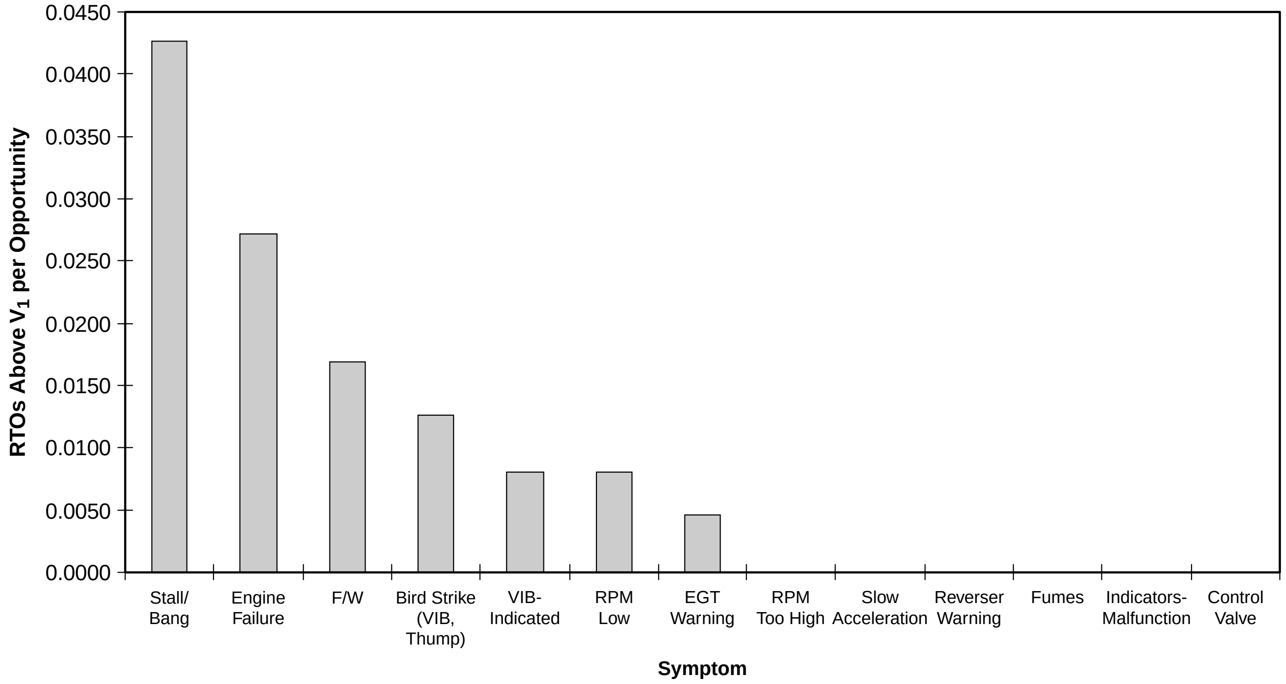
Date	Type	Phase of Flight	Region	Damage
1994	Boeing 737	Takeoff	Asia	Hull Loss
During local training following the fourth or fifth touch-and-go, on liftoff the airplane turned to the left and impacted the ground near the international terminal. Debris from the 737 impacted an Aeroflot Ilyushin IL-86 parked at the terminal. Both airplanes were destroyed by impact and post impact fire. Operator reports simulated engine failures (simulated by low thrust) were being practiced during the touch-and-gos. Four fatalities were from the 737 and the rest from the IL-86 or ground personnel.				
1996	Douglas DC8	Takeoff	South America	Hull Loss
Airplane crashed one minute after takeoff. Captain was conducting first officer training and pulled no. 1 engine back during the takeoff roll. He then pulled no. 2 back after rotation. First officer allowed the airplane nose to get too high and the airplane stalled and went into a flat spin.				
1998	Embraer 145J	Takeoff	United States	Substantial
Control lost during takeoff during simulated engine failure on rotation during a crew training flight. The port wing hit the runway, aircraft impacted grass alongside the runway and undercarriage collapsed, damaging both port and starboard wings, the fuselage and fan sections of both engines, which ingested large quantities of mud. Of the four on board, one was seriously injured, two others sustained minor injuries and the fourth escaped unharmed.				

EGT = Exhaust gas temperature
ILS = Instrument landing system
LH = Left hand (left)
MLG = Main landing gear
RH = Right hand (right)
VFR = Visual flight rules

Appendix G

Summary of General Electric/CFM International Commercial Fleet Rejected Takeoff Study

Conditional Probability* of RTO above V_1 By Symptom for a High Bypass Turbofan Fleet



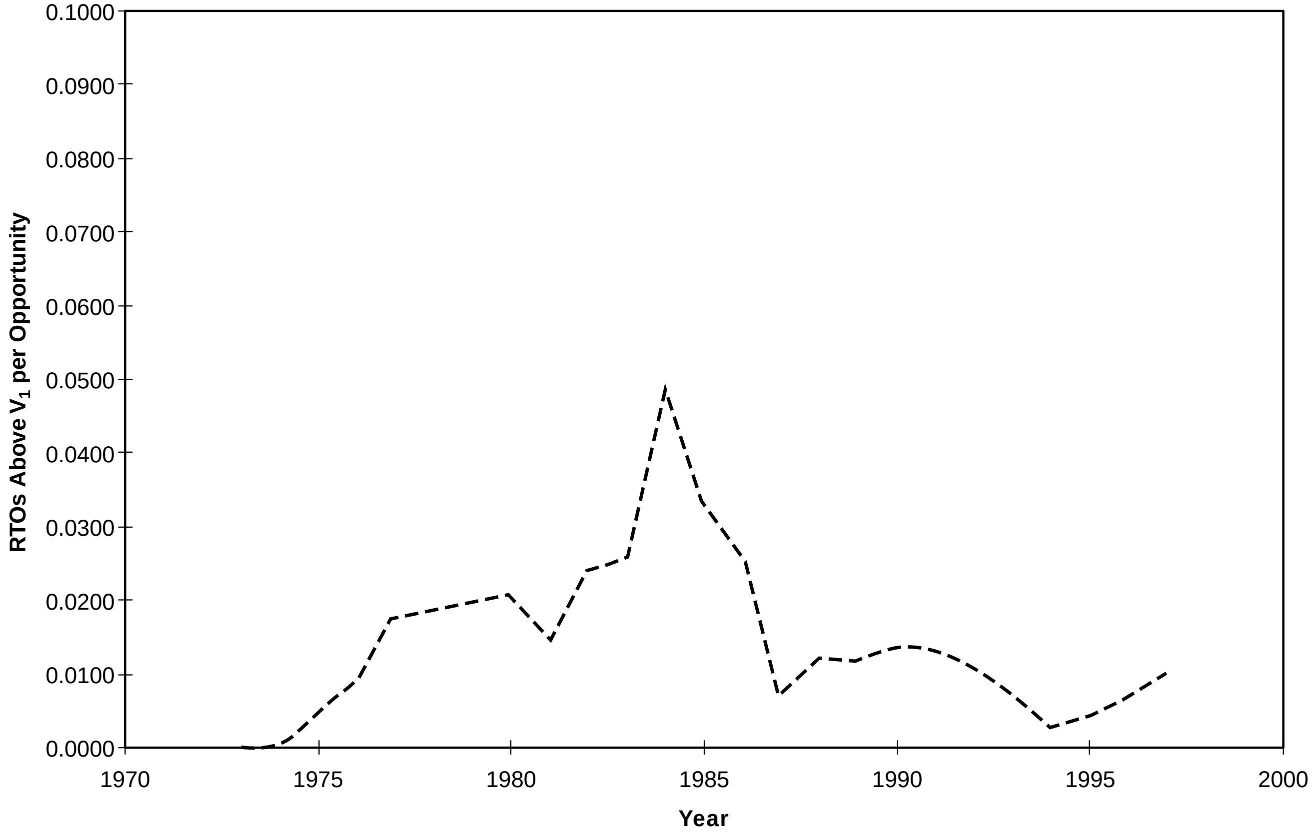
* Conditional probability calculated as number of RTOs above V_1 with given primary symptom, divided by number of symptom occurrences in high-speed portion of takeoff roll, normal operation.

RTO = Rejected takeoff F/W = Flight deck warning VIB = Vibration EGT = Exhaust gas temperature

Source: G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 1

Conditional Probability* of RTO above V_1 Showing Three-year Average



* Conditional probability calculated as number of propulsion-caused RTOs above V_1, divided by number of events in the high-speed portion of the takeoff roll with symptoms conducive to rejecting the takeoff.

RTO = Rejected takeoff

Source: G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Figure 2

Appendix H

Summary of Turboprop Data

Glossary

A/C = Aircraft
AGL = Above ground level
ATC = Air traffic control
BAe = British Aerospace
C = Captain
CB = Circuit breaker
CIS = Commonwealth of Independent States
CVR = Cockpit voice recorder
deg = Degrees
DHC = de Havilland Canada
ECS = Environmental control system
eng(s) = Engine(s)
Event H = Hull loss
Event HF = Hull loss, fatal
Event S = Substantial damage
F = Fahrenheit
FAR = (FARs) U.S. Federal Aviation Regulations
ft = Feet
FO = First officer
Hazard Level 2 = Significant consequences
Hazard Level 4 = Severe consequences
Hazard Level 5 = Catastrophic consequences
HP = High pressure
HS = Hawker Siddeley
IAI = Israel Aircraft Industries
IAS = Indicated airspeed
ILS = Instrument landing system
IMC = Instrument meteorological conditions
ITT = Interstage turbine temperature
km = Kilometers
lbs = Pounds
LH = Left hand (left)
m = Meters
MLG = Main landing gear
MTOW = Maximum takeoff weight
N = No
No(s). = Number(s)
Np = (N_P) Propeller speed
NTS = Negative-torque-sensing system
prop = Propeller
RH = Right hand (right)
RPM = Revolutions per minute
TO = Takeoff
USSR = Union of Soviet Socialist Republics
V_2 = Takeoff safety speed
Vmc = (V_{MC}) Minimum control speed with the critical engine inoperative
VMC = Visual meteorological conditions
Y = Yes

PSM+ICR Turboprop Data, January 1985 – April 1997

Event No:	003	**Geographical Region of Operator:**	North America
Date:	1-May-85	**Location:**	Nashville, Tennessee, U.S.
Airplane Model:	Gulfstream G-159	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Loss of control after engine failure on takeoff climb		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:	100		
Vmc infringed?:	Y		
Pilot Flying (C/FO):	C		
Weather Conditions:	Night/VMC		
Runway Conditions:			
Engine/Propeller Model:	Dart 529		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	N		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	No 1 engine failed because HP cock lever was in wrong position		
Crew Action:	Failed to feather prop before applying max power to remaining engine.		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:	N		
Narrative:	During initial TO climb LH eng lost power. Crew attempted to continue climbout but after applying water meth pilot lost directional control. A/C banked left, entered descent and impacted between parallel runways. No pre-impact system malfunction found. CVR indicated pre-takeoff checks not properly completed. LH HP cock lever found between Fuel Off and Feather. This shut down engine and disarmed autofeather system.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	004	**Geographical Region of Operator:**	South America
Date:	23-Jun-85	**Location:**	Juara, Brazil
Airplane Model:	Embraer 110	**Event:**	HF
Airplane Generation:	Second	**Hazard Level:**	5

PSM+ICR Category:	Loss of control
Summary of Event:	Stalled during single engine approach
Type of Airline Operation (FAR):	135
Engine Training Flight?:	N
Phase of Flight:	Approach
Flight Phase Detail:	Finals
Initiating Event Altitude:	200
Vmc infringed?:	N
Pilot Flying (C/FO):	
Weather Conditions:	
Runway Conditions:	
Engine/Propeller Model:	PT6A-34
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	SD
Autofeather/autocoarsen fitted?:	N
Autofeather/autocoarsen armed?:	N
Number of Engines:	2
Engine Position:	1
Engine/Propeller Symptom:	Crew saw fuel leak from engine
Propulsion System Malfunction:	Faulty fuel nozzle damaged turbine hardware, leading to fuel line rupture
Crew Action:	Crew shut down engine on approach but stalled short of runway
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S, R
Autopilot engaged?:	N
Narrative:	Faulty fuel nozzle on LH engine generated blowtorch effect damaging turbine hardware. Rotor imbalance ruptured fuel return line. On seeing fuel leak crew shut down LH engine and attempted landing on nearby runway. A/C stalled and crashed short of runway.

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	006	**Geographical Region of Operator:**	South America
Date:	4-Aug-85	**Location:**	Mocoa, Brazil
Airplane Model:	Embraer 110	**Event:**	H
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Loss of control after engine failure on takeoff climb		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:	100		
Vmc infringed?:	Y		
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	PT6A-34		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	N		
Autofeather/autocoarsen armed?:	N		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Engine exploded		
Crew Action:			
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:	N		
Narrative:	On takeoff at V2 LH engine exploded. A/C continued in uncontrolled flight and collided with trees 1600 m from runway.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	007	**Geographical Region of Operator:**	North America
Date:	25-Aug-85	**Location:**	Auburn, Minnesota, U.S.
Airplane Model:	Beech 99	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Crashed after engine failure on approach		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Approach		
Flight Phase Detail:	Finals		
Initiating Event Altitude:	150		
Vmc infringed?:	N		
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	PT6A-27		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	N		
Autofeather/autocoarsen armed?:	N		
Number of Engines:	2		
Engine Position:			
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Engine failed		
Crew Action:			
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S, R		
Autopilot engaged?:	N		
Narrative:	Engine failure on finals, aircraft crashed, post crash fire. All 8 on board killed.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	00x	**Geographical Region of Operator:**	Europe
Date:	4-Dec-85	**Location:**	Palma de Mallorca, Spain
Airplane Model:	Aero Commander 680T	**Event:**	H
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Overrun		
Summary of Event:	Overran after power loss on takeoff run		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Runway		
Initiating Event Altitude:	0		
Vmc infringed?:	N		
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	TPE331-43A		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:			
Engine/Propeller Symptom:	Low power		
Propulsion System Malfunction:			
Crew Action:	Aborted takeoff but failed to prevent overrun		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S, R		
Autopilot engaged?:	N		
Narrative:	Pilot reported low power on one or both engines on TO. Hit small concrete wall after running off runway. Collapsed nose gear and one main gear. Prop strike on both engines and one prop went through fuselage. 5 on board.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	010	**Geographical Region of Operator:**	USSR
Date:	2-Mar-86	**Location:**	Bugulma, Russia
Airplane Model:	Antonov 24	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Stalled during single engine approach		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Approach		
Flight Phase Detail:	5 miles out		
Initiating Event Altitude:	1500		
Vmc infringed?:	N		
Pilot Flying (C/FO):			
Weather Conditions:	IMC		
Runway Conditions:			
Engine/Propeller Model:	AL24A		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Electrical fault caused prop to feather and engine to stop.		
Crew Action:	Failed to apply control inputs to counter thrust asymmetry following engine failure.		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:	N		
Narrative:	During IMC approach, 1 second after flap extension, No 1 engine stopped and the prop feathered. Crew did not counter asymmetric thrust. Airspeed decreased and A/C stalled and crashed 8 km from runway. Failure of autofeather sensor CB caused prop to feather and eng to stop.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	011	**Geographical Region of Operator:**	Asia
Date:	30-Mar-86	**Location:**	Pemba, India
Airplane Model:	Antonov 26	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Loss of control after engine failure on takeoff climb		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Climb		
Initiating Event Altitude:	1000		
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	AL24A		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:			
Engine/Propeller Symptom:	Problems		
Propulsion System Malfunction:			
Crew Action:			
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S, R		
Autopilot engaged?:	N		
Narrative:	A/C crashed and burned shortly after TO from Pemba. Crash occurred seconds after crew reported engine problems and that emergency landing would be attempted.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	013	**Geographical Region of Operator:**	Asia
Date:	15-Dec-86	**Location:**	Lanzhou, China
Airplane Model:	Antonov 24	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	4

PSM+ICR Category:	Loss of control
Summary of Event:	Crashed on approach after engine failure during climb
Type of Airline Operation (FAR):	135
Engine Training Flight?:	N
Phase of Flight:	Climb
Flight Phase Detail:	
Initiating Event Altitude:	
Vmc infringed?:	
Pilot Flying (C/FO):	
Weather Conditions:	Severe icing
Runway Conditions:	
Engine/Propeller Model:	AL24A
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F
Autofeather/autocoarsen fitted?:	Y
Autofeather/autocoarsen armed?:	?
Number of Engines:	2
Engine Position:	2
Engine/Propeller Symptom:	
Propulsion System Malfunction:	Failed
Crew Action:	Lost control during single engine approach
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S
Autopilot engaged?:	
Narrative:	Severe icing occurred during climb. RH eng failed and prop was feathered. A/C returned for landing but crashed during approach.

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	016	**Geographical Region of Operator:**	North America
Date:	18-Feb-87	**Location:**	Quincy, Illinois, U.S.
Airplane Model:	Westwind E18S	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Stalled and crashed during return to airport shortly after TO.		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:	400		
Vmc infringed?:	Y		
Pilot Flying (C/FO):	FO		
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	PT6A-20		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:			
Crew Action:			
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S, R		
Autopilot engaged?:			
Narrative:	A/C on initial climb after TO near gross weight. Witness said engs sounded normal. At 400 feet A/C seen to pitch up 10 deg then level off and enter LH turn. A/C made another LH turn and pilot reported he was returning to field. Did not state problem. Witness said A/C was in 30 deg LH bank turning toward airport when A/C stalled and descended to ground in vertical nose down attitude. LH prop found feathered. No eng problem found. Previous LH eng problem on 28/1/87.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	019	**Geographical Region of Operator:**	North America
Date:	23-Apr-87	**Location:**	Wilmington, North Carolina, U.S.
Airplane Model:	Fairchild SA226TC	**Event:**	HF
Airplane Generation:	Second	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Loss of control after uncontained eng failure on TO		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:	150		
Vmc infringed?:			
Pilot Flying (C/FO):	FO		
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	TPE331-3		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Uncontained 3rd stage turbine failure		
Crew Action:	Failed to maintain control following eng failure on takeoff		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S, R		
Autopilot engaged?:	N		
Narrative:	During TO copilot said they had lost RH eng. Witnesses heard loud noise and saw flame shoot from RH eng. Saw A/C nose high cross end of runway at 150 ft before hitting trees. RH eng had uncontained 3rd stage turbine failure. Some loss of electrical power resulted from eng failure. Pilot should have been able to land back on runway after eng failure.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	020	**Geographical Region of Operator:**	Europe
Date:	26-Apr-87	**Location:**	Blackbushe, U.K.
Airplane Model:	Cessna 441	**Event:**	HF
Airplane Generation:	Second	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Crashed on go-around from short finals. Engine failure suspected.		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Go-around		
Flight Phase Detail:			
Initiating Event Altitude:	200		
Vmc infringed?:	Y		
Pilot Flying (C/FO):	C		
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	TPE331-8		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:			
Crew Action:	Lost control after aborting go-around in favor of immediate landing		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:			
Narrative:	A/C cleared to land. On short finals reported that he had problem and was going around. Pilot’s next call was that he was “going in.” Controller saw A/C veer to left and crash. Investigation found go-around initiated due to unsafe MLG indication. Curved flight path of A/C from go-around to impact and progressive increase in bank angle suggests asymmetric thrust most probable cause.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No: 023

Geographical Region of Operator: Europe

Date: 12-Sep-87

Location: Southend, U.K.

Airplane Model: Beech 200

Event: HF

Airplane Generation: Second

Hazard Level: 4

PSM+ICR Category: Loss of control

Summary of Event: Loss of control after engine failure during climb

Type of Airline Operation (FAR): 91

Engine Training Flight?: N

Phase of Flight: Climb

Flight Phase Detail: 2 miles out

Initiating Event Altitude:

Vmc infringed?:

Pilot Flying (C/FO): C

Weather Conditions: Night/IMC

Runway Conditions:

Engine/Propeller Model: PT6A-41

Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O): F

Autofeather/autocoarsen fitted?: N

Autofeather/autocoarsen armed?: N

Number of Engines: 2

Engine Position: 1

Engine/Propeller Symptom:

Propulsion System Malfunction: Ruptured diaphragm in LP compressor bleed valve, causing engine instability

Crew Action: Failed to maintain control following engine shutdown after takeoff

Crew Error Classification — Skill (S), Rule (R) or Knowledge (K): S

Autopilot engaged?: N

Narrative: A/C much lower than usual during initial climb. Witnesses reported uneven engine sounds and loud bang. In-flight fire seen. LH prop found feathered, RH prop rotating at high rpm at fine pitch. LH shutoff valve found closed. Likely that LH eng was shut down. No pre-impact damage to LH eng rotating assembly found. Only damage was ruptured diaphragm in the LP compressor bleed valve. Previous similar failures of valve (on other A/C) caused dramatic flux of torque and ITT requiring eng shutdown.

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	029	**Geographical Region of Operator:**	North America
Date:	29-Dec-87	**Location:**	Telluride, Colorado, U.S.
Airplane Model:	Swearingen SA226	**Event:**	S
Airplane Generation:	Second	**Hazard Level:**	2
PSM+ICR Category:	Loss of directional control		
Summary of Event:	Applied asymmetric reverse thrust on landing, departed runway		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Landing		
Flight Phase Detail:	Landing roll		
Initiating Event Altitude:	0		
Vmc infringed?:	N		
Pilot Flying (C/FO):			
Weather Conditions:	Crosswind		
Runway Conditions:	Icy		
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	O		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:	No beta light on landing		
Propulsion System Malfunction:			
Crew Action:	Applied reverse thrust despite having evidence of prop control malfunction		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:	N		
Narrative:	During approach pilot felt downdrafts and crosswind. After touchdown pilot said he did not get RH beta light. Said he applied reverse power on both engs. A/C drifted left, pilot corrected with brakes and nosewheel steering, then applied TO power. A/C veered right, ran off RH side of runway. Witness said A/C landed fast and long. No eng or prop malfunction found. Reverse not recommended on icy runway or when beta light not lit on one eng.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	032	**Geographical Region of Operator:**	Europe
Date:	25-Jan-88	**Location:**	East Midlands, U.K.
Airplane Model:	Beech King Air	**Event:**	HF
Airplane Generation:	Second	**Hazard Level:**	4

PSM+ICR Category:	Loss of control
Summary of Event:	Stalled following engine failure on go-around
Type of Airline Operation (FAR):	91
Engine Training Flight?:	N
Phase of Flight:	Go-around
Flight Phase Detail:	
Initiating Event Altitude:	100
Vmc infringed?:	Y
Pilot Flying (C/FO):	C
Weather Conditions:	IMC
Runway Conditions:	
Engine/Propeller Model:	PT6A-28
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F
Autofeather/autocoarsen fitted?:	N
Autofeather/autocoarsen armed?:	N
Number of Engines:	2
Engine Position:	2
Engine/Propeller Symptom:	
Propulsion System Malfunction:	Split in RH eng compressor bleed valve diaphragm
Crew Action:	Failed to maintain control during go-around following engine failure
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S
Autopilot engaged?:	
Narrative:	A/C on short finals in low visibility ILS approach. Pilot called for go-around. A/C crashed 600m beyond threshold and caught fire killing sole occupant. Checks on engs found small split in RH eng compressor bleed valve diaphragm. Would have caused 300 ft. lbs. torque loss at go-around. Pilot failure to control this condition, plus possible disorientation in poor visibility, caused A/C to stall.

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	035	**Geographical Region of Operator:**	North America
Date:	25-Mar-88	**Location:**	Decatur, Texas, U.S.
Airplane Model:	Jetstream 31	**Event:**	H
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of height		
Summary of Event:	After precautionary shutdown, aircraft could not maintain altitude and made forced landing		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Descent		
Flight Phase Detail:	4000 ft		
Initiating Event Altitude:	4000		
Vmc infringed?:	N		
Pilot Flying (C/FO):	C		
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	SD		
Autofeather/autocoarsen fitted?:	N		
Autofeather/autocoarsen armed?:	N		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:	Torque fluctuations of up to 30%		
Propulsion System Malfunction:	No actual malfunction found		
Crew Action:	Failed to verify that torque flux was real (rather than indication fault). Applied wrong shutdown drill.		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:	N		
Narrative:	LH torque flux seen during descent, but no yaw noticed. Elected to shut down eng. LH prop did not feather and drag increased until A/C could not maintain altitude. Eng restarted and descent rate increased (even with full power on RH eng). Shut down LH eng again. Descent continued and forced landing made in a field. No eng defects found. LH prop found on start locks. Likely cause was inadvertent use of ground shutdown drill, putting prop on start locks, resulting in high drag.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:		**Geographical Region of Operator:**	North America
Date:	15-Apr-88	**Location:**	Seattle, Washington, U.S
Airplane Model:	Dash 8	**Event:**	H
Airplane Generation:	Second	**Hazard Level:**	4

PSM+ICR Category:	Loss of directional control
Summary of Event:	Engine fire on takeoff. Went around. Didn’t shut down engine. Lost hydraulics and departed runway on
Type of Airline Operation (FAR):	121
Engine Training Flight?:	N
Phase of Flight:	Takeoff
Flight Phase Detail:	Initial climb
Initiating Event Altitude:	
Vmc infringed?:	N
Pilot Flying (C/FO):	
Weather Conditions:	Day/VMC
Runway Conditions:	
Engine/Propeller Model:	PW120
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	O
Autofeather/autocoarsen fitted?:	Y
Autofeather/autocoarsen armed?:	Y
Number of Engines:	2
Engine Position:	2
Engine/Propeller Symptom:	Power loss, then fire
Propulsion System Malfunction:	Gross fuel leakage from improperly fitted HP fuel filter cover
Crew Action:	Failed to shut off fuel supply to engine in accordance with fire drill
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R
Autopilot engaged?:	N
Narrative:	Shortly after takeoff crew noted RH eng power loss. Decided to return for landing. Large fire seen in RH nacelle when gear lowered. After landing, directional control and all braking lost. Aircraft left LH side of runway when power lever set to flight idle. Aircraft rolled onto ramp, struck ground equipment and jetways. Destroyed by fire. Cause found to be fuel leak from improperly installed HP fuel filter during overhaul, not discovered following engine installation.

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	036	**Geographical Region of Operator:**	North America
Date:	24-May-88	**Location:**	Lawton, Oklahoma, U.S.
Airplane Model:	Embraer 110	**Event:**	H
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Loss of control after engine failure on takeoff climb		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:	100		
Vmc infringed?:	Y		
Pilot Flying (C/FO):	C		
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	PT6A-34		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Turbine blade separation		
Crew Action:			
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:			
Narrative:	LH eng failed during takeoff. A/C yawed sharply left and climbed to 100 ft before losing height. Struck ground and ran several hundred feet before coming to rest. Examination of LH eng showed turbine blade separation. Prop had autofeathered.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	038	**Geographical Region of Operator:**	South America
Date:	6-Jul-88	**Location:**	Barranquilla, Colombia
Airplane Model:	Canadair CL 44	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	4

PSM+ICR Category:	Loss of control
Summary of Event:	Crashed after uncontained engine failure on takeoff
Type of Airline Operation (FAR):	135
Engine Training Flight?:	N
Phase of Flight:	Takeoff
Flight Phase Detail:	Rotation
Initiating Event Altitude:	25
Vmc infringed?:	Y
Pilot Flying (C/FO):	
Weather Conditions:	
Runway Conditions:	
Engine/Propeller Model:	Tyne
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F, SD
Autofeather/autocoarsen fitted?:	?
Autofeather/autocoarsen armed?:	?
Number of Engines:	4
Engine Position:	
Engine/Propeller Symptom:	
Propulsion System Malfunction:	Uncontained failure
Crew Action:	Lost control after losing engines Number 3 and Number 4.
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S
Autopilot engaged?:	N
Narrative:	Immediately after rotation Number 4 eng had uncontained failure. Flew circuit and approach but lost control and crashed short of runway. Reported that Number 3 eng also had to be shut down and RH wing on fire prior to crash.

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	043	**Geographical Region of Operator:**	North America
Date:	20-Jan-89	**Location:**	Buena Vista, Colorado, U.S.
Airplane Model:	Convair 580	**Event:**	S
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Loss of thrust		
Summary of Event:	One engine was shut down. Crashed after remaining engine failed when pilot inadvertently shut off first engine		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Cruise		
Flight Phase Detail:			
Initiating Event Altitude			
Vmc infringed?:	N		
Pilot Flying (C/FO):			
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	Allison 501D13H		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	SD		
Autofeather/autocoarsen fitted?:	?		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:			
Engine/Propeller Symptom:	Low oil pressure		
Propulsion System Malfunction:	Not confirmed		
Crew Action:	Shut down good engine during clean-up drills following first engine shutdown. Used wrong restart procedure		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S, R		
Autopilot engaged?:			
Narrative:	During flight, crew shut down RH eng for low oil pressure. Shortly after, LH eng lost power (tank shutoff valve switch was near crossfeed switch). Attempts to restart LH eng failed. With no A/C power, pilot could not unfeather RH prop for restart. Emergency landing made on uneven ground. Check of RH eng did not show malfunction. Examination of LH eng showed severe turbine heat damage. Pilot set power lever ahead of flight idle during LH restart, against flight manual caution to set at flight idle.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:		**Geographical Region of Operator:**	Europe
Date:	21-Jan-89	**Location:**	Dragoer, Denmark
Airplane Model:	Fairchild Metro II	**Event:**	H
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Crashed on approach following engine shutdown. Prop did not feather.		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Cruise		
Flight Phase Detail:			
Initiating Event Altitude:			
Vmc infringed?:	Y		
Pilot Flying (C/FO):			
Weather Conditions:	Day/Icing		
Runway Conditions:			
Engine/Propeller Model:	TPE331-3U		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	SD		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:	Low oil pressure and torque. Severe vibration		
Propulsion System Malfunction:			
Crew Action:	Lost control during single engine approach		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:			
Narrative:	One eng began to lose oil pressure and torque. Aircraft was in icing so elected to keep eng running. Finally shut down eng after severe vibration encountered. Prop did not feather. Crashed on approach short of runway in weather.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	044	**Geographical Region of Operator:**	North America
Date:	8-Apr-89	**Location:**	Tampa, Florida, U.S.
Airplane Model:	Beech C45H	**Event:**	S
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Loss of thrust		
Summary of Event:	Loss of thrust resulting in forced landing immediately after becoming airborne		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:	100		
Vmc infringed?:			
Pilot Flying (C/FO):	C		
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	PT6A-20		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	?		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Fuel contamination		
Crew Action:	Failed to continue takeoff after engine failure		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	LH eng failed after takeoff due to fuel contamination. Pilot made forced landing off departure end of runway with RH eng still developing power, as seen from prop strike marks on ground. Post accident fuel analysis showed sand and fiber contamination. Pilot had just refueled but source of contamination was not determined.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	048	**Geographical Region of Operator:**	North America
Date:	5-Nov-89	**Location:**	Dallas, Texas, U.S.
Airplane Model:	Jetstream 31	**Event:**	S
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Heavy landing		
Summary of Event:	Heavy landing due to mis-selection of flaps following engine failure en route.		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Climb		
Flight Phase Detail:	En route		
Initiating Event Altitude:			
Vmc infringed?:	N		
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	SD		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:	Low oil pressure		
Propulsion System Malfunction:	Damaged seal on prop piston allowing oil leakage into bleed air		
Crew Action:	Selected wrong flap setting for single engine landing at diversion airfield		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	At 6000 ft, smoke entered cabin and passengers panicked. Shortly after, RH oil pressure fell and RH eng was shut down. During diversion, mis-selection of flaps resulted in hard landing with tailcone hitting ground. Veered off runway. Prop had recent maintenance on dome O-ring. Extensive oil contamination in cowl. Piston seal found damaged. Oil entered ECS causing smoke.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	050	**Geographical Region of Operator:**	North America
Date:	9-Jan-90	**Location:**	Jacksonville, Florida, U.S.
Airplane Model:	Mitsubishi MU-2B	**Event:**	S
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of thrust		
Summary of Event:	Forced landing. Engine shut down, unable to apply full power on remaining engine.		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Cruise		
Flight Phase Detail:			
Initiating Event Altitude:			
Vmc infringed?:	N		
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	SD		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:			
Engine/Propeller Symptom:	Fluctuating torque		
Propulsion System Malfunction:	None found		
Crew Action:	Failed to confirm engine malfunction before shutting down		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S, R		
Autopilot engaged?:			
Narrative:	In cruise, shut down an eng for fluctuating torque. Unable to get more than 40% torque from remaining eng. Landed in marsh. Investigation did not find any eng malfunction.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	051	**Geographical Region of Operator:**	North America
Date:	19-Jan-90	**Location:**	Broomfield, Colorado, U.S.
Airplane Model:	Mitsubishi MU-2B	**Event:**	S
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Engine malfunction on takeoff roll. Lost control and departed runway.		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Takeoff roll		
Initiating Event Altitude:	0		
Vmc infringed?:	Y		
Pilot Flying (C/FO):	C		
Weather Conditions:	Day/IMC, heavy snow showers		
Runway Conditions:	Snow covered		
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:	Lost RPM		
Propulsion System Malfunction:			
Crew Action:	Failed to maintain direction control on runway		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:	N		
Narrative:	Pilot said during takeoff roll, LH eng lost RPM. Lost directional control and plane departed LH side of runway. Struck runway sign and 2 lights. Skidded sideways for 3000 ft, crossed runway and stopped in ditch. Heavy snow falling and runway covered in snow.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	052	**Geographical Region of Operator:**	North America
Date:	9-Feb-90	**Location:**	Rapid City, South Dakota, U.S.
Airplane Model:	Mitsubishi MU-2B	**Event:**	HF
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Loss of control after engine failure on takeoff		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:	100		
Vmc infringed?:	Y		
Pilot Flying (C/FO):			
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Coupling shaft failed in fatigue		
Crew Action:	Failed to maintain control following eng failure on takeoff		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:	N		
Narrative:	Shortly after lift-off, aircraft entered steep nose-up attitude at low IAS. Pilot witness said A/C reached height of approximately 100 ft, slowed and entered Vmca roll and crashed inverted, nose down, left of runway. Investigation showed coupling shaft in LH eng failed through fatigue. LH prop had feathered.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	054	**Geographical Region of Operator:**	Asia
Date:	3-Apr-90	**Location:**	Libuhanraio, Indonesia
Airplane Model:	DHC 6	**Event:**	H
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Loss of height		
Summary of Event:	Engine oversped during takeoff, aircraft lost height and hit hill		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:			
Vmc infringed?:	N		
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	PT6A-27		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:	Engine oversped		
Propulsion System Malfunction:			
Crew Action:	Failed to maintain climb performance following eng failure on takeoff		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:	N		
Narrative:	Soon after takeoff, LH eng oversped, aircraft lost height and struck crest of hill, crashing into trees.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	055	**Geographical Region of Operator:**	South America
Date:	18-Apr-90	**Location:**	Contadora Island, Panama
Airplane Model:	DHC 6	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Loss of control after engine failure on takeoff		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:			
Vmc infringed?:	Y		
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	PT6A-27		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:			
Propulsion System Malfunction:			
Crew Action:	Failed to maintain control following eng failure on takeoff		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:	N		
Narrative:	Shortly after takeoff, RH eng failed and aircraft entered descending right turn which continued until impact with the sea.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	056	**Geographical Region of Operator:**	South America
Date:	10-May-90	**Location:**	Tuxla Gutierrez, Mexico
Airplane Model:	Fokker F27	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of height		
Summary of Event:	Crashed after engine failure on approach		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Approach		
Flight Phase Detail:	4.5 km out		
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	Dart 522		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:			
Propulsion System Malfunction:			
Crew Action:	Failed to maintain approach flight path after engine failure		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:			
Narrative:	RH eng failed on approach. Aircraft struck trees and crashed 4.5 km from airport		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	057	**Geographical Region of Operator:**	Asia
Date:	18-May-90	**Location:**	Manila, Philippines
Airplane Model:	Beech 1900	**Event:**	HF
Airplane Generation:	Second	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Loss of control after engine failure on takeoff		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Climb		
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	PT6A-65		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:			
Engine/Propeller Symptom:			
Propulsion System Malfunction:			
Crew Action:	Failed to maintain control following eng failure on takeoff		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:			
Narrative:	Crashed and burned in residential area shortly after takeoff, reportedly following an engine failure		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	058	**Geographical Region of Operator:**	North America
Date:	23-Aug-90	**Location:**	Houston, Texas, U.S.
Airplane Model:	Gulfstream G-159	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Loss of control after engine failure on takeoff		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:			
Vmc infringed?:	Y		
Pilot Flying (C/FO):			
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	Dart 529		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Partial power loss due to faulty fuel pump		
Crew Action:	Failed to maintain control following eng failure on takeoff		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S, R		
Autopilot engaged?:			
Narrative:	Passengers and witnesses said that during takeoff, aircraft yawed both left and right after liftoff, then veered left and contacted ground LH wing low. Investigation showed LH eng had partial power loss due to faulty fuel pump. Power loss not enough to trip autofeather. Manual feathering had been started, but blades had not reached full feather before impact.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	059	**Geographical Region of Operator:**	North America
Date:	24-Aug-90	**Location:**	Mattapan, Massachusetts, U.S.
Airplane Model:	Piper PA31	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of height		
Summary of Event:	Crashed on approach following engine shutdown		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Go-around		
Flight Phase Detail:			
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):	C		
Weather Conditions:	Day/IMC		
Runway Conditions:			
Engine/Propeller Model:	PT6A-28		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	SD		
Autofeather/autocoarsen fitted?:	?		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:	Overtorque indication		
Propulsion System Malfunction:	Fuel pump drive shaft failure		
Crew Action:	Failed to maintain approach flight path after engine failure		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:			
Narrative:	Pilot noted LH eng overtorque as aircraft was on ILS approach. Made go-around and started another approach with eng shut down. Unable to maintain height and descended. Crashed into 2 houses 6 miles from airport. Examination of LH eng showed fuel pump drive shaft sheared at plastic coupling. Driveshaft bearings also failed, allowing shaft to move and cause overtorque.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	060	**Geographical Region of Operator:**	North America
Date:	6-Sep-90	**Location:**	Nashville, Tennessee, U.S.
Airplane Model:	Mitsubishi MU-2B	**Event:**	HF
Airplane Generation:	Second	**Hazard Level:**	5
PSM+ICR Category:	Loss of height		
Summary of Event:	Took off with known low power defect on one engine. Failed to climb. Crashed.		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:			
Vmc infringed?:	Y		
Pilot Flying (C/FO):	C		
Weather Conditions:	Day/VMC 95 deg F		
Runway Conditions:			
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	O		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:			
Engine/Propeller Symptom:	Low power		
Propulsion System Malfunction:	None found		
Crew Action:	Took off with known engine defect.		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	On previous flight, low power noted in RH eng. RH fuel flow 5 gallons/hour less than left and RH ITT 50 deg less. Decided to ferry aircraft. Aircraft remained low after takeoff, then rolled right and dropped sharply. Impacted RH wing low 2 miles from end of runway. No pre-impact failure found. Both engs had evidence of rotation at impact. Maintenance not informed of engine problem before flight.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	062	**Geographical Region of Operator:**	North America
Date:	29-Nov-90	**Location:**	Des Moines, Iowa, U.S.
Airplane Model:	Piper PA31	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Loss of control after engine failure on approach		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Approach		
Flight Phase Detail:	Finals		
Initiating Event Altitude:			
Vmc infringed?:	Y		
Pilot Flying (C/FO):	C		
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	PT6A-35		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	?		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	None found		
Crew Action:	Failed to feather prop after engine failure		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	On final approach, pilot told controller he might have to shut down an eng. Did not declare emergency. On short finals, aircraft rolled left and descended into terrain. Examination showed LH eng was not developing power, although LH prop was not feathered. Evidence that RH was producing high power at impact. No mechanical defect in LH eng or prop found.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	063	**Geographical Region of Operator:**	North America
Date:	17-Dec-90	**Location:**	Chattanooga, Tennessee, U.S.
Airplane Model:	Jetstream 31	**Event:**	S
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of directional control		
Summary of Event:	Landed with one engine stuck at full power. Departed runway		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Climb		
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):	C		
Weather Conditions:	Night/VMC		
Runway Conditions:	Dry		
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	O		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:			
Engine/Propeller Symptom:	Engine stuck at full power		
Propulsion System Malfunction:	Power lever disconnect		
Crew Action:	Failed to shut down engine prior to landing		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot Engaged?			
Narrative:	Power lever disconnected after takeoff, leaving eng stuck at full power. Pilot elected not to shut down eng until after touchdown, upon which directional control was lost. Aircraft left runway and was damaged in outfield.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	064	**Geographical Region of Operator:**	North America
Date:	22-Feb-91	**Location:**	Tulsa, Oklahoma, U.S.
Airplane Model:	Mitsubishi MU-2B	**Event:**	HF
Airplane Generation:	Second	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Loss of control after engine failure on takeoff		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:	500		
Vmc infringed?:	Y		
Pilot Flying (C/FO):	C		
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	SD		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	None found		
Crew Action:	Failed to apply rudder trim after engine failure		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S, R		
Autopilot engaged?:	N		
Narrative:	Aircraft doing test flight after replacement of both engs. Witnesses said takeoff roll and initial climb appeared normal, but at 500 ft aircraft entered right bank until wings were vertical. Nose fell through and aircraft hit ground inverted in steep nose down attitude. Exam showed RH eng shut down and feathered. No evidence of pre-impact failure of either eng or airframe systems. Gear was up and LH spoiler deployed. Rudder trim should have been used to prevent spoiler deployment. Rudder trim found in neutral position. Pilot was not regular line pilot.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	065	**Geographical Region of Operator:**	South Pacific
Date:	18-Apr-91	**Location:**	Tahiti
Airplane Model:	Dornier 228	**Event:**	HF
Airplane Generation:	Second	**Hazard Level:**	5
PSM+ICR Category:	Loss of thrust		
Summary of Event:	One engine failed, crew shut down the other		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Cruise		
Flight Phase Detail:			
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	TPE331-5		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:			
Engine/Propeller Symptom:			
Propulsion System Malfunction:			
Crew Action:	Did not correctly identify failed engine. Shut down remaining good engine.		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	During flight one eng failed and crew shut down remaining eng by mistake. Made emergency landing with no motive power.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	067	**Geographical Region of Operator:**	Africa
Date:	10-Jun-91	**Location:**	Luanda, Angola
Airplane Model:	Hercules L100	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Loss of control after engine failure on takeoff		
Type of Airline Operation (FAR):			
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	Allison 501		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	N		
Autofeather/autocoarsen armed?:	N		
Number of Engines:	4		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:			
Crew Action:			
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:	N		
Narrative:	LH eng reportedly failed shortly after takeoff. Control lost. Aircraft exploded on impact.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	068	**Geographical Region of Operator:**	South America
Date:	7-Oct-91	**Location:**	Moron, Argentina
Airplane Model:	IAI 101	**Event:**	S
Airplane Generation:	First	**Hazard Level:**	4

PSM+ICR Category:	Loss of directional control
Summary of Event:	No reverse on one engine during landing. Attempted to take off again. Crashed.
Type of Airline Operation (FAR):	135
Engine Training Flight?:	N
Phase of Flight:	Landing
Flight Phase Detail:	Landing roll
Initiating Event Altitude:	0
Vmc infringed?:	
Pilot Flying (C/FO):	
Weather Conditions:	
Runway Conditions:	
Engine/Propeller Model:	PT6A-36
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	O
Autofeather/autocoarsen fitted?:	?
Autofeather/autocoarsen armed?:	?
Number of Engines:	2
Engine Position:	1
Engine/Propeller Symptom:	Prop did not apply reverse thrust
Propulsion System Malfunction:	
Crew Action:	Failed to cancel reverse thrust when asymmetry experienced on runway. Wrongly decided to take off again.
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S
Autopilot engaged?:	
Narrative:	Aircraft was making touch and go landings and had landed for final touchdown. When reverse thrust applied eng accelerated but prop did not go into reverse. RH eng responded normally. Lost directional control. To avoid veering off runway, aircraft was lifted off but fell violently to ground. Bounced and deviated 1000 m from centerline, struck 2 cement posts and hit wire fence.

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	070	**Geographical Region of Operator:**	CIS
Date:	9-Feb-92	**Location:**	Guryev, Kazakhstan
Airplane Model:	Antonov 24	**Event:**	S
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Loss of airspeed		
Summary of Event:	Attempted single-engine approach after go-around. Landed (very) short of runway.		
Type of Airline Operation (FAR):			
Engine Training Flight?:	N		
Phase of Flight:	Descent		
Flight Phase Detail:			
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:	IMC		
Runway Conditions:			
Engine/Propeller Model:	AL24A		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	?		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:			
Crew Action:	Failed to maintain airspeed after engine failure		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:			
Narrative:	Go-around flown with LH eng failed. On second approach aircraft lost speed and landed 6 km short of runway. Attributed to combination of eng failure, approach in conditions below minimums and lack of radar control on final approach.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	072	**Geographical Region of Operator:**	North America
Date:	22-Apr-92	**Location:**	Perris Valley, California, U.S.
Airplane Model:	DHC 6	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of thrust		
Summary of Event:	Engine failure on takeoff. May have shut down wrong engine.		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	PT6A-20		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Gross fuel contamination		
Crew Action:	May have shut down remaining good engine		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	Ground loader fueled aircraft from fuel truck. Said flight crew did not sump tanks after fueling. Immediately after takeoff RH eng lost power, RH wing lowered to 90 deg and aircraft hit ground beside runway. Forward fuel tank, which feeds RH eng, found to contain 8 gallons mixture of water, emulsifier and bacteria. LH prop control found seized in feather position. LH prop blades near feather.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	073	**Geographical Region of Operator:**	North America
Date:	16-Jun-92	**Location:**	New Castle, Delaware, U.S.
Airplane Model:	Beech 200	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Engine failure on final approach. Attempted go-around. Lost control.		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Go-around		
Flight Phase Detail:			
Initiating Event Altitude:			
Vmc infringed?:	Y		
Pilot Flying (C/FO):			
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	PT6A-41		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	N		
Autofeather/autocoarsen armed?:	N		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Turbine blade failure		
Crew Action:	Failed to maintain control during go-around following engine failure		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	Witnesses saw aircraft on normal final approach, then saw it drop low and slow, retract the gear and roll to the left into trees. Examination of LH eng showed failure of turbine blade. RH eng OK. Radar confirmed drop in airspeed before hitting trees.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No: 075

Geographical Region of Operator: North America

Date: 10-Aug-92

Location: Gainesville, Georgia, U.S.

Airplane Model: Cessna 441

Event: S

Airplane Generation: First

Hazard Level: 4

PSM+ICR Category: Partial loss of thrust

Summary of Event: Bird strike after takeoff. Lost power on one engine. Forced landing

Type of Airline Operation (FAR): 91

Engine Training Flight?: N

Phase of Flight: Takeoff

Flight Phase Detail: Initial climb

Initiating Event Altitude: 50

Vmc infringed?: N

Pilot Flying (C/FO): C

Weather Conditions: Day/VMC

Runway Conditions:

Engine/Propeller Model: TPE331-8

Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O): O

Autofeather/autocoarsen fitted?: Y

Autofeather/autocoarsen armed?: Y

Number of Engines: 2

Engine Position: 2

Engine/Propeller Symptom: Partial power loss

Propulsion System Malfunction: Bird-strike damage to turbine section

Crew Action: Failed to establish single-engine climb configuration (raise gear)

Crew Error Classification — Skill (S), Rule (R) or Knowledge (K): R

Autopilot engaged?:

Narrative: Pilot said that after takeoff he hit a flock of birds. Said RH eng immediately had a partial loss of power. Did not try to raise gear or flaps, and aircraft would not maintain altitude. Examination of engs showed rotational scoring of RH turbine housing only.

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	076	**Geographical Region of Operator:**	North America
Date:	25-Aug-92	**Location:**	Hot Springs, Alaska, U.S.
Airplane Model:	Swearingen SA227	**Event:**	HF
Airplane Generation:	Second	**Hazard Level:**	5
PSM+ICR Category:	Partial loss of thrust		
Summary of Event:	Lost power and crashed shortly after takeoff		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:			
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:			
Engine/Propeller Symptom:			
Propulsion System Malfunction:			
Crew Action:			
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):			
Autopilot engaged?:			
Narrative:	Aircraft reportedly lost power and crashed shortly after taking off on test flight following maintenance.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	079	**Geographical Region of Operator:**	North America
Date:	30-Aug-92	**Location:**	Greenwood, Mississippi, U.S.
Airplane Model:	Cessna 425	**Event:**	S
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Engine shut down in cruise. Stalled and crashed on approach.		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Cruise		
Flight Phase Detail:			
Initiating Event Altitude:	20000		
Vmc infringed?:			
Pilot Flying (C/FO):	C		
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	PT6A-112		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	SD		
Autofeather/autocoarsen fitted?:	?		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:	Fluctuating oil pressure		
Propulsion System Malfunction:	Oil leakage due to broken chip detector		
Crew Action:	Mis-set power on approach and lost height		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:			
Narrative:	In cruise at 20,000 ft pilot shut down LH eng and feathered prop due to fluctuating oil pressure. Declared emergency and was executing single-eng approach when he noted his sink rate was high so he retracted the gear and flaps. Aircraft crashed short of runway. Chip detector on LH eng found broken due to brittle condition from manufacture.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No: 081

Geographical Region of Operator: CIS

Date: 19-Oct-92

Location: Ust’nem, Russia

Airplane Model: Antonov 28

Event: HF

Airplane Generation: First

Hazard Level: 5

PSM+ICR Category: Loss of control

Summary of Event: Aircraft crashed following engine failure on takeoff

Type of Airline Operation (FAR): 135

Engine Training Flight?: N

Phase of Flight: Takeoff

Flight Phase Detail:

Initiating Event Altitude:

Vmc infringed?:

Pilot Flying (C/FO):

Weather Conditions:

Runway Conditions:

Engine/Propeller Model: TVD-10S

Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O): F

Autofeather/autocoarsen fitted?: ?

Autofeather/autocoarsen armed?: ?

Number of Engines: 2

Engine Position:

Engine/Propeller Symptom:

Propulsion System Malfunction:

Crew Action:

Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):

Autopilot engaged?:

Narrative: Aircraft crashed following engine failure on takeoff.

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	082	**Geographical Region of Operator:**	South America
Date:	21-Oct-92	**Location:**	L Caballocha, Peru
Airplane Model:	DHC 6	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5

PSM+ICR Category:	Loss of height
Summary of Event:	Engine failure en route. Made forced landing on lake and sank.
Type of Airline Operation (FAR):	135
Engine Training Flight?:	N
Phase of Flight:	Cruise
Flight Phase Detail:	
Initiating Event Altitude:	
Vmc infringed?:	
Pilot Flying (C/FO):	
Weather Conditions:	
Runway Conditions:	
Engine/Propeller Model:	PT6A-27
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F
Autofeather/autocoarsen fitted?:	Y
Autofeather/autocoarsen armed?:	?
Number of Engines:	2
Engine Position:	
Engine/Propeller Symptom:	
Propulsion System Malfunction:	
Crew Action:	
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	
Autopilot engaged?:	
Narrative:	While en route pilot reported an eng had failed. Aircraft subsequently crashed into lake and sank during attempted forced landing.

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	083	**Geographical Region of Operator:**	Asia
Date:	9-Jan-93	**Location:**	Surabaya, Indonesia
Airplane Model:	HS 748	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Crashed during attempted return following engine failure after takeoff		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:			
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	Dart 552		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:			
Propulsion System Malfunction:			
Crew Action:			
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:			
Narrative:	Shortly after takeoff RH engine believed to have failed. Pilot attempted to return to airport but aircraft crashed into swamp, overturned, broke in two and caught fire.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	084	**Geographical Region of Operator:**	CIS
Date:	16-Jan-93	**Location:**	Kustanay, Kazakhstan
Airplane Model:	Antonov 24	**Event:**	H
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Crashed short following engine failure on approach		
Type of Airline Operation (FAR):			
Engine Training Flight?:	N		
Phase of Flight:	Approach		
Flight Phase Detail:			
Initiating Event Altitude:	1300		
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:			
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	?		
Autofeather/autocoarsen armed?:	?		
No of Engines:			
Engine Position:			
Engine/Propeller Symptom:			
Propulsion System Malfunction:			
Crew Action:			
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):			
Autopilot engaged?:			
Narrative:	On approach at 1300 ft AGL, 7.5 miles from airfield, LH eng suddenly shut down and prop feathered. Crew did not report problem to ATC and continued approach. On finals at 200 ft, began to veer to left. ATC told crew to go around. Captain increased power on RH eng and retracted gear. Aircraft continued to lose height and struck ground in left bank 200 yards short and 500 yards left of runway. Slid into ramp and hit another aircraft. Visibility was 3,000 yards, cloud base 1,000 ft.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	090	**Geographical Region of Operator:**	South America
Date:	12-May-93	**Location:**	Rio de Janeiro, Brazil
Airplane Model:	Embraer 120	**Event:**	S
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Landed hot with one engine stuck at full power. Overran.		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Approach		
Flight Phase Detail:	Finals		
Initiating Event Altitude:	300		
Vmc infringed?:	N		
Pilot Flying (C/FO):			
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	PW118		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	O		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	N		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:	Sudden uncommanded power increase on RH engine.		
Propulsion System Malfunction:			
Crew Action:	Failed to establish suitable engine power condition for landing. Should have elected to go around.		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	During final visual approach, at 300 ft, power suddenly increased on RH eng. Crew tried to reduce power on both engs. LH responded normally, but RH stayed at high power. Pilot continued approach and touched down 1,000 ft along runway 30 knots higher than normal. Aircraft overran and collided with rocks just beyond end of runway.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	091	**Geographical Region of Operator:**	CIS
Date:	5-Jul-93	**Location:**	Ramenskoye, Russia
Airplane Model:	Ilyushin 114	**Event:**	HF
Airplane Generation:	Second	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Lost power and stalled shortly after takeoff		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Takeoff roll		
Initiating Event Altitude:	0		
Vmc infringed?:	Y		
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	TV 7-117		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	?		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:	Loss of thrust		
Propulsion System Malfunction:			
Crew Action:	Continued takeoff with evident loss of thrust on one engine		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	During takeoff run, RH eng failed to produce enough thrust and there was also an electrical system fault warning. Takeoff continued but as soon as aircraft became airborne it was seen to roll then pitch up steeply. Stalled and crashed.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	092	**Geographical Region of Operator:**	Europe
Date:	28-Dec-93	**Location:**	Ampuria, Spain
Airplane Model:	Shorts Skyvan	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Aircraft struck trees and crashed during attempted go-around		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Approach		
Flight Phase Detail:			
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):	C		
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	TPE331-2		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:			
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Fuel starvation		
Crew Action:	Failed to maintain control during go-around following engine failure		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	Aircraft struck trees and crashed during attempted go-around. At impact, one eng not developing power and was believed to have been shut down earlier in approach. Suspect that eng failed due to lack of fuel.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	094	**Geographical Region of Operator:**	Europe
Date:	25-Feb-94	**Location:**	Uttoxeter, U.K.
Airplane Model:	Vickers Viscount	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Loss of height		
Summary of Event:	Forced landing after multiple engine failures and ice accretion		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Descent		
Flight Phase Detail:			
Initiating Event Altitude:	15000		
Vmc infringed?:	N		
Pilot Flying (C/FO):	C		
Weather Conditions:	Night/Severe icing		
Runway Conditions:			
Engine/Propeller Model:	Dart 530		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	4		
Engine Position:			
Engine/Propeller Symptom:	Flameout		
Propulsion System Malfunction:	Multiple flameouts due to ice ingestion		
Crew Action:	Failed to avoid extreme icing conditions. Failed to follow checklists to relight failed engines.		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	On descent at 15,000 ft, no. 2 eng failed and prop autofeathered. One minute later, no. 3 eng started to run down. Attempts to restart both were initially unsuccessful, but eventually no. 2 restarted. At this point no. 4 eng failed. Despite further attempts, nos. 3 and 4 never restarted. Aircraft unable to maintain height and yaw control was lost. Aircraft struck ground and broke up. Cause found to be multiple eng failures due to extreme ice encounter These were compounded by poor crew actions in completing emergency drills, preventing successful recovery of available engine power.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No: 095

Geographical Region of Operator: Europe

Date: 4-Apr-94

Location: Amsterdam, Holland

Airplane Model: Saab 340B

Event: HF

Airplane Generation: Second

Hazard Level: 4

PSM+ICR Category: Loss of control

Summary of Event: Made approach and go-around with one engine at flight idle. Lost control due to asymmetry.

Type of Airline Operation (FAR): 135

Engine Training Flight?: N

Phase of Flight: Climb

Flight Phase Detail:

Initiating Event Altitude: 16500

Vmc infringed?: Y

Pilot Flying (C/FO): C

Weather Conditions: Day/VMC

Runway Conditions:

Engine/Propeller Model: CT7-9B

Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O): T

Autofeather/autocoarsen fitted?: Y

Autofeather/autocoarsen armed?: N

Number of Engines: 2

Engine Position: 2

Engine/Propeller Symptom: Low oil pressure warning light

Propulsion System Malfunction: No engine defect. Oil pressure switch was faulty, giving erroneous warning.

Crew Action: Failed to follow checklist regarding oil pressure warning. Failed to apply rudder to counter asymmetric thrust during go-around

Crew Error Classification — Skill (S), Rule (R) or Knowledge (K): S, R

Autopilot engaged?: Y

Narrative: During climb thru 16,500 ft crew saw RH low oil pressure warning light. Elected to return to departure airport on ILS approach with RH eng at flight idle. During approach captain applied little or no rudder and aircraft drifted to right of runway. Go-around was executed but during climb no rudder was applied to counter high asymmetric thrust and aircraft rolled to right. Pitch increased, IAS fell and bank angle increased. Captain lost control and aircraft hit ground in 80 deg bank. Cause found to be inadequate use of flight controls during asymmetric go-around, resulting in loss of control. Crew criticised for being unaware of consequences of making an approach with one eng in flight idle.

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	096	**Geographical Region of Operator:**	North America
Date:	18-Jun-94	**Location:**	Fort Frances, Ontario, Canada
Airplane Model:	Cessna 441	**Event:**	H
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Bird strike after takeoff. Lost power on one engine. Lost control and crashed		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Rotation		
Initiating Event Altitude:	0		
Vmc infringed?:	Y		
Pilot Flying (C/FO):	C		
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	TPE331-8		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:			
Crew Action:	Failed to maintain control following eng failure on takeoff		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S, R		
Autopilot engaged?:	N		
Narrative:	On takeoff just after rotation, bird struck LH eng. LH eng lost power but pilot continued takeoff. Aircraft veered to left, LH wing tip struck ground and aircraft crashed.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	097	**Geographical Region of Operator:**	Asia
Date:	5-Jul-94	**Location:**	Dera Ismail Khan, Pakistan
Airplane Model:	Fokker F27	**Event:**	H
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Loss of height		
Summary of Event:	Power loss on approach. Go-around attempted but lost height and made forced landing		
Type of Airline Operation (FAR):			
Engine Training Flight?:	N		
Phase of Flight:	Approach		
Flight Phase Detail:	Finals		
Initiating Event Altitude:			
Vmc infringed?:	N		
Pilot Flying (C/FO):			
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	Dart 522		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:	Lost power		
Propulsion System Malfunction:			
Crew Action:	Failed to properly configure aircraft for single-engine go-around		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	During finals on visual approach, LH eng began to lose power. At 200 ft, elected to go around. Applied full power to RH eng and retracted flaps and gear. Aircraft continued to lose height and pilot made successful forced landing in paddy.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	098	**Geographical Region of Operator:**	Europe
Date:	17-Jul-94	**Location:**	Ajaccio, Corsica
Airplane Model:	Beech 90	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Lost control on approach with one engine feathered		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Approach		
Flight Phase Detail:			
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	PT6A-20		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	?		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Loss of fuel pump drive		
Crew Action:	Lost control during single engine approach		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S		
Autopilot engaged?:			
Narrative:	Aircraft was on approach with LH eng feathered due to loss of fuel pump drive. Lost control 200 m short of runway and crashed on beach.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	099	**Geographical Region of Operator:**	North America
Date:	4-Aug-94	**Location:**	Williamstown, Massachusetts, U.S.
Airplane Model:	Beech A100	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Lost control after engine failure on takeoff climb		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:			
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):	C		
Weather Conditions:	Day/VMC		
Runway Conditions:	Dry		
Engine/Propeller Model:	PT6A-28		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	?		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	None found		
Crew Action:	Failed to maintain control following eng failure on takeoff		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S, R		
Autopilot engaged?:			
Narrative:	Aircraft had had maintenance for slow acceleration on RH eng. LH and RH fuel controls swapped over. On subsequent takeoff, witnesses reported aircraft was slow and low. LH prop blades seen nearly stopped. Aircraft turned left and LH wing tip hit ground. Complete disassembly of both engines revealed no defects. LH prop blades found at feather at impact.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No: 100

Geographical Region of Operator: South America

Date: 2-Sep-94

Location: Fortaleza, Brazil

Airplane Model: Embraer 110

Event: S

Airplane Generation: Second

Hazard Level: 4

PSM+ICR Category: Loss of control

Summary of Event: Stalled onto runway during go-around with one engine at idle power

Type of Airline Operation (FAR):

Engine Training Flight?: N

Phase of Flight: Takeoff

Flight Phase Detail:

Initiating Event Altitude:

Vmc infringed?:

Pilot Flying (C/FO):

Weather Conditions:

Runway Conditions:

Engine/Propeller Model: PT6A-27

Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O): F

Autofeather/autocoarsen fitted?: Y

Autofeather/autocoarsen armed?: Y

Number of Engines: 2

Engine Position: 1

Engine/Propeller Symptom: LH engine power dropped to idle

Propulsion System Malfunction: Engine control linkage to fuel control disconnected

Crew Action: Failed to feather prop of failed engine

Crew Error Classification — Skill (S), Rule (R) or Knowledge (K): R

Autopilot engaged?:

Narrative: After takeoff, LH eng power dropped to idle. Turned back. During final approach with gear/flaps down, LH eng at idle, pilot lost runway alignment and attempted go-around. Gear selected up and full power applied to RH eng. Aircraft did not react and stalled. Found ball end fitting of fuel control linkage disconnected. Nut and washer found in cowling. Cotter pin not found.

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	101	**Geographical Region of Operator:**	North America
Date:	13-Dec-94	**Location:**	Raleigh-Durham, North Carolina, U.S.
Airplane Model:	Jetstream 32	**Event:**	HF
Airplane Generation:	Second	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Stalled during attempted go-around with one engine at flight idle		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	N		
Phase of Flight:	Approach		
Flight Phase Detail:			
Initiating Event Altitude:	2100		
Vmc infringed?:	N		
Pilot Flying (C/FO):	C		
Weather Conditions:	Night/IMC		
Runway Conditions:			
Engine/Propeller Model:	TPE331-12		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	T		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:	Ignition light illuminated		
Propulsion System Malfunction:	None. Engine was functioning properly at all times up to impact.		
Crew Action:	Failed to follow drills for engine failure identification, go-around and stall recovery.		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	Aircraft was on ILS approach. At 2100 ft captain noticed an ignition light had come on. Concluded that LH eng had flamed out, but did not follow emergency procedures for eng failure. Elected to carry out missed approach. Called for max power on RH eng. Aircraft turned to left. LH eng was at flight idle. IAS dropped and stall warning horns sounded. FO told captain to lower nose. Soon after, descent rate increased dramatically. Captain lost control and aircraft crashed 4 miles southwest of runway. Probable causes were captain's improper assumption that an engine had failed, and captain's subsequent failure to follow approved procedures for engine failure, single-engine approach and go-around, and stall recovery.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	102	**Geographical Region of Operator:**	CIS
Date:	20-Jan-95	**Location:**	Krasnoyask, Russia
Airplane Model:	LET L-410	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Lost control after engine failure on takeoff climb		
Type of Airline Operation (FAR):			
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:	Night/VMC		
Runway Conditions:			
Engine/Propeller Model:	M 601		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	?		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Fuel contamination?		
Crew Action:	Failed to maintain control following eng failure on takeoff		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	Shortly after takeoff in darkness but normal weather, aircraft began to veer to right. Control not regained and aircraft struck trees 1000 m beyond end of runway and 450 m to right. On impact, RH eng was not developing power and RH prop was feathered. Aircraft believed to be 440 lbs above MTOW. Possibility of fuel contamination.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	105	**Geographical Region of Operator:**	North America
Date:	13-May-95	**Location:**	Boise, Idaho, U.S.
Airplane Model:	Lockheed C130	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Crashed after takeoff following reported Number 2 engine fire		
Type of Airline Operation (FAR):			
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	T56		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	O		
Autofeather/autocoarsen fitted?:	N		
Autofeather/autocoarsen armed?:	N		
Number of Engines:	4		
Engine Position:	2		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Engine fire		
Crew Action:	Failed to maintain control following eng fire on takeoff		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	Shortly after takeoff pilot declared emergency and reported fire in no. 2 eng. Shortly after, contact lost. Witnesses reported seeing aircraft go out of control and “nose over.”		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	107	**Geographical Region of Operator:**	Asia
Date:	3-Oct-95	**Location:**	Bakangan-Tapak Tuan, Indonesia
Airplane Model:	CASA 212-100	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	4

PSM+ICR Category: Loss of height

Summary of Event: Unable to maintain height after engine failure en route. Crashed into trees.

Type of Airline Operation (FAR):

Engine Training Flight?: N

Phase of Flight: Cruise

Flight Phase Detail:

Initiating Event Altitude:

Vmc infringed?:

Pilot Flying (C/FO):

Weather Conditions: Day/VMC

Runway Conditions:

Engine/Propeller Model: TPE331-5

Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O): SD

Autofeather/autocoarsen fitted?: Y

Autofeather/autocoarsen armed?: Y

Number of Engines: 2

Engine Position: 1

Engine/Propeller Symptom: Loss of oil pressure

Propulsion System Malfunction:

Crew Action:

Crew Error Classification — Skill (S), Rule (R) or Knowledge (K): R

Autopilot engaged?:

Narrative: About 30 minutes after takeoff crew reported they had shut down LH eng due to loss of oil pressure and were unable to maintain height. Continued to make calls until 500 ft AGL. Just before impact with tree tops pilot shut down RH eng. Aircraft was close to max weight.

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	111	**Geographical Region of Operator:**	North America
Date:	19-Jan-96	**Location:**	West Columbia, South Carolina, U.S.
Airplane Model:	Mitsubishi MU-2B	**Event:**	H
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Lost control on approach after engine shut down during flight		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Cruise		
Flight Phase Detail:			
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	SD		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:	Would not restart. No fuel or ignition		
Propulsion System Malfunction:	Fuel shutoff valve found closed		
Crew Action:	Failed to use proper engine restart drill.		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	On maintenance test flight pilot performed NTS check on LH eng. Two attempts to restart LH eng unsuccessful. Each time prop came out of feather and started to windmill but there was no fuel or ignition. Aircraft returned to land. On short finals witness saw aircraft pitch up then down, then heard sound of power increase. Aircraft rolled to left, pitched nose down and impacted ground. Examination of LH eng found no sign of pre-impact failure or malfunction. LH eng fuel shutoff valve found in closed position.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	112	**Geographical Region of Operator:**	North America
Date:	16-May-96	**Location:**	Houston, Texas, U.S.
Airplane Model:	Mitsubishi MU-2B	**Event:**	S
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Shut down engine after takeoff. Configured aircraft wrongly for climbout. Returned.		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:			
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):	C		
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	SD		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:	Fluctuating torque		
Propulsion System Malfunction:			
Crew Action:	Failed to follow single-engine flying procedures		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	Pilot reported that after takeoff aircraft yawed to left and LH indicated torque was fluctuating. Shut down and feathered LH eng and returned to airport. At 115 knots, 20 deg flap, pilot claimed he could not climb. Required configuration is 140 knots, 5 deg flap. Approached runway at 90 degrees then made 90 deg turn to align. Delayed gear extension to reach runway. Landed before gear fully down. Gear collapsed and slid off runway.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	113	**Geographical Region of Operator:**	North America
Date:	20-Jul-96	**Location:**	Scottsdale, Arizona, U.S.
Airplane Model:	Mitsubishi MU-2B	**Event:**	H
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of height		
Summary of Event:	Uncontained engine failure on takeoff. Unable to climb. Forced landing.		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Rotation		
Initiating Event Altitude:	50		
Vmc infringed?:	N		
Pilot Flying (C/FO):	C		
Weather Conditions:	Day/VMC		
Runway Conditions:	Dry		
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Uncontained rotor failure		
Crew Action:	Failed to follow single engine flying procedures		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	Just after lift-off, RH eng had uncontainted failure as gear was retracting. Aircraft would not climb and pilot elected for forced landing. Aircraft destroyed by fire.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:	114	**Geographical Region of Operator:**	Asia
Date:	7-Dec-96	**Location:**	Banjarmasin, Indonesia
Airplane Model:	CASA 212	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Engine fire shortly after takeoff. Lost control and crashed.		
Type of Airline Operation (FAR):			
Engine Training Flight?:	N		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	TPE331-5		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	O		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:			
Engine/Propeller Symptom:	Engine fire		
Propulsion System Malfunction:			
Crew Action:	Failed to follow fire drill and fly the aircraft		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	Crew reported engine fire shortly after takeoff. Witnesses on ground saw fire while aircraft was still airborne. Aircraft crashed into factory.		

PSM+ICR Turboprop Data, January 1985–April 1997 *(continued)*

Event No:		**Geographical Region of Operator:**	Asia
Date:	18-Apr-97	**Location:**	Tanjungpandan, Indonesia
Airplane Model:	BAe ATP	**Event:**	HF
Airplane Generation:	Second	**Hazard Level:**	5
PSM+ICR Category:	Loss of control		
Summary of Event:	Engine failure on descent. Failed prop not feathered. Control lost when good engine power increased		
Type of Airline Operation (FAR):			
Engine Training Flight?:	N		
Phase of Flight:	Descent		
Flight Phase Detail:			
Initiating Event Altitude:	4000		
Vmc infringed?:	Y		
Pilot Flying (C/FO):	C		
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	PW126A		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	N		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	None found. Fire damage precluded complete investigation of engine accessories		
Crew Action:	Failed to recognize engine failure and to follow engine shutdown drill to feather prop.		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	During descent at 4,000 ft, pilot retarded both power levers to flight idle. The LH eng flamed out. RH eng continued to operate normally. LH eng Np continued at 80% due to windmilling. 40 seconds later, LH low oil pressure warning light illuminated. Prop still not feathered. Descent continued at 160 knots IAS. At 800 ft, gear and flap selected. Airspeed started to fall. At 140 knots, LH Np started to droop below 80%, indicating prop blades on flight idle stop. IAS continued to fall to 100 knots. RH power lever then fully advanced and max power applied on RH eng. Likely that control lost at this point and aircraft fell rapidly to ground.♦		

Appendix I

Summary of Turboprop Training Events

Glossary

A/C = Aircraft
AFB = (U.S.) Air Force base
AFM = Aircraft flight manual
C = Captain
CIS = Commonwealth of Independent States
deg = Degrees
eng(s) = Engine(s)
Event H = Hull loss
Event HF = Hull loss, fatal
Event S = Substantial damage
FAR = (FARs) U.S. Federal Aviation Regulations
FO = First officer
fpm = Feet per minute
ft = Feet
Hazard Level 4 = Severe consequences
Hazard Level 5 = Catastrophic consequences
IAS = Indicated airspeed
ILS = Instrument landing system
LH = Left hand (left)
m = Meters
N = No
No(s). = Number(s)
PIC = Pilot-in-command
RH = Right hand (right)
TO = Takeoff
V_2 = Takeoff safety speed
Vmc = (V_{MC}) Minimum control speed with the critical engine inoperative
VMC = Visual meteorological conditions
VSI = Vertical speed indicator
Y = Yes

PSM+ICR Turboprop Training Event Data, January 1985–April 1997

Event No:		**Geographical Region of Operator:**	Middle East
Date:	1-Apr-87	**Location:**	Oman
Airplane Model:	Dornier Do-228	**Event:**	H
Airplane Generation:	Second	**Hazard Level:**	4

PSM+ICR Category:	Loss of thrust
Summary of Event:	Crashed after instructor failed one engine and student shut down the other on training flight
Type of Airline Operation (FAR):	91
Engine Training Flight?:	Y
Phase of Flight:	Takeoff
Flight Phase Detail:	Initial climb
Initiating Event Altitude:	
Vmc infringed?:	N
Pilot Flying (C/FO):	FO
Weather Conditions:	Day/VMC
Runway Conditions:	
Engine/Propeller Model:	TPE331-5
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	T
Autofeather/autocoarsen fitted?:	Y
Autofeather/autocoarsen armed?:	Y
Number of Engines:	2
Engine Position:	
Engine/Propeller Symptom:	
Propulsion System Malfunction:	
Crew Action:	Did not correctly identify failed engine. Shut down remaining good engine.
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R
Autopilot engaged?:	
Narrative:	Training instructor failed an engine at low altitude. Student shut down good engine.

PSM+ICR Turboprop Training Event Data, January 1985–April 1997 *(continued)*

Event: No:	018	**Geographical Region of Operator:**	North America
Date:	8-Apr-87	**Location:**	Travis AFB, California, U.S.
Airplane Model:	Hercules L100	**Event:**	HF
Airplane Generation:	First	**Hazard Level:**	5

PSM+ICR Category:	Loss of control
Summary of Event:	Loss of control after 2 engs failed to respond during go-around.
Type of Airline Operation (FAR):	
Engine Training Flight?:	Y
Phase of Flight:	Go-around
Flight Phase Detail:	
Initiating Event Altitude:	
Vmc infringed?:	Y
Pilot Flying (C/FO):	C
Weather Conditions:	Day/VMC
Runway Conditions:	
Engine/Propeller Model:	Allison 501-D22A
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	F
Autofeather/autocoarsen fitted?:	N
Autofeather/autocoarsen armed?:	N
Number of Engines:	4
Engine Position:	
Engine/Propeller Symptom:	Engs failed to respond when throttles advanced
Propulsion System Malfunction:	Bleed valves contaminated with oil/tar
Crew Action:	Failed to maintain control following eng failures on go-around
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R
Autopilot engaged?:	N
Narrative:	A/C crashed during go-around after baulked landing. Nos. 1 and 2 engs failed to respond when throttles advanced. Both engs decelerated and airspeed decreased during go-around. Flaps were retracted causing reduction in hydraulic pressure. Instructor could not maintain Vmc and lost control. A/C destroyed by fire. Heavy oil and tar residues found on bleed valves and no. 1 and 2 compressors, limiting eng response to throttle movement. Recent oil leak marks found.

PSM+ICR Turboprop Training Event Data, January 1985–April 1997 *(continued)*

Event: No:	024	**Geographical Region of Operator:**	North America
Date:	24-Sep-87	**Location:**	Twin Falls, Idaho, U.S.
Airplane Model:	Fairchild SA227AC	**Event:**	H
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of control		
Summary of Event:	Simulated V_1 cut, unable to gain height. Flaps mis-set.		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	Y		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Initial climb		
Initiating Event Altitude:	25		
Vmc infringed?:	Y		
Pilot Flying (C/FO):	FO		
Weather Conditions:	Night/VMC		
Runway Conditions:			
Engine/Propeller Model:	TPE331-11		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	T		
Autofeather/autocoarsen fitted?:	N		
Autofeather/autocoarsen armed?:	N		
Number of Engines:	2		
Engine Position:	2		
Engine/Propeller Symptom:			
Propulsion System Malfunction:	Simulated engine cut by check pilot.		
Crew Action:	Failed to maintain control following (simulated) eng failure on TO, compounded by mis-set flaps.		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	S, R		
Autopilot engaged?:	N		
Narrative:	Check pilot conducting captain proficiency on another company pilot under night conditions. Pilot in command started TO, check pilot simulated eng cut after TO. PIC unable to accelerate to V_2, climb or maintain directional control. A/C levelled off, lost IAS and drifted right. Check pilot failed to take control or terminate eng cut simulation. A/C hit ILS tower, lost RH wing tip and lost control. Hit ground and slid to stop. Flaps and flap handle found at 1/2 position instead of 1/4.		

PSM+ICR Turboprop Training Event Data, January 1985–April 1997 *(continued)*

Event: No: 034

Geographical Region of Operator: North America

Date: 9-Feb-88

Location: Springfield, Ohio, U.S.

Airplane Model: Jetstream 31

Event: HF

Airplane Generation: Second

Hazard Level: 4

PSM+ICR Category: Loss of control

Summary of Event: Aircraft pitched up, rolled and crashed on go-around

Type of Airline Operation (FAR): 135

Engine Training Flight?: Y

Phase of Flight: Go-around

Flight Phase Detail:

Initiating Event Altitude: 150

Vmc infringed?: Y

Pilot Flying (C/FO): FO

Weather Conditions:

Runway Conditions:

Engine/Propeller Model: TPE331-10

Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O): T

Autofeather/autocoarsen fitted?: N

Autofeather/autocoarsen armed?: N

Number of Engines: 2

Engine Position: 2

Engine/Propeller Symptom:

Propulsion System Malfunction: Simulated engine cut by check pilot.

Crew Action: Failed to maintain control following (simulated) eng failure on go-around, compounded by mis-set flaps.

Crew Error Classification — Skill (S), Rule (R) or Knowledge (K): S, R

Autopilot engaged?: N

Narrative: Training flight. A/C on finals, but started to climb and began to oscillate in yaw and roll. Pitched up, rolled right and entered vertical descent. Rolled through 270 deg and hit ground steep nose down. RH eng found operating at reduced power. LH at full power. Flaps found retracted contrary to AFM. No evidence of system malfunction. Training pilot known to be harsh towards students, especially during one-eng go-arounds.

PSM+ICR Turboprop Training Event Data, January 1985–April 1997 *(continued)*

Event: No:	046	**Geographical Region of Operator:**	South America
Date:	3-Jul-89	**Location:**	Manaus, Brazil
Airplane Model:	Embraer 110	**Event::**	H
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of thrust		
Summary of Event:	Forced landing after instructor failed one engine and student shut down the other on training flight		
Type of Airline Operation (FAR):	91		
Engine Training Flight?:	Y		
Phase of Flight:	Go-around		
Flight Phase Detail:	Climb		
Initiating Event Altitude:	1500		
Vmc infringed?:	N		
Pilot Flying (C/FO):	FO		
Weather Conditions:	Day/VMC		
Runway Conditions:			
Engine/Propeller Model:	PT6A-34		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	T		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:	Second engine flamed out after first engine was failed		
Propulsion System Malfunction:			
Crew Action:	Did not correctly identify failed engine. Shut down remaining good engine.		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	After missed approach, instructor cut LH eng at 1,500 ft. Few seconds later RH eng flamed out. Attempts to restore power unsuccessful, and pilot made forced landing with gear up on a road 1 mile from threshold. Aircraft caught fire. Wrong engine secured?		

PSM+ICR Turboprop Training Event Data, January 1985–April 1997 *(continued)*

Event: No: 080

Geographical Region of Operator: Europe

Date: 6-Oct-92

Location: Prestwick, Scotland

Airplane Model: Jetstream 32

Event: HF

Airplane Generation: Second

Hazard Level: 4

PSM+ICR Category: Loss of control

Summary of Event: Aircraft rolled and crashed following simulated V_1 cut

Type of Airline Operation (FAR): 91

Engine Training Flight?: Y

Phase of Flight: Takeoff

Flight Phase Detail: Rotation

Initiating Event Altitude: 0

Vmc infringed?: Y

Pilot Flying (C/FO): FO

Weather Conditions: Day/VMC

Runway Conditions: Dry

Engine/Propeller Model: TPE331-12

Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O): T

Autofeather/autocoarsen fitted?: Y

Autofeather/autocoarsen armed?: Y

Number of Engines: 2

Engine Position: 2

Engine/Propeller Symptom: Retarded to flight idle

Propulsion System Malfunction: None

Crew Action: Focused on engine identification, failed to raise gear and maintain attitude

Crew Error Classification — Skill (S), Rule (R) or Knowledge (K): R

Autopilot engaged?:

Narrative: During takeoff run captain simulated an eng failure by retarding RH power lever to flight idle once control had been passed to first officer. Aircraft rotated and climbed slightly steeper than usual with gear still down. Approximately 10 seconds after rotation FO reminded to raise gear. Captain made Up selection on FO's command 2 seconds later. Gear warning and stall warning horns sounded simultaneously. Two seconds later captain took controls and restored power to retarded eng but aircraft continued to roll right and struck ground inverted. No evidence of aircraft malfunction or medical factors.

PSM+ICR Turboprop Training Event Data, January 1985–April 1997 *(continued)*

Event: No:	087	**Geographical Region of Operator:**	North America
Date:	19-Apr-93	**Location:**	Merced, California, U.S.
Airplane Model:	Jetstream 31	**Event:**	H
Airplane Generation:	Second	**Hazard Level:**	4
PSM+ICR Category:	Loss of height		
Summary of Event:	Crashed following simulated engine failure after takeoff		
Type of Airline Operation (FAR):	135		
Engine Training Flight?:	Y		
Phase of Flight:	Takeoff		
Flight Phase Detail:	Rotation		
Initiating Event Altitude:	0		
Vmc infringed?:			
Pilot Flying (C/FO):	FO		
Weather Conditions:	Night/VMC		
Runway Conditions:	Dry		
Engine/Propeller Model:	TPE331-10		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	T		
Autofeather/autocoarsen fitted?:	Y		
Autofeather/autocoarsen armed?:	Y		
Number of Engines:	2		
Engine Position:	1		
Engine/Propeller Symptom:	Retarded power lever to near flight idle		
Propulsion System Malfunction:	None		
Crew Action:	Failed to maintain climb performance following eng failure on takeoff		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	Shortly after becoming airborne, check pilot retarded LH power lever approximately to flight idle to simulate engine failure. Aircraft heading drifted left by 70 degrees. Pilot then returned aircraft to correct heading. VSI showed climb rate of 500 fpm. Shortly after, aircraft levelled then began to descend at 500 fpm. IAS increased from 120 to 130 knots. Aircraft struck ground 1/4 mile from runway. Both engines later found to be operating at point of impact.		

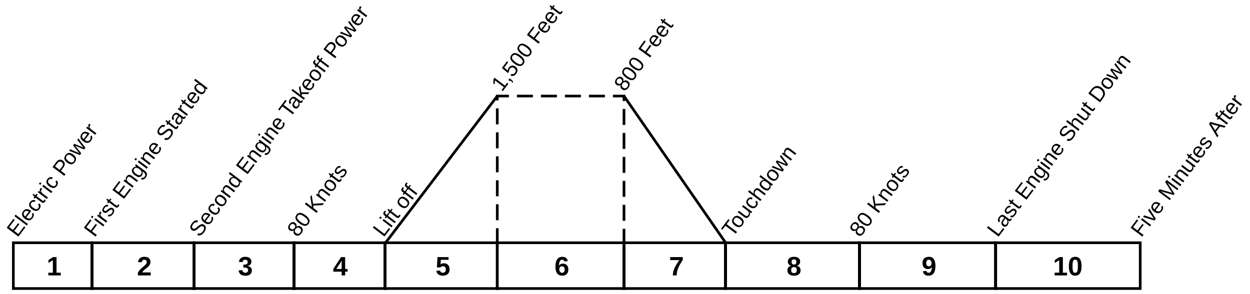
PSM+ICR Turboprop Training Event Data, January 1985–April 1997 *(continued)*

Event: No:	108	**Geographical Region of Operator:**	CIS
Date:	1-Nov-95	**Location:**	Chimkent, Kazakhstan
Airplane Model:	Antonov 24	**Event:**	S
Airplane Generation:	First	**Hazard Level:**	4
PSM+ICR Category:	Loss of thrust		
Summary of Event:	Forced landing after instructor failed one engine and student shut down the other on training flight		
Type of Airline Operation (FAR):			
Engine Training Flight?:	Y		
Phase of Flight:	Approach		
Flight Phase Detail:	Finals		
Initiating Event Altitude:			
Vmc infringed?:			
Pilot Flying (C/FO):			
Weather Conditions:			
Runway Conditions:			
Engine/Propeller Model:	AL24		
Engine Shut Down (SD), Throttled (T), Failed (F) or Other (O):	T		
Autofeather/autocoarsen fitted?:	?		
Autofeather/autocoarsen armed?:	?		
Number of Engines:	2		
Engine Position:			
Engine/Propeller Symptom:	Shut down		
Propulsion System Malfunction:			
Crew Action:	Did not correctly identify failed engine. Shut down remaining good engine.		
Crew Error Classification — Skill (S), Rule (R) or Knowledge (K):	R		
Autopilot engaged?:			
Narrative:	During crew training, on final approach instructor shut down LH eng to simulate eng failure. IAS decreased and instructor called for power to be increased on RH eng. Student attempted to increase power on LH eng and shut down remaining eng. Aircraft touched down hard 1100 m short of runway.♦		

Appendix J

Fleet Survey of Engine Failure Indications – Turbofans

Airbus Alert Inhibit Points



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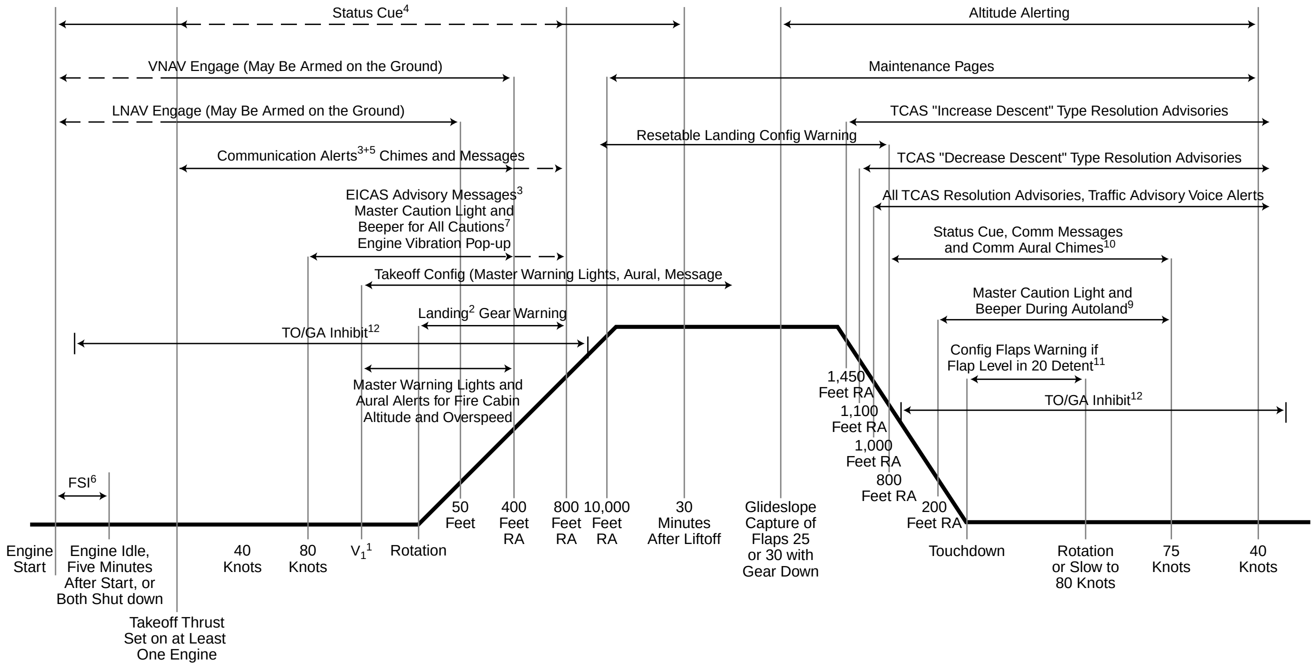
Engine Failure Indications for Airbus Fleet

Warning Cautions Message/Inhibits	**A300/A310**	**A319/A320/A321**	**A340**	**A330**
Sub Idle	2	2 None	2 None	2 None
Surge–bang	No	Sub Idle 2 3,4,5,7,8	Sub Idle 2 3,4,5,7,8	High Power 2 Except GE Engine
Engine Fail	No	No	No	No
RPM Over Redline	2	Red Display 2 4,8	(Red Display) 3 4,8	(Red Display) 3 4,8
EGT Over Redline	2	Red Display 2 4,8	(Red Display) 2 4,8	(Red Display) 2 4,8
EVM HI	I	1	1	1
Engine Thrust	No	No	No N_1 Lim Validation only	No N_1 Lim validation only
Reverse Thrust				
Reverse Unlock		2 (uncommanded) 4,8	2 (uncommanded) 4,5,8,9	2 (uncommanded) 4,5,8,9
Reverse Armed			2 1,8,9,10	2 1,8,9,10
Tire Fail				

(3 = Master Warning, 2 = Master Caution, 1 = No Master Caution, No = Nothing)

Source: Reprinted with minor changes from G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Boeing Alert Inhibit Points



1. Rotation through 5° pitch angle used for default if CAS not available: 80 knots if V_1 not available.
2. Resettable Landing Gear Warning inhibit ends at 800 feet or 140 seconds, whichever occurs first.
3. Inhibit option: to 800 feet or 30 seconds after rotation.
4. Basic: any on-ground engine start to 30 minutes after liftoff or any engine shut down after ESI. Option: from takeoff thrust to 800 feet or 30 seconds after rotation or groundspeed <75 knots.
5. CABIN ALERT message not inhibited.
6. Engine Start Inhibit applies to all Cautions and Advisories except engine start critical messages.
7. Inhibit option to 800 feet or 30 seconds after rotation or groundspeed <75 knots.

Note: TCAS advisories are inhibited from on ground to 1,000 feet for all resolution type and traffic advisory voice alerts, to 1,200 feet for "descend" type and 1,450 feet for "increase descent" types.

9. Except for AUTOPILOT, NO AUTOLAND, SPEEDBRAKE EXTENDED, AUTOTHROTTLE DISC.
10. Except Cabin Alert.
11. Touch and Go condition only.
12. Takeoff/Go-around Inhibit — Inhibit enabled when takeoff/go-around thrust selected, Five (or 10) minute timer started when rotor or EGT limit is exceeded.

Source: Reprinted with minor changes from G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Engine Failure Indications for Boeing Fleet

Warning/ Caution Messages	B747-400	B777	B747	B767/757	B737	B707	B727
Sub Idle	ENG X Fail Caution message a->e, k->l	ENG FAIL L/R Caution message	no	767 L/R ENG FAIL Optional Caution message a->e, k->l 757 no message	6/7/800 ENG FAIL (Eng Display) 1/2/3/4/500 no message	no	no
Surge	no	no	no	no	no	no	no
Engine Fail engine is producing less than commanded thrust	no	Time Critical ENG FAIL (PFD) a,b, e->l Thrust Shortfall ENG THRUST Caution message a->d, k->l	no	no	no	no	-100$_1$ -200$_2$
RPM over redline Engine RPM limited by EEC redlines	Limited by overspeed governor. ENG X RPM LIMIT. Advisory message If redline exceeded, red gage on display b->g h+, i->l	Limited by overspeed governor. ENG X RPM LIMITED L/R Advisory message If redline exceeded, red gage on display b->g h+, i->l	(N1 TACH) round dial: indicators have a "max indications" pointer. Vertical scale: illuminates amber light on the indicator.	Limited by overspeed governor. For 767, L/R ENG RPM LIM Advisory message If redline exceeded, red gage on display b->h, h+, i->l	3/4/5/6/7/8 Limited by overspeed governor. If redline exceeded, red gage on display 6/7/800 b->g, h+, i->l 1/200 no overspeed governor	no$_3$	no$_3$
EGT over redline	Red Gage on Display b->g h+, i->l	Red Gage on Display b->g, h+, i->l	Round dial EGT: indicators display an amber light. Vertical Scale indicators have amber and red, 2 mode of over temperature.	Red Gage on Display" b->g, h+, i->l	6/7/800 Red Gage on Display b->f, h+, i->l 3/4/500 Red light	no$_3$	no$_5$

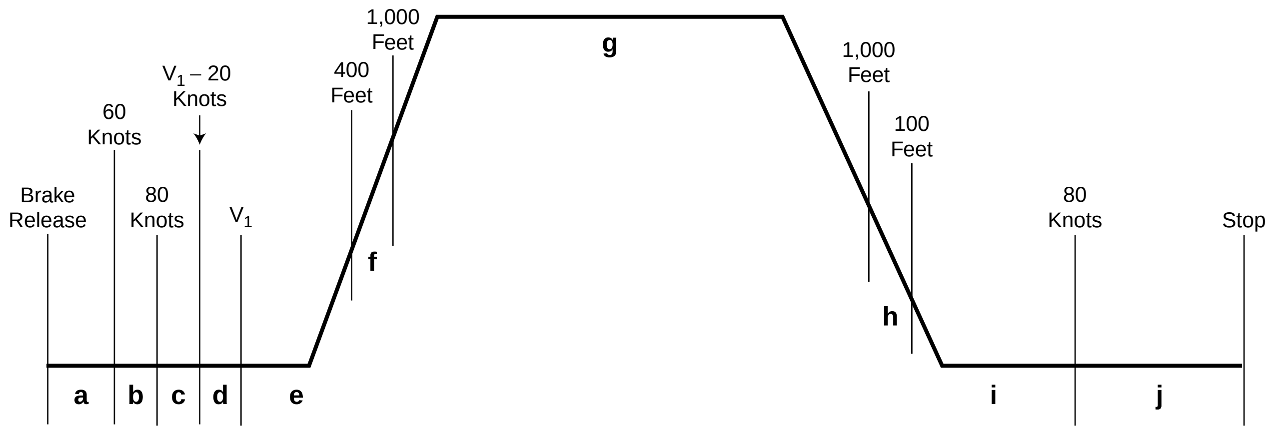
Engine Failure Indications for Boeing Fleet *(continued)*

Warning/ Caution Messages	B747-400	B777	B747	B767/757	B737	B707	B727
FADEC fault FADEC no dispatch faults	ENG X CONTROL Advisory Message d->k+	ENG CONTROL Advisory Message L/R d->k+	n/a	767 L/R ENG CONTROL Advisory Message d->k+ 757 PW: ENG CONTROL Advisory Message RR N/A	6/7/800 ENG CONTROL (Light) d->k+ 1/2/3/4/500 N/A	n/a	n/a
EVM Hi	reverse video at 2.5 scalar units pop-up d->f	reverse video at 4 scalar units pop-up d->f	no$_6$ RR RB211-524 has vib monitor.	amber/white video at 2.5 scalar units (RR) pop-up	6/7/800 over/under reverse video at 2.5 scalar units pop-up d->f	no$_6$	no$_6$
Engine Thrust	no	see above	no	no	no	no	no
Reverse Thrust	Green REV on Eng Display	Green REV on Eng Display	Green REV on Eng Display. Option$_{7,8,9}$	Green REV on Eng Display	Green REV on Eng Display.	no	no
Reverse Unlocked	Amber REV on Eng Display	Amber REV on Eng Display	Amber REV on Eng Display. Option $_{7,8,9}$	Amber REV on Eng Display	6/7/800 Amber REV on Eng Display 1/2/3/4/500 NA	amber light	amber light
Reverse Armed	no	no	no	no	no	no	no
Tire Fail	Tire Pressure Caution Message f->k	Tire Pressure Advisory Message	no	Tire Pressure Optional Advisory Message	no	no	no

Notes: 1. No indication. 2. Engine FAIL illuminates, Bleed air <105 psi. 3. Redline indication only. 4. Redline indication only, no overspeed governor to limit RPM. 5. Some 727s and 737-100/-200 have EGT indicators with internal amber over temp light. 6. Option only. Also called AVM (Airborne Vibration Monitor). Monitored at the Flight Engineer (FE) panel, indication only. FE has a test switch to verify the operational integrity of the engine vibration system. 7. Amber light for REV operating, blue for reverser in transit. 8. Amber light for reverser unlock, blue for reverser in transit. 9. Amber light only - steady for stowed and full reverse position, flashing while in transit.

Source: Reprinted with minor changes from G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Douglas Alert Inhibit Points



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Engine Failure Indications for DAC Aircraft

Warning/Caution Message (Inhibited)	MD-11	DC-10	MD-95	MD-90	MD-80	DC-9
Sub Idle	2 (a->e; h->j)	No	2 (TBD)	2 (a->e, i)	No	No
Surge-bang	1 (Option) (a->e; h->j)	No	1 (TBD)	2 (a->e, h, i)	No	No
Engine Fail	N1 Diff (e->j)	N1 Diff (Flt Rev Thrust)	No	No	No	No
RPM over redline	2 (d, e, i)	No	2 (TBD)	2 (d, e, i)	No	No
EGT over redline	2 (d, e, i)	Small light on gage	2 (TBD)	2 (d, e, i)	No	No
EVM HI	1 (Option) (a->f, h, i)	1 (Option)	TBD (TBD)	1 (a->f, h, i)	No	No
Reverse Thrust	Eng Display (none)	Eng Display	Eng Display (TBD)	Eng Display (none)	Eng Display	Eng Display
Reverse Unlock	Eng Display (none)	Eng Display	Eng Display (TBD)	Eng Display (none)	Eng Display	Eng Display
Reverse Armed	GE only 1 d, e, h, i	Some GE	2 (TBD)	2 (d, e, h, i)	No	No
Tire Fail (no inhib)	2 Aural	No	TBD	No	No	No

Source: Reprinted with minor changes from G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Appendix K

Fleet Survey of Engine Failure Indications — Turboprop

Fleet Survey of Engine Failure Indications — Turboprop

A/C Manufacturer	Aircraft Model	Engine Model	Passengers	Engine Failure Indication	Triggering Mechanism	Simulator	Autofeather System With Uptrim	Auto Relight or Auto Ignition	Low Pitch/ Beta Light
AI(R)	ATR 42-300	2 X P&WC PW120	50	No dedicated “Engine out” light or look-up panel light. Decaying parameters, A/C system alerts, and A/C yaw.			Yes	No	Yes
	ATR 42-320	2 X P&WC PW121	50	Same as above		Yes	Yes	No, except for mod kit	Yes
	ATR 42-500	2 X P&WC PW127E	50	Same as above			Yes	Yes	Yes
	ATR 72	2 X P&WC PW124B	70	Same as above		Yes	Yes	Yes	Yes
	ATR 72-200	2 X P&WC PW127	74	Same as above			Yes	Yes	Yes
	ATR 72-210	2 X P&WC PW127F	74	Same as above			Yes	Yes	Yes
	Jetstream Super 31	2 X Garrett 2 TPE331-12UAR	19+2	No dedicated “Engine out” light. Decaying parameters, negative torque, A/C system alerts, and A/C yaw		Yes	NTS with uptrim	No, yes for -32	Yes
	Jetstream 41	2 X Garrett TPE331-14GR/HR	29+3	Same as above		Yes	Yes	Yes	Yes
	Jetstream 61	2 X P&WC PW127D	70+4	No dedicated “Engine out” light. Decaying parameters, A/C systems alert and A/C yaw.			Yes	Yes	Yes
	ATP	2 X P&WC PW126A	72+2	Same as above		Yes	Yes	Yes	Yes
Bombardier	de Havilland DHC-6 Twin Otter	2 X P&WC PT6A-20/27	19	No engine light or look-up panel light. Decaying parameters and A/C yaw.		Yes	Yes, but no uptrim		Yes
	de Havilland Dash 7-150	4 X P&WC PT6A-50	50	Glare panel amber “Engine Fail” light	Torque pressure falls below 30 psi.	Yes	Yes, but no uptrim		Yes
	de Havilland Dash 8-100	2 X P&WC PW120A	39	No dedicated “Engine out” indication. Decaying parameters, A/C systems alert, and A/C yaw.	Low oil pressure triggers when less than 52 psi	Yes	Yes	No	Yes
	de Havilland Dash 8-200	2 X P&WC PW123C	39	Same as above	Same as above	Yes	Yes	No	Yes

Fleet Survey of Engine Failure Indications — Turboprop *(continued)*

A/C Manufacturer	Aircraft Model	Engine Model	Passengers	Engine Failure Indication	Triggering Mechanism	Simulator	Autofeather System With Uptrim	Auto Relight or Auto Ignition	Low Pitch/ Beta Light
	de Havilland Dash 8-300	2 X P&WC PW123B	60	Same as above	Same as above	Yes	Yes	No	Yes
CASA	C212-300 Aviocar	2 X Garrett TPE331-10R	26	No dedicated “Engine out” light. Decaying parameters, system alerts and A/C yaw.					
CASA/IPTN	CN-235-100	2 X GE CT7-9C	44/45	Same as above					
Convair	580	2 X Allison 501-D13		No dedicated “Engine out” light			No, light in CLA handle	No	
	640	2 X RR Dart		“Low torque light”			No, light in CLA handle	No	
Fairchild Dornier (Swearingen)	228-212	2 X Garrett TPE331-5A-252D	19	No dedicated “Engine out” light. A/C yaw, torque, and EGT are prime indications.	Torque goes negative, low EGT, oil pressure below 40 psi, generator drops off at 62% Ng.		NTS, no uptrim	Yes	Yes
	328	2 X P&WC PW119B	30	No dedicated “Engine out’ light. Decaying parameters, system and A/C yaw.		Yes	Yes (B and C models, no uptrim)	Yes	Yes
	Metro 23-12/III	2 X Garrett TPE331-12UAR	19	Aircraft yaw followed by amber SRL light, low oil pressure, hydraulic pressure and generator off-line	Single Red Line (SRL) triggers when engine is below 80% RPM, low oil pressure below 40 psi, low hydraulic pressure below 1250 psi.	Yes	NTS, no uptrim	Yes	Yes
Embraer	EMB-110P1-41 Bandeirante	2 X P&WC PT6A-34	19	No dedicated “Engine out” light. Decaying parameters, A/C systems alerts, and A/C yaw.		Yes	No	No	Yes
	EMB 120 Brasilia	2 X P&WC PW118	30	Same as above		Yes	Yes	No	Yes
	EMB 120ER Advanced Brasilia	2 X P&WC PW118A	30+3	Same as above			Yes	No	Yes

Fleet Survey of Engine Failure Indications — Turboprop *(continued)*

A/C Manufacturer	Aircraft Model	Engine Model	Passengers	Engine Failure Indication	Triggering Mechanism	Simulator	Autofeather System With Uptrim	Auto Relight or Auto Ignition	Low Pitch/ Beta Light
Fokker Aircraft	Fokker 50	2 X P&WC PW125B	58	"L ENG OUT" or "R ENG OUT" lights on the central annunciator panel along with Master Caution	Nh less than 60% sends a signal to the Integrated Alert System and Auto-ignition.		Yes	Yes	Yes
	Fokker 50	2 X P&WC PW127B	58	"L ENG OUT" or "R ENG OUT" lights on the central annunciator panel along with Master Caution	Nh less than 60% sends a signal to the integrated Alert System and Auto-ignition.		Yes	Yes	Yes
	Fokker F27	2 X RR Dart 6/7	48	"Low Torque Light"	Torque less than 50 psi	Yes	Yes	No	Yes
HAMC	Y-12-11	2 X P&WC PT6A-27	17+2	Cockpit gages are the only indication. No special lights.			No	No	
Lockheed	Electra	4 X Allison 501-D13		No dedicated "Engine out" light			No	No	
	L100	4 X Allison 501-D22A		No dedicated "Engine out" light.		Yes	No	No	
Raytheon Aircraft	Beech 1900C	2 X P&WC PT6A-65B	19+2	No dedicated "Engine out" light. Decaying parameters and A/C yaw.		Yes	Yes, but no uptrim	Yes	No
	Beech 1900D	2 X P&WC PT6A-67D	19+1/2	Same as above		Yes	Yes, but no uptrim	Yes	No
SAAB	340B	2 X GE CT7-9B	37	No dedicated "Engine out" light. Decaying parameters, system alerts and A/C yaw.		Yes	Auto coarsen	Yes	Yes
	2000	2 X Allison AE2100A	50(58)	Red EICAS "ENG OUT" message and Master Warning Light	Gas generator speed decreases below 56% triggers the FADEC to check appropriate signals.	Yes	Yes	Yes	Yes
Short Brothers	330	2 X P&WC PT6A-45R	30	No dedicated "Engine out" light. Decaying parameters, system alerts and A/C yaw.			Yes		
	360	2 X P&WC PT6A-67R	39	Same as above		Yes	Yes		

Source: Reprinted with minor changes from G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Appendix L

Survey of Simulators

Turbofan Aircraft Simulator Worldwide Census

Airplane Model	Number of Simulators	FAA Certified Simulators
A300	21	5
A300-600	14	2
A310	17	7
A320	35	14
A330	9	1
A340	12	3
Astra	1	—
Avro RJ (all)	11	3
B707	15	2
B727	70	45
B737	117	50
B747	91	19
B757	31	23
B767	39	17
B777	13	7
BAC 1-11	6	1
BAe 146	5	3
Beechjet (BE-400)	4	1
Caravelle	1	—
Challenger (all)	13	13
Citation (all)	28	24
Concorde	2	—
DC-8	14	9
DC-9	32	29
DC-10	23	11
F28	8	8
F70/100	10	—
Falcon (all)	16	16
Gulfstream (all)	16	10
Hawker 700/800, BAe 125	8	7
Il-86/96	2	—
Jetstar	1	1
L-1011	15	6
Learjet	18	17
MD-11	14	11
MD-80+	39	8
MD-90	4	4
MU-2/300	2	1
NA-265	3	3
Premier 1	1	—
Sabreliner	3	—
Tu-204	2	—
Westwind I/II	3	2
Total Turbofan Simulators	**781**	**373**

FAA = U.S. Federal Aviation Administration

Source: Reprinted with minor changes from G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Turboprop Aircraft* Simulator Worldwide Census

Airplane Model	Number of Simulators	FAA Certified Simulators
ATR42/72	9	7
BAe ATP	1	1
BAe 125	7	7
BAe HS 748	1	—
Beech 1900A/B/C/D	6	4
Beech Bonanza*	6	6
Beech Baron*	5	2
Cessna 172/182*	1	—
Cessna 300/400*	4	4
Cessna Caravan	2	—
Cessna Centurion*	1	—
Cessna Conquest	3	—
Commander*	1	—
Convair 440	1	—
CN325 (Casa)	2	—
Dash 6	1	1
Dash 7	1	1
Dash 8	8	8
Do-228/328	3	2
EMB-110/120	10	6
F27	2	—
F50	3	—
G-159	2	2
Hawker 700/800	1	—
Jetstream (all)	9	9
King Air (incl. C12, U-21)	28	—
L-382	1	1
Metro (all)	7	1
Mooney (252)*	1	—
Pilatus PC-12	1	—
Piper Cheyenne (all)	18	—
Piper Malibu*	1	—
Piper Navajo Chieftain*	2	—
Piper Seneca*	1	—
SA-226/227	6	6
Saab 340 (all)	12	12
Saab 2000	2	1
Shorts 360	1	1
Viscount	2	—
Xian Y7-100	1	—
Total Turboprop Simulators	**174**	**86**

* FSF editorial note: Model, or some aircraft in model series, have reciprocating (piston) engines.
FAA = U.S.. Federal Aviation Administration

Source: Reprinted with minor changes from G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Appendix M

Proposed Simulator Turbofan Propulsion System Malfunctions

Safety Significant Modes

Single Engine Flameout — A single engine flameout will result in overall airplane thrust loss, thrust asymmetry and resulting aircraft yaw proportional to the thrust difference and moment arm (engine installation position relative to airplane centerline). It will cause loss of engine-provided services from the flamed-out engine, i.e., generator trip to "off." The failure condition may not produce a change of noise cue but may result in an lessening of the overall engine noise level. Fuel flow will drop to the minimum level (not zero) and the rotor speeds will drop to levels lower than idle while exhaust gas temperature (EGT) will also drop. The aircraft yaw, indications of electrical power loss and low and decreasing levels of rotor speed, engine pressure ratio [EPR], and fuel flow are key cues which should lead to recognition. (Frequency of single-engine flameout is between 1 per 10,000 and 1 per 100,000 airplane flights.)

Multiple Engine Flameouts — Multiple (two or more) engine flameouts will result in a relatively larger overall thrust loss and may or may not produce thrust asymmetry and resulting airplane yaw. The flameouts of all engines will produce loss of engine-provided services, i.e., electrical power. The loss of engine noise, decreasing engine parameters, generator trips to off and loss of pressurization are all cues. Loss of aircraft speed, in all modes but descent, will also be a cue requiring the airplane to be pitched over to retain speed. All of the engine parameters will be decreasing. The majority of total power loss events will be as the result of fuel management error or encounters with environmental factors like severe rain, hail, volcanic ash and icing. While the order of flameouts may appear random, they are essentially simultaneous. (Frequency of multiple engine power loss will depend on the number of engines installed, but will range from 1 per 100,000 to 1 per million aircraft flights.) The cues should lead flight crews to confirm that fuel is flowing to all engines and to immediately attempt to in-flight restart the engines. Sequential engine flameouts, those not due to a common cause, are much less likely to occur (less than 1 per 100 million aircraft flights and slightly more likely on four-engine and three-engine aircraft than on twin-engine aircraft).

Engine Seizure — In-flight engine-rotor seizure is a rare event and requires that significant internal damage has occurred. (Engine-rotor-seizure events reported as found on the ground, after flight, are not proof that the rotor stopped turning while in flight.) Seizure is sudden stoppage of the rotation of any of the engine rotors. The failure will occur very quickly and the affected rotor rpm (revolutions per minute) will drop to zero, significant airplane/engine vibration will occur and EGT will rise above limits (at least initially). Thrust loss and resulting yaw will be immediate cues.

If the fan rotor seizes (likelihood between 1 per 10 million and 1 per 100 million aircraft flights), there will be mild buffet and some incrementally increased drag over the drag level that occurs for a windmilling engine (about 25 percent increase of normal windmilling engine drag). The aircraft drag for a locked fan rotor will vary with flight speed, and the required rudder deflection will be slightly increased, but there will be no difficulty in controlling the airplane (based on service experience). There will be a slight decrease, less than 5 percent, in airplane range performance. The high-pressure rotor will continue to rotate but at a reduced speed from normal windmilling.

If the high-pressure rotor seizes, immediate thrust loss will occur, the high-pressure rotor speed will drop to zero and no services will be provided for the locked-up engine. EGT will rise initially above redline. Windmilling drag, however, will not be noticeably affected.

Engine Stall/Surge — Engine surge at high power settings will cause a loud noise (equivalent to cannon fire at a distance or shotgun blasts at 10 feet from your ear) which will have one or more bangs or reports. There will be yaw-coupled aircraft vibration. EGT may increase towards redline but is no longer a key cue since surge-recovery logic in modern controls may have restabilized the engine airflow. Engine spool speeds will fluctuate while the engine is surging and will stabilize upon recovery. The key cue is "loud noise" and yaw vibration coupling. Which engine has surged may not be detectable from the flight deck parameter displays. Severe engine failures will usually be announced by an engine surge and be immediately followed by a permanent thrust loss and rising EGT. Surge by itself, breakdown in engine airflow, will usually self-recover so that the pilot is left with the loud noise along with yaw-coupled vibration followed by "situation normal." Overreaction to the loud noise and yaw-coupled vibration should be avoided. Look for other cues including continuing thrust oscillations or permanent thrust loss or rising EGT prior to taking action. (An engine surge will be experienced between 1 per 10,000 and 1 per 100,000 airplane flights.)

Engine Thrust Runaway (fuel control failure mode) — Engine fuel control failure modes that cause engine thrust runaway will cause engine thrust to increase with fuel flow going to the maximum level. All related engine parameters will be increasing, and some may exceed limits. Asymmetric thrust and the resulting yaw may be experienced with the level of yaw dependent on flight speed and degree of thrust difference between engines on the airplane. The normal response of reducing thrust through power lever reduction may not be effective. The crew may need to shut down the engine with the fuel cut-off switch/lever or fire handle. (This engine fuel control system failure condition occurs about 1 per 10 million aircraft flights.)

Engine Thrust Failed Fixed (fuel control failure mode) — Engine thrust will not respond to movement of the throttle or may respond in one direction only. (This engine fuel control system failure condition occurs about 1 per 10 million aircraft flights.)

Engine Separation — When an engine separation occurs, thrust loss, yaw and coupled roll (for wing-mounted engines) will result, reflecting the loss of powerplant weight as well as thrust. Engine parameter flight deck indications will indicate loss of signal (wires will have separated) and electrical, hydraulic and pneumatic system performance will reflect loss of supply. Aft-body-mounted engines can separate without significant audio or tactile cues. Separation of engines while running normally is likely to cause severe consequences while separation at low (flight idle or below) forward thrust are more likely to be benign. (Frequency of occurrence is between 1 in 10 million and 1 in 100 million aircraft flights.)

Severe Damage — Severe-engine-damage events will result in loss of thrust, yaw due to thrust asymmetry, vibration, loud noise, engine parameters of rotor speed and EPR falling to windmilling levels or near zero, EGT rises to redline and fuel flow decreases. EGT may then fall, indicating flameout. A fire warning may occur in some but not all events. Severe engine damage events may include the following**:**

- N_1 [low-pressure compressor speed] and N_2 [high-pressure compressor speed] fall rapidly to below idle levels, fuel flow and EGT rise into red zone with no response to throttle, and vibration may continue due to out-of-balance loads; and,

- Loud noise, N_1 and N_2 fall rapidly to below idle levels, fuel flow drops, EGT rises into red zone with no response to throttle, and fire warning goes off — no effect for initial fire bottle discharge.

(Severe engine failures will occur at a rate between 1 and 5 per million aircraft flights.)

Onset of Severe Engine Vibration — The onset of engine vibration will be detected by tactile cues or by annunciations, and indicates an internal engine failure**.** A core engine blade failure will be accompanied by engine surge with rotor speed disagreements with other engines, and an EGT increase may occur. Thrust loss may also occur and may vary from non-detectable to significant yaw. A fan blade failure will be accompanied with an engine surge (loud noise), vibration and perhaps odor in the cabin. The vibration may continue after engine shutdown. (Engine vibration associated with failures will occur between 5 and 10 per million aircraft flights.)

Engine Thrust Reverser Deployment (inadvertent) — Inadvertent thrust reverser deployment on older aircraft types (non-high-bypass-ratio-engine powered) have demonstrated that the aircraft can be controlled with thrust reverser deployed at low engine power. "Rev" annunciation display with immediate reduction of power to idle coupled with severe yaw (depending on engine installation and distance from airplane centerline) will serve as cues. (Frequency of occurrence is between 1 per million and 1 per 10 million aircraft flights.) Inadvertent thrust reverser deployment on some high-bypass-ratio-engine-powered airplanes is considered to be a hazardous or worse failure condition. Retroactive design changes and new designs have been made to preclude the occurrence of inadvertent thrust reverser deployment in flight. (No training is required or should be required for an extremely improbable and uncontrollable failure condition.)

Power Lever Failure (mechanical systems) — Power lever failures include the following:

- Power lever cannot be moved — engine operating normally;

- Power lever moves, but no engine response; and,

- Power lever mechanism fails, causing engine to accelerate or decelerate and not respond to power lever motion.

Crew may need to use the fuel shutoff switch/lever or fire handle to shut engine down. (Power lever failures occur at a 1 per 10 million to 1 per 100 million aircraft flights.)

Engine Idle Disagree — Not a safety-significant failure mode.

Fire and Overheat Warning — Fires and overheats are annunciated and warned as appropriate. Fire may or may not be a part of severe engine failures. (In-flight fires occur about 1 per million aircraft flights.)

Fuel Leakage/Loss of Fuel Quantity — Fracture of a fuel pipe or component downstream from the fuel flow measuring device on the engine will result in a high fuel flow being indicated without equivalent or appropriate response of the engine. The fuel flow will be high and fuel quantity in the tank may confirm the differences. Cues are higher-than-normal fuel flow for other engine parameter indications (N_1, N_2, EGT, EPR), fuel flow higher than other engines, and/or sudden decreases in and loss of fuel quantity. (Rate of fuel leakage/loss of fuel quantity events are about 1 per million aircraft flights.)

In-flight Restarting — In-flight restarting is a response to multiple engine flameout or shutdown and is accomplished using windmill restarting, quick restarting or power-assisted restarting procedures (either engine or APU [auxiliary power unit]). If a total power loss occurs, the flight crew should attempt to restart engines in accordance with published in-flight restarting procedures. However, since the engine response will be *slower* than on the ground, pilots may be confused about the successfulness of the restart. The engine will spool up very slowly, and crew awareness of how engines will normally behave during an altitude in-flight restart is recommended. (In-flight engine restarting occurs at the rate of 1 per 100,000 to 1 per 1 million aircraft flights based on service history.)

Engine Oil Indications — Engine oil indications include the following:

- Oil filter delta pressure — annunciated cue may be due to blockage or instrumentation failure;
- Loss of oil quantity — annunciated cue may be due to leakage or high oil consumption;
- High oil temperature — annunciated cue may be due to leakage, trapped/blocked flow, or cooler failure; and,
- Engine low oil pressure — annunciation cue of low oil pressure.

Engine oil indications should be ignored during the takeoff until a safe altitude is reached. Oil pressure loss can occur for a variety of reasons: leakage, seal failure or pump failure. The loss of oil quantity or increase in oil temperature should be used to confirm oil systems malfunctioning. An engine-low-oil indication in combination with increasing vibration and fluctuating or dropping rotor speed is a much more substantive "situation" an may indicate a the progression of: a bearing failure. (Engine oil indication will occur between 1 per 10,000 and 1 per 100,000 airplane flights. Precautionary shutdown may be indicated to minimize engine repair cost.) Ignoring engine oil malfunction indications for more than a few minutes may lead to severe engine failure or seizure with the cues defined above.

Engine Starting Malfunctions — Engine starting malfunctions on the ground will occur at a rate of about 5 to 10 per 10,000 airplane flights. Malfunctions include:

- Hot start — Hot start is indicated by rapidly rising EGT, at a faster rate than normal, and is usually accompanied with a slower-than-normal rate of rotor speed increase); and,
- Hung start — Rotor speed acceleration rate is very slow and may not continue to rise after starter cut-out speed is achieved.♦

Appendix N

U.S. Federal Aviation Regulations Part 63 Appendix C — Flight Engineer Training Course Requirements

(a) Training course outline —

(1) Format.

The ground course outline and the flight course outline are independent. Each must be contained in a loose-leaf binder to include a table of contents. If an applicant desires approval of both a ground school course and a flight school course, they must be combined in one loose-leaf binder that includes a separate table of contents for each course. Separate course outlines are required for each type of airplane.

(2) Ground course outline.

(i) It is not mandatory that the subject headings be arranged exactly as listed in this paragraph. Any arrangement of subjects is satisfactory if all the subject material listed here is included and at least the minimum programmed hours are assigned to each subject. Each general subject must be broken down into detail showing the items to be covered.

(ii) If any course operator desires to include additional subjects in the ground course curriculum, such as international law, flight hygiene, or others that are not required, the hours allotted these additional subjects may not be included in the minimum programmed classroom hours.

(iii) The following subjects and classroom hours are the minimum programmed coverage for the initial approval of a ground training course for flight engineers. Subsequent to initial approval of a ground training course, an applicant may apply to the Administrator for a reduction in the programmed hours. Approval of a reduction in the approved programmed hours is based on improved training effectiveness due to improvements in methods, training aids, quality of instruction, or any combination thereof.

Subject	*Classroom hours*
[U.S.] Federal Aviation Regulations	10
To include the regulations of this chapter that apply to flight engineers.	
Theory of Flight and Aerodynamics	10
Airplane Familiarization	90
To include as appropriate:	
Specifications.	
Construction features.	
Flight controls.	
Hydraulic systems.	
Pneumatic systems.	
Electrical systems.	
Anti-icing and de-icing systems.	
Pressurization and air-conditioning systems.	
Vacuum systems.	
Pitot static systems.	
Instrument systems.	
Fuel and oil systems.	
Emergency equipment.	
Engine Familiarization	45
To include as appropriate:	
Specifications.	
Construction features.	
Lubrication.	
Ignition.	
Carburetor and induction, supercharging and fuel control systems.	
Accessories.	
Propellers.	
Instrumentation.	
Emergency equipment.	
Normal Operations (Ground and Flight)	50
To include as appropriate:	
Servicing methods and procedures.	
Operation of all the airplane systems.	
Operation of all the engine systems.	
Loading and center of gravity computations.	
Cruise control (normal, long range, maximum endurance).	
Power and fuel computation.	
Meteorology as applicable to engine operation.	
Emergency Operations	80
To include as appropriate:	
Landing gear, brakes, flaps, speed brakes, and leading edge devices.	
Pressurization and air conditioning.	
Portable fire extinguishers.	
Fuselage fire and smoke control.	
Loss of electrical power.	
Engine fire control.	
Engine shut-down and restart.	
Oxygen.	
Total (exclusive of final tests)	235

The above subjects, except Theory of Flight and Aerodynamics, and Regulations, must apply to the same type of airplane in which the student flight engineer is to receive flight training.

(3) Flight Course Outline.

(i) The flight training curriculum must include at least 10 hours of flight instruction in an airplane specified in [Part] 63.37(a). The flight time required for the practical test may not be credited as part of the required flight instruction.

(ii) All of the flight training must be given in the same type airplane.

(iii) As appropriate to the airplane type, the following subjects must be taught in the flight training course:

Subject

Normal duties, procedures and operations.

To include as appropriate:

- Airplane preflight.
- Engine starting, power checks, pretakeoff, postlanding and shut-down procedures.
- Power control.
- Temperature control.
- Engine operation analysis.
- Operation of all systems.
- Fuel management.
- Logbook entries.
- Pressurization and air conditioning.

Recognition and correction of in-flight malfunctions.

To include:

- Analysis of abnormal engine operation.
- Analysis of abnormal operation of all systems.
- Corrective action.

Emergency Operations in Flight

To include as appropriate:

- Engine fire control.
- Fuselage fire control.
- Smoke control.
- Loss of power or pressure in each system.
- Engine overspeed.
- Fuel dumping.
- Landing gear, spoilers, speed brakes, and flap extension and retraction.
- Engine shut-down and restart.
- Use of oxygen.

(iv) If the Administrator finds a simulator or flight engineer training device to accurately reproduce the design, function, and control characteristics, as pertaining to the duties and responsibilities of a flight engineer on the type of airplane to be flown, the flight training time may be reduced by a ratio of 1 hour of flight time to 2 hours of airplane simulator time, or 3 hours of flight engineer training device time, as the case may be, subject to the following limitations:

(a) Except as provided in subdivision (b) of this paragraph, the required flight instruction time in an airplane may not be less than 5 hours.

(b) As to a flight engineer student holding at least a commercial pilot certificate with an instrument rating, airplane simulator or a combination of airplane simulator and flight engineer training device time may be submitted for up to all 10 hours of the required flight instruction time in an airplane. However, not more than 15 hours of flight engineer training device time may be substituted for flight instruction time.

(v) To obtain credit for flight training time, airplane simulator time, or flight engineer training device time, the student must occupy the flight engineer station and operate the controls.

(b) Classroom equipment. Classroom equipment should consist of systems and procedural training devices, satisfactory to the Administrator, that duplicate the operation of the systems of the airplane in which the student is to receive his flight training.

(c) Contracts or agreements.

(1) An approved flight engineer course operator may contract with other persons to obtain suitable airplanes, airplane simulators, or other training devices or equipment.

(2) An operator who is approved to conduct both the flight engineer ground course and the flight engineer flight course may contract with others to conduct one course or the other in its entirety but may not contract with others to conduct both courses for the same airplane type.

(3) An operator who has approval to conduct a flight engineer ground course or flight course for a type of airplane, but not both courses, may not contract with another person to conduct that course in whole or in part.

(4) An operator who contracts with another to conduct a flight engineer course may not authorize or permit the course to be conducted in whole or in part by a third person.

(5) In all cases, the course operator who is approved to operate the course is responsible for the nature and quality of the instruction given.

(6) A copy of each contract authorized under this paragraph must be attached to each of the 3 copies of the course outline submitted for approval.

(d) Instructors.

(1) Only certificated flight engineers may give the flight instruction required by this Appendix in an airplane, simulator, or flight engineer training device.

(2) There must be a sufficient number of qualified instructors available to prevent an excess ratio of students to instructors.

(e) Revisions.

(1) Requests for revisions of the course outlines, facilities or equipment must follow the procedures for original approval of the course. Revisions must be submitted in such form that

an entire page or pages of the approved outline can be removed and replaced by the revisions.

(2) The list of instructors may be revised at any time without request for approval, if the requirements of paragraph (d) of this Appendix are maintained.

(f) Ground school credits.

(1) Credit may be granted a student in the ground school course by the course operator for comparable previous training or experience that the student can show by written evidence; however, the course operator must still meet the quality of instruction as described in paragraph (h) of this Appendix.

(2) Before credit for previous training or experience may be given, the student must pass a test given by the course operator on the subject for which the credit is to be given. The course operator shall incorporate results of the test, the basis for credit allowance, and the hours credited as part of the student's records.

(g) Records and reports.

(1) The course operator must maintain, for at least two years after a student graduates, fails, or drops from a course, a record of the student's training, including a chronological log of the subject course, attendance examinations, and grades.

(2) Except as provided in paragraph (3) of this section, the course operator must submit to the Administrator, not later than January 31 of each year, a report for the previous calendar year's training, to include:

(i) Name, enrollment and graduation date of each student;

(ii) Ground school hours and grades of each student;

(iii) Flight, airplane simulator, flight engineer training device hours, and grades of each student; and

(iv) Names of students failed or dropped, together with their school grades and reasons for dropping.

(3) Upon request, the Administrator may waive the reporting requirements of paragraph (2) of this section for an approved flight engineer course that is part of an approved training course under Subpart N of Part 121 of this chapter.

(h) Quality of instruction.

(1) Approval of a ground course is discontinued whenever less than 80 percent of the students pass the FAA [U.S. Federal Aviation Administration] written test on the first attempt.

(2) Approval of a flight course is discontinued whenever less than 80 percent of the students pass the FAA practical test on the first attempt.

(3) Notwithstanding paragraphs (1) and (2) of this section, approval of a ground or flight course may be continued when the Administrator finds —

(i) That the failure rate was based on less than a representative number of students; or

(ii) That the course operator has taken satisfactory means to improve the effectiveness of the training.

(i) Time limitation. Each student must apply for the written test and the flight test within 90 days after completing the ground school course.

(j) Statement of course completion.

(1) The course operator shall give to each student who successfully completes an approved flight engineer ground school training course, and passes the FAA written test, a statement of successful completion of the course that indicates the date of training, the type of airplane on which the ground course training was based, and the number of hours received in the ground school course.

(2) The course operator shall give each student who successfully completes an approved flight engineer flight course, and passed the FAA practical test, a statement of successful completion of the flight course that indicates the dates of the training, the type of airplane used in the flight course, and the number of hours received in the flight course.

(3) A course operator who is approved to conduct both the ground course and the flight course may include both courses in a single statement of course completion if the provisions of paragraphs (1) and (2) of this section are included.

(4) The requirements of this paragraph do not apply to an air carrier or commercial operator with an approved training course under Part 121 of this chapter providing the student receives a flight engineer certificate upon completion of that course.

(k) Inspections. Each course operator shall allow the Administrator at any time or place, to make any inspection necessary to ensure that the quality and effectiveness of the instruction are maintained at the required standards.

(l) Change of ownership, name, or location.

(1) Approval of a flight engineer ground course or flight course is discontinued if the ownership of the course changes. The new owner must obtain a new approval by following the procedure prescribed for original approval.

(2) Approval of a flight engineer ground course or flight course does not terminate upon a change in the name of the course that is reported to the Administrator within 30 days. The Administrator issues a new letter of approval, using the new name, upon receipt of notice within that time.

(3) Approval of a flight engineer ground course or flight course does not terminate upon a change in location of the course that is reported to the Administrator within 30 days. The Administrator issues a new letter of approval, showing the new location, upon receipt of notice within that time, if he finds the new facilities to be adequate.

(m) Cancellation of approval.

(1) Failure to meet or maintain any of the requirements of this Appendix for the approval of a flight engineer ground course or flight course is reason for cancellation of the approval.

(2) If a course operator desires to voluntarily terminate the course, he should notify the Administrator in writing and return the last letter of approval.

(n) Duration. Except for a course operated as part of an approved training course under Subpart N of Part 121 of this chapter, the approval to operate a flight engineer ground course or flight course terminates 24 months after the last day of the month of issue.

(o) Renewal.

(1) Renewal of approval to operate a flight engineer ground course or flight course is conditioned upon the course operator's meeting the requirements of this Appendix.

(2) Application for renewal may be made to the Administrator at any time after 60 days before the termination date.

(p) Course operator approvals. An applicant for approval of a flight engineer ground course, or flight course, or both, must meet all of the requirements of this Appendix concerning application, approval, and continuing approval of that course or courses.

(q) Practical test eligibility. An applicant for a flight engineer certificate and class rating under the provisions of Sec. 63.37(b)(6) is not eligible to take the practical test unless he has successfully completed an approved flight engineer ground school course in the same type of airplane for which he has completed an approved flight engineer flight course.

[Amdt. 63-3, 30 FR 14560, Nov. 23, 1965, as amended by Amdt. 63-15, 37 FR 9758, May 17, 1972] ♦

Appendix O

Human Factors Error Classification Summary and Database

Summary

Error Classification Model Development Based on Turbofan Data

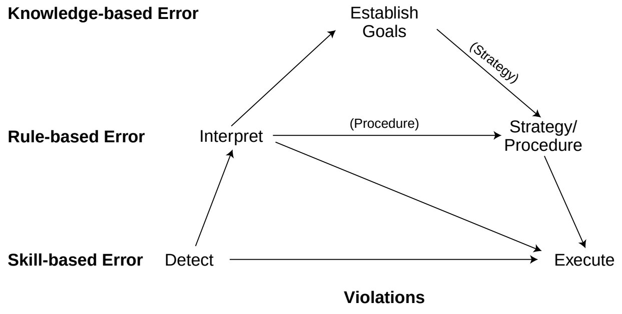
Error Classification Model

Before discussing the error classification scheme, it is important to make a distinction between what happens in human error and why it happens. The inappropriate crew response (ICR) term which is a prominent part of the workshop title refers to "what" happened in terms of human behavior. An ICR can be intentional or unintentional. As was discussed in Human Factors Section 8.0, we are most concerned about the intentional ICRs based on faulty cognitive processes, because the inappropriateness of these responses is much more difficult for the flight crew to detect and correct. Errors in cognitive processes are the primary concern here because understanding the "why" of these errors will lead to properly focused solutions in terms of training or design. The ICRs of the accidents and incidents analyzed here can be found in the Turbofan Summary Database. The cognitive errors inferred from that database are to be found in the Human Factors Error Classification database in this appendix. It is the combined analysis of cognitive errors plus contributing factors that ultimately enables us to understand the "why" of airplane accidents and incidents that have been attributed to "pilot error."

An error classification scheme for modeling cognitive errors in conjunction with propulsion system malfunctions (PSM) was developed as part of the human factors function for the PSM+ICR workshop series. The objective was to provide a vehicle whereby the error data derived from the event databases could be mapped onto the recommendations developed through the workshop, thus providing a direct link to the event data. The model developed is an adaptation of Rasmussen's[1] and Reason's[2] taxonomies for classifying information processing failures and interpreted within the framework of Shontz's[3] concept of the data transformation process. It represents a cognitive approach to human error analysis with the emphasis on understanding the "why" of human error as well as the "what." The extremely limited data available in the Turbofan–Data Collection and Analysis Task Group (DC&ATG) Summary Database on which to base inferences about why cognitive errors occurred in a particular event mean that the attempt to understand "why" can have only limited success. Nevertheless, the attempt provides a much richer database for developing and supporting recommendations and allows the development of more detailed recommendations for addressing the issues of PSM+ICR.

The model developed is illustrated in Figure 1. The primary error categories are represented by the terms located around an "inverted U-shaped function." The higher-level classifications of skill-based, rule-based and knowledge-based errors are shown in approximate relationship to the primary categories. The mapping of these relationships, however, is only approximate as can be seen by reviewing the detailed classification of errors as shown in the second major section of this appendix. Subcategories within each of the primary error categories also were developed to provide for a finer-grained analysis which could support more detailed recommendations. The Turbofan–DC&ATG Summary Database contains accident/incident events which occurred between 1968 and 1996. References to time frame (early, middle, late) are made within this range without fixed boundaries. However, the time frames the terms refer to are roughly "early" (late 1960s and 1970s), "middle" (1980s) and "late" (1990s).

Classification of Errors That Led To Inappropriate Crew Response to Propulsion System Malfunction



Sources: G.P. Sallee and D.M. Gibbons, "AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)," Aerospace Industries Association and The European Association of Aerospace Industries, November 1998 [from: Rasmussen, J. "Human Errors: A Taxonomy for Describing Human Malfunctions in Industrial Installations." *Journal of Occupational Accidents* (No. 4, 1982): 311–333; Reason, James. *Human Error.* Cambridge, England: Cambridge University Press, 1990; and, Shontz, W.D. "Crew Information Requirements Analysis (CIRA)." Boeing Document D6-82110. 1997].

Figure 1

The number of subcategories under each of the primary categories varies. The objective was to develop meaningful breakdowns in the data which could be used to support recommendations. Most of the subcategories contain at least two additional groupings of the error data. Since the model is a work in progress, a few subcategories were retained which have no event-driven error data as yet.

In addition to the categories shown above and their attendant subcategories, "contributing factors" were identified when possible that may have influenced crew behavior during the event. Mapping contributing factors to the errors identified or inferred in the events can strengthen the inferences that must be made when attempting to analyze the cognitive behavior in a PSM event. Clearly, developing a relational database and instantiating it with the descriptions of error behavior would provide the ideal vehicle for the analysis. Unfortunately, the resources required for such an activity were not available to support this workshop activity. However, a similar but more qualitative and limited activity was accomplished using a spreadsheet format containing the ICR and contributing factor data.

Summary of Error Classification Data

At this point, a caveat regarding the error classification database found in this appendix should be noted. While continuing members of the Human Factors Task Group (HFTG) have reviewed the database, they have not verified the individual error/event assignments by a detailed review of the turbofan event summary database. The error model and assignment of error behaviors to categories were accomplished by a single member of the HFTG. Constraints placed on distribution of the database by its contributors precluded sending detailed copies of the turbofan event summary database to individual HFTG members. Other members of the task group were not available to come to Boeing–Seattle where the turbofan database is kept in order to accomplish the verification task. However, members of the HFTG have reviewed the error classification data as shown in this appendix and concur with the classifications based on the data presented. While the HFTG does not consider this situation to invalidate the error classification database, the support provided for the recommendations must be tempered with this knowledge.

Summary statements regarding the error classification database are presented below by primary category and subcategory.

Detect

Errors classified under this general category relate to the initial process of gathering data needed to ascertain "what is happening and where" during an abnormal event. Errors committed here can affect the entire process of transforming data into information as the basis for decisions and actions.

- Data not attended to (cues, annunciations, context, weather information, etc.): These errors relate to a failure to obtain the data necessary to ascertain system state. It was generally difficult, if not impossible, to determine "why" data were not obtained given the level of detail available in the Turbofan–DC&ATG Summary Database. However, the fact that the necessary data were not used in determining action taken was usually quite obvious. The answer to the "why" question of crew behavior often lies in integrating relevant information about contributing factors from the event report. While events have been assigned to the contributing factor categories where the determination could be made from direct report in the summary database or through inference based on the same source, resources were not available to set up a relational database with the error classification and contributing factor data. Therefore, inferences as to the "why" of crew errors are not a part of this analysis but could be if resources became available in the future. This statement applies to all the categories of the error classification analysis.

  There are two subcategories within this category:

  - Failure to monitor throttle position and/or engine parameter display behavior (EPDB): There were seven (7) instances of this type of error spread across the database from the latest to the earliest entries and across three generations of airplanes. Crews failed to monitor either throttle position or engine parameter displays for up to several minutes until upset occurred or the crew took wrong engine action. Workload conditions on the flight deck preceding the event varied across events from very high (initial climb) to very low (cruise). Thus, while the context varied considerably across these events, the results where the same — lack of systems awareness; and,

  - Failure to monitor EPDB over time between/across engines: There were also seven (7) instances of this type of error occurring across the time frame of the database and airplane types. The time available to monitor EPDB also varied widely but this error was recorded when it was clear that the engine performance data were available but not used in determining what action to take. It should be emphasized that what was available was data dispersed over the engine displays, not information about what was happening and where.

- Data attended to, then forgotten: These memory lapse errors are difficult to identify or infer unless there is a direct report of their occurrence by the crew. It was not possible to make this determination on any of the events from the summary database. Nevertheless, it is a possible explanation for behavior, particularly decision making behavior, in many of the events. Therefore the subcategory is retained in the error classification database for possible use in the future.

- Data misperceived: This category is meant to cover those instances where the crew misread, mishear data/cues in the process of trying to ascertain "what is happening and where." This is also very difficult to infer and differentiate from "not attending to" and "partially or poorly integrated" error classifications. Examples are:

  - Look at one parameter and encode it mentally as another — e.g., observe engine no. 1 parameters decreasing but label them engine no. 2 for further action; or,

  - Misperceive call-out of “engine no. 2 fail” as “engine no. 1 fail.”

  There were four (4) instances of this type of error occurring. The evidence for the occurrence of the type of error was very direct, including self-report data. It is the type of error against which there is little defense other than crew coordination and cross-checking.

Interpretation

This category contains more errors than any of the others. The integration and interpretation functions of the data transformation process are most sensitive to rule-based errors and knowledge-based errors. These errors are cognitive errors and, as such, are very difficult to verify as to their exact nature because their classification depends so heavily on inference. The strength of the inferences varies across events as a function of the availability of the human factors related data that are typically included in accident, incident and occurrence reports.

- Data partially or poorly integrated (key relationships not noted): These errors represent failure to properly and adequately complete the integration function in transforming data (as individual cues) into information (as the answer to the questions “what’s happening and where is it happening” — i.e., system or component affected). The accident/incident/occurrence event typically occurs because of a combination of system malfunction plus crew error in terms of incorrect interpretations of system state (based on incomplete data) coupled with actions taken on the basis of these incorrect interpretations. It is extremely difficult to differentiate between “not attended to” and “partially or poorly integrated” cognitive behavior, given the database. Thus, classification of this inferred behavior may, in some cases, be arbitrary or even redundant between these two types of error. Proper completion of the integration function is critical to accurate interpretation. Failures may be the result of lack of knowledge, time constraint or perceptual inadequacies (e.g., can’t read instruments due to vibration). There are three subcategories:

  - Action taken on the basis of one or two cues (e.g., loud bang, bang and yaw, bang and vibration, yaw and vibration, etc.): This was one of the largest categories of error in the error classification database with twenty-two (22) events containing errors associated with this type of ICR. Most, but not all, of the events in which this ICR occurred were rejected takeoff (RTO) overrun events. The ICR occurred throughout the time frame of the database and with glass-cockpit airplanes as well as earlier generations of airplanes. Dealing with this type of ICR is one of the central concerns addressed by recommendations from the Aerospace Industries Association workshop;

  - Action taken on wrong engine based on interpretation of incomplete or poorly integrated pattern of cues: The six (6) ICRs are identified here as a subgroup because they all relate to taking action of some sort on the wrong or unaffected engine during an event. The ICRs occurred across the middle and late time frame of the database and across all three generations of airplanes; and,

  - Failure to integrate EPDB and other cues over time (difficult to differentiate from “data not attended to” errors): The errors associated with the four (4) events assigned to this category represent failures in crew monitoring behavior which occurred over time and clearly indicated a failure to integrate data over time. In most of the events, monitoring over time was required in order to ascertain what was happening and where. In one instance, integrating environmental conditions (runway) with EPDB was required for arriving at the appropriate decision/action.

- Assumptions about data relationships incorrect: These errors are due to either limited or inaccurate mental model at the system level and possibly the airplane level (i.e., relationship between propulsion and other systems), or misidentification of individual cues leading to misinterpretation of the nature of the event and selection of inappropriate action. There are two subcategories:

  - Erroneous assumption(s) about system or cue relationships: Assignment of the errors to this category was based on direct crew reports. This error was found in two events; and,

  - Misidentification/misinterpretation of cues: Assignment of the errors to this category was also based on direct crew reports. This error was also found in two events.

- Data pattern misinterpreted: Errors of this type may be directly linked to failures to properly integrate cue data because of incomplete or inaccurate mental models at the system and airplane levels as well as misidentification of cues. Time constraints and workload are also contributing factors in this type of error. There are useful distinctions to be made between the former and latter causes of the errors, but it was difficult, if not impossible, to distinguish between or among causes based on the data available in the database. Initial attempts to make this distinction were abandoned.

Twenty-three (23) errors involving misinterpretation of the pattern of cues available to the crew during an event were assigned to this category. The assignment was clearly warranted based on inappropriate action taken and/or direct crew report. Designation of error to this level can be used to support more detailed recommendations than error data based on less substantial evidence.

- Failure to obtain relevant data/information from crewmembers: Errors classified under this category might also be classified as being of the "partially or poorly integrated data" type. However, the separate call-out of failing to integrate input from crewmembers into the pattern of cues is considered important for developing recommendations. These errors are different from "not attending to inputs from crewmembers" which would be classified as detection errors. These errors could be lumped under a poor crew coordination category, but again specificity would be lost. Errors assigned to the "poor crew coordination" category are more complex and usually refer to crew activity throughout the event.

  Errors in this category can be further subdivided into failures of captains to obtain specific, relevant inputs from the crew or for crewmembers failing to inform the captain of data crucial to understanding what is happening and where. In either case, important data do not get integrated into the overall pattern of cues surrounding or generated by the event. Nine (9) of these errors were identified from the database.

- Failure to interpret condition (event and context) as abnormal: This error classification is used when crews failed to realize that the airplane was in an unsafe or abnormal condition. Two instances of this type of error were identified.

- Nature of relationships among cues/annunciations not understood: The behavior that would dictate a classification difference between this category and "data pattern misinterpreted" were impossible to come by from the database as it exists. The "bewilderment" aspect of behavior during an event would support this error classification. While identification of this type of error would be particularly useful in developing specific recommendations for training, it was not possible to break the classification down to this level. The category is retained here as a place holder for errors of this type when they can be identified.

- Knowledge of system operation under abnormal conditions lacking or incomplete: These errors are based on erroneous or incomplete mental models of system performance under abnormal conditions. There is some apparent overlap with the third interpretation category, but the link to faulty mental model is clearer in the behavior representing errors in this category.

  This category contained ICRs based on faulty mental models at the system level (propulsion) or the airplane level (relationships among airplane systems). There were eleven (11) instances of knowledge-based errors of this type in the database.

Establish Goal

Errors classified under this general category are knowledge-based errors. The turbofan summary database was too limited to permit useful inferences about these types of errors. The categories are included here to illustrate this aspect of the error classification scheme.

- Established an inappropriate goal: RTO events would be listed here only if there were no airline published policy or procedure and the crew was never exposed to the Boeing Takeoff Safety Training Aid. Otherwise, the RTO events are rule-based errors.

- Failure to properly prioritize goals: Selection of a goal for first action blocks achievement of other important goals.

- Failure to recognize conflicting goals.

Strategy/Procedure

The terms strategy and procedure are used here to indicate two different types of errors. When the term "procedure" is used, the inference is that a written procedure or widely recognized "best practice" is available for implementation when proper interpretation of a cue pattern occurs. Errors where this is the case are rule-based errors. When the term "strategy" is used, it refers to the case where no procedure exists so the crew must devise a strategy for action when they encounter the event. Employing an inappropriate strategy is a knowledge-based error if the situation has no precedent for the crew to follow in terms of either written procedure or best practice. The recommendations will be different for these two different types of errors.

- Improper strategy/procedure chosen: These are rule-based errors where the crew chose to execute an inappropriate procedure for the conditions or a strategy which deviated from "best practices." Aborting a takeoff above V_1 is an example of the former; reducing power on engines below safe altitude is an example of the latter.

  Of the 43 instances of strategy and procedural error, 49 percent involved aborting takeoffs above V_1, 12 percent involved power reductions below safe operating altitudes, and 29 percent were other strategies involving deviation from best practices. Combined, these represent the largest subcategory of errors leading to ICRs in the database.

- Strategy/procedure could not be achieved due to lack of appropriate skill/knowledge: These errors are knowledge-based. The goal selected may have been appropriate, but the crew did not have the knowledge or skill to implement an appropriate strategy. Two events in the database involved errors of this type.

- Choosing not to implement appropriate procedure: These are rule-based errors where correct procedures or strategies were clearly available but disregarded. They are often the flip side of choosing an improper procedure/strategy. Two events in the database involved errors of this type.

Execute

The number of errors in the general area of execution of actions taken in the presence of propulsion system malfunctions rivaled that of the general area of interpretation. There were seven subcategories of errors in this general area.

- Carry out unintended action: These are the classic "slip" errors as defined by Reason (1990). Most of the fifteen (15) ICRs classified under this heading involved moving the wrong throttle or fuel valve, then following through with the engine-shutdown steps. Indications were that the action began with a slip and then continued without verification of correctness of the initial act.

- Failure to complete action: These errors are typical "lapse" errors or errors of omission (Reason, 1990) where all steps in a procedure are not carried out, usually because of workload or interruptions. There were three (3) of these errors identified across the events in the database involving fire handles, fire extinguishers or fuel shutoff valves.

- Poor execution of action: These are errors of technique rather than omission. The action taken was poorly executed. This subcategory contains thirteen (13) instances of ICRs representing a wide variety of poorly executed actions. Assignment of some of the errors to this category versus one on "poor piloting skills" can be argued depending on the breadth or narrowness of one's definition of piloting skills. These errors tend to be in the way a procedure or step(s) in the procedure are executed as opposed to airplane handling skills. The latter errors are classified as poor piloting skills here.

- Failure to initiate action: These errors may be caused by inattention or a failure to recognize a cue pattern as indicating an abnormal condition. They are the action side of failure to recognize. One event contained an error that could clearly be categorized as being of this type.

- Poor/no crew coordination in carrying out action: There is some ambivalence as to whether this is an error type or contributing factor at this point. There is also a "poor/no crew coordination" category under Contributing Factors. The event lists do overlap to some extent, but the distinction is between poor/no crew coordination in executing a particular action (here) vs. lack of crew coordination in general (contributing factor). It is further distinguished from an earlier discussed error category which focused on failures to communicate specific cue data between captain and crew.

  This was another large subcategory of errors which spanned the time frame of the database as well as airplane generation. In other words, it continues to be a contributor to PSM+ICR events. There were twenty-one (21) errors in this category.

- Poor piloting skills (closed-loop control skills): These errors are specifically related to controlling the flight path of the airplane. There were ten (10) errors of this type in the database events with the majority occurring in events which happened during middle years of the database time frame.

- Failure to initiate action in a timely manner: This is an attempt to capture the timing aspect of errors. The nine (9) errors identified in this section represent instances where the timing error played a major role in the poor performance in dealing with the event. Timing may also have played a part in other errors identified elsewhere.

Violations

Reason (1990) defines two levels of violations. His terms are used here but the definitions are specific to this application. Crew actions in these events were assigned to the following categories when specific evidence of a violation was documented in the database. Needless to say, this was very rare. Inferred violations were not recorded.

- Routine: These are the more "minor" violations of company policy or procedures but which can have a major impact on the course of an event. Two violations of the sort could be positively identified from the turbofan summary database.

- Exceptional: This category was used when the violation was of a more serious nature and made a direct contribution to the event. Two violations of the sort could be positively identified from the turbofan summary database

Factors that Contribute to Errors

These aspects of the events were identified and categorized for the purpose of providing "context" for the events. Relating contributing factors to the error data offers the possibility of understanding at least some of the conditions which have relevance to or seriously impact human performance and may provide a framework for better understanding the "why" of human error.

Several different "contributing factors" were identified as being present and having played a part in enhancing the potential for errors. These were:

- Data not present or unreadable — present in four (4) events;
- Workload due to weather or air traffic control (ATC) and dispatch communication requirements — one event;
- Lack of training on condition (event and context) — twenty-one (21) events; all but one inferred from time frame and/or availability of training aids;
- Little or no experience with condition(s) — thirteen (13) events; inferred from actions or time in position data;
- Fatigue — two events;
- Weather — twelve (12) events; this factor was generally reported for all events;
- Runway conditions — nine (9) events; this factor was also reported if other than bare and dry;
- Loss of situation awareness — three events; strong evidence available to support inference; may have been present at some level in most, if not all, events;
- Poor/no crew coordination — twenty-four (24) events. The classification of poor crew coordination as a contributing factor is based on evidence and inference of its poor quality or absence based on overall crew performance;
- System(s) fail to operate because of minimum equipment list (MEL) action — one event;
- Bird strike or assumed bird strike — nine (9) events. Usually the assumption made was that more than one engine had been affected by bird strike;
- Conditions not as calculated (weight, wind speed/direction, etc.) — one event;
- Night — one event. There may have been a number of events which occurred at night, but in only one was it considered a contributing factor to the event itself;
- Equipment failure — ten (10) events where the equipment failure contributed to the severity of the event. All events began with some type of PSM;
- Maintenance error(s) — one event;
- Design — four events, all involving lack of alert for thrust asymmetry;
- Negative transfer — three events, all inferred from previous pilot experience (sometimes extensive) with "outside-in" attitude director indicator (ADI) where pilots were flying "inside-out" ADI at the time of the event;
- Inadequate/inappropriate procedures in place for the conditions — two events; and,
- Procedure not available (no formal procedure exists) — database detail too limited to support identification of this condition as a contributing factor at this time.

Human Factors Error Classification Database

Background

The attached material is an attempt to classify cognitive errors based on analysis of the Turbofan Summary Database in such a way as to support the development of detailed recommendations on solutions for addressing PSM+ICR issues. The "model" used as adapted from Rasmussen (1982) is shown in Figure 1. It illustrates the now ubiquitous error classification levels of skill-based, rule-based and knowledge-based errors, as well as Rasmussen's inverted-U components. The error categories identified within this context include only the basic cognitive functions. The transitions between functions are illustrated with arrows. Application of the model to accident/incident data has resulted in the identification of varying numbers of specific error types (subcategories) within the basic categories. Additional error types may be defined, and refinement of existing definition wording can be expected with any future work on the model.

The primary weakness in the error classification process is the variability in the amount of human performance data in the accident/incident reports upon which to base error classification interpretations. In some cases, the classifications are highly inferential, while in others the conclusions are well supported by the data available. The rationale for assigning the cognitive errors in a particular event (accident/incident/occurrence) to a particular error classification category are illustrated by general descriptive material plus behavioral statements or statements of conditions. These statements are labeled with an alphanumeric identifier (ID) which matches the event ID on the Turbofan–DC&ATG Summary Database. Thus, the error judgments are tied directly to the database. Most of the error categories have examples of crew behavior or assumptions about crew behavior (i.e., inappropriate crew responses) that support the assignment of a particular error category to a particular event.

The items that are listed at the end under "Factors that Contribute to Errors" are a partial listing of the "ecological" variables that must be considered in solving human-machine interface problems. As Vicente[4] proposes, we must take an ecological as well as cognitive approach to developing the interface. This applies whether the solutions proposed are training, procedural or design.

Types of Errors (with Explanations and Examples)

Detect (D)

Errors classified under this general category relate to the initial process of gathering data needed to ascertain "what is happening and where" during an abnormal event. Errors committed here can affect the entire process of transforming data into information as the basis for decisions and actions.

1. Data not attended to (cues, annunciations, context, weather information, etc.): These errors relate to a failure to *obtain* the data necessary to ascertain system state. It is generally difficult, if not impossible, to determine "why" data were not obtained. However, the fact that the necessary data were not used in determining action taken is usually quite obvious. The answer to the "why" question often lies in integrating relevant information about contributing factors from the event report. There are two additional subcategories within this category:

   - Failure to monitor throttle position and EPDB:

     - 96/MNB/2/I: Engine indications showing no. 1 engine at flight idle not flamed out as assumed by crew; no. 1 engine throttle at idle position.

     - 95/EWB/2/HF: Engine indications showing no. 1 engine thrust settings lower than no. 2 and decreasing; no. 1 engine throttle retarding toward idle while no. 2 throttle remains at high thrust level.

     - 95/MWB/2/I-2: No. 2 engine throttle jammed at 94 percent while no. 1 engine throttle slowly reducing power under autothrottle command. Failed to notice no. 2 engine throttle position when diagnosing problem in no. 1 engine.

     - 92/MNB/2/HF: No. 2 engine throttle stuck at idle during level off while no. 1 throttle advanced with autothrottle engaged; autopilot holding left aileron; airplane began to bank right.

     - 92/MWB/2/I: No. 1 engine went subidle during level-off at cruise and was not detected for over seven minutes; throttle split, airspeed bled off, finally 15-degree bank when autopilot could not compensate for asymmetric thrust.

     - 85/EWB/4/S: Crew failed to note that no. 4 engine had gone subidle while engines controlled by autothrottle.

     - 69/2ND/2/H: None of the three pilots on flight deck noticed that no. 2 throttle had inadvertently been displaced below full power.

   - Failure to monitor EPDB over time between/across engines:

     - 89/MNB/2/HF: Vibration indication on no. 1 engine ignored; EPDB of both engines not monitored closely due to numerous radio communication interruptions and initiations. Missed erratic behavior of N_1 (low-compressor-shaft speed) on no. 1 engine.

     - 88/MNB/2/S: Captain as pilot not flying (PNF) apparently not monitoring engine instruments.

     - 88/EWB/3/I: Flight engineer (FE) not monitoring reverser unlock lights.

     - 86/2ND/2/I: Engine operating status not determined following bird strike.

     - 85/EWB/4/I-1: Failed to acquire relevant EPDB before abort decision.

     - 75/2ND/3/S: Captain failed to obtain input on status of propulsion system prior to abort decision.

     - 70/2ND/2/H: Captain as PNF failed to carefully scan engine instruments before acting.

2. Data attended to, then forgotten: These memory-lapse errors are difficult to identify or infer unless there is a direct report of their occurrence by the crew.

3. Data misperceived: This category is meant to include those instances where the crew misread, mishear data/cues in the process of trying to ascertain "what is happening and where." This is also very difficult to infer and differentiate from "not attending to" and

"partially or poorly integrated" error classifications. Examples are:

- Look at one parameter and encode it mentally as another — e.g., observe engine no. 1 parameters decreasing but label them engine no. 2 for further action; or,
- Misperceive call-out of "engine no. 2 fail" as "engine no. 1 fail."
  - 81/EWB/4/I: Apparent misperception of EPDB cues.
  - 81/2ND/2/I: Both engines perceived as failed, only no. 1 engine had in fact failed.
  - 70/2ND/2/H: Captain misinterpreted first officer (FO) rudder overcorrection to right as no. 2 engine failure and incorrectly "perceived" no. 2 engine instruments spooling down.
  - 94/2ND/3/I: Tower personnel misperceived affected engine and gave incorrect identification of affected engine to the crew.

Interpretation (I)

This category contains more errors than any of the others. The integration and interpretation functions of the data transformation process are most sensitive to rule-based errors and knowledge-based errors. These errors are cognitive errors and as such very difficult to verify as to their exact nature because their classification depends so heavily on inference. The strength of the inferences varies across events as a function of the paucity of the human factors related data that are typically included in accident, incident and occurrence reports.

1. Data partially or poorly integrated (key relationships not noted): These errors represent failure to properly and adequately complete the integration function in transforming data (as individual cues) into information (as the answer to the questions "what's happening and where is it happening" — i.e., system or component affected). The accident, incident or event often occurs because of a combination of system malfunction plus pilot error in terms of incorrect interpretations of system state (based on incomplete data) coupled with actions taken on the basis of these incorrect interpretations. It is extremely difficult to differentiate between "not attended to" and "partially or poorly integrated" cognitive behavior, given the database. Thus, classification of this inferred behavior may, in some cases, be arbitrary or even redundant between these two types of error. Proper completion of the integration function is critical to accurate interpretation. Failures may be knowledge-driven, the result of time constraint or perceptual (e.g., cannot read instruments due to vibration).

- Action taken on the basis of one or two cues (e.g., loud bang, bang and yaw, bang and vibration, yaw and vibration, etc.):
  - 96/MWB/4/I: Action taken in reaction to one or two ambiguous cues; yaw, noise.
  - 94/MWB/2/I-1: Crew could not readily determine which engine was affected. Action taken in reaction to one or two ambiguous cues; yaw, noise.
  - 94/MWB/4/I: Action taken in reaction to one or two ambiguous cues; noise.
  - 93/MWB/2/I-3: Retarding of both throttles at low altitude (500 feet) indicates pilot not sure which engine is surging.
  - 93MWB/3/I: Speed of reaction to noise and yaw cues precluded analysis of what actually was happening.
  - 93/MNB/2/I: Failed the correlate throttle position/movement, autothrottle engaged and EPDB to properly identify the problem. Action taken in reaction to one or two ambiguous cues; engine parameters winding down.
  - 93/MWB/3/I: Action taken in reaction to one or two ambiguous cues; yaw, noise.
  - 88/MNB/2/S: Quick scan by FO as pilot flying (PF) missed EPDB to indicate what was happening where. Action taken in reaction to one or two ambiguous cues; two loud bangs and slight yaw to left.
  - 88/EWB/4/S: Action taken in reaction to one or two ambiguous cues; action taken based on captain's hand movement toward throttles.
  - 86/EWB/2/H: Action taken in reaction to one or two ambiguous cues; loud noise, heavy vibrations.
  - 85/2ND/2/HF: Malfunctioning engine not properly identified by both crewmembers. Action taken in reaction to one or two ambiguous cues; yaw and noise.
  - 85/MWB/2/I: Buffet cue was difficult to isolate to an engine. Other cues not properly integrated to identify affected engine. Action taken on vibration alone.
  - 85/EWB/4/I-1: Failed to integrate and interpret EPDB reflecting engine performance before

  initiating RTO procedures. Action taken in reaction to one or two ambiguous cues; birds present, loud bang.

  - 81/EWB/4/S: FE based response to captain's query re what was happening on exhaust gas temperature (EGT) limit light only. Called "engine fire."
  - 81/2ND/3/S: EPDB data not integrated over time. Action taken in reaction to one or two ambiguous cues; loud bang(s), partial power loss on affected engine.
  - 78/EWB/4/S: Captain apparently was not certain whether no. 3 or no. 4 engine was affected. Failed to deploy thrust reversers on no. 3 and no. 4 engine. Action taken in reaction to one or two ambiguous cues; loud bang.
  - 76/EWB/3/I: EPDB not integrated for accurate assessment of propulsion system status. Action taken on loud bang only.
  - 75/2ND/3/S: No additional data other than perceived "marked deceleration" cue used in making abort decision.
  - 75/EWB/4/I-1: Interpretation of no. 3 engine failure based only on "N_1 decreasing."
  - 72/2ND/2/S: Time between hitting pools of standing water and decision to abort was adequate to evaluate engine performance; power recovery underway. Action taken in reaction to one or two ambiguous cues; momentary reduction in rate of acceleration plus some directional control difficulties from hitting pools of standing water.
  - 70/2ND/2/H: Captain reacted to bang and FO induced yaw to the right without reference to EPDB.
  - 69/2ND/2/H: Pilot-in-command (PIC) did not integrate all aspects of EPDB on both engines before calling "throttle it" command (or suggestion) based only on perceived 20-degree Celsius discrepancy in EGT between no. 1 and no. 2 engines.

- Action taken on wrong engine based on interpretation of incomplete or poorly integrated pattern of cues:
  - 94/MWB/2/I-2: Discrepancy between engine crew reported surged and engine throttled.
  - 94/2ND/3/I: Failed to verify incorrect identification of affected engine by tower.
  - 89/MNB/2/HF: EPDB not monitored closely so pattern of parameter behaviors not observed. Failed to include vibration and erratic N_1 behavior indications over time in decision to shut down an engine.
  - 85/EWB/4/I-2: All EPDB on no. 4 engine not considered in shutdown decision. Drop in fuel flow not related to thrust reduction for air turn-back (ATB; return to departure airport).
  - 81/EWB/4/I: Apparent failure to integrate EPDB cues to correctly identify affected engine.
  - 81/2ND/2/I: EPDB on no. 2 engine not integrated over time.

- Failure to integrate EPDB and other cues over time (subtle but important difference between this subcategory and "data not attended to" errors):
  - 96/MNB/2/I: Cues indicating difference between flight idle and flameout not properly interpreted.
  - 95/MWB/2/I-2: Failed to note no. 2 jammed at 94 percent while parameters on no. 1 falling (due to autothrottle action) while no. 1 throttle moving to idle.
  - 78/EWB/3/I-2: Data on runway conditions not integrated with engines' status for "go" decision.
  - 72/EWB/4/I-2: EPDB of no. 2 engine not evaluated over time for true picture of its operating condition, resulting in wrong engine shutdown.

2. Assumptions about data relationships incorrect: These errors are due to either limited or inaccurate mental model at the system level and possible the airplane level (i.e., relationship between propulsion and other systems), or misidentification of individual cues leading to misinterpretation of the nature of the event and selection of inappropriate action.

   - Erroneous assumption(s) about system or cue relationships:
     - 89/MNB/2/HF: Assumed air-conditioning to cockpit provided by no. 2 engine, so thought smoke and smell coming from no. 2 engine.
     - 75/2ND/3/S: Association of marked deceleration cue with engine failure incorrect under the conditions (substantial standing water on runway).
   - Misidentification/interpretation of cues:

- 88/MNB/2/S: Captain's decision to abort made on assumption that loud bang was a blown tire when stall/surge occurred due to turbine blade failure.

- 81/2ND/3/S: Captain's decision to abort made on assumption of uncontained engine failure.

3. Data pattern misinterpreted: Errors of this type may be directly linked to failures to properly integrate cue data because of incomplete or inaccurate mental models at the system and airplane levels as well as misidentification of cues. Time constraints and workload are also contributing factors in this type of error. There are useful distinctions to be made between the former and latter causes of the errors, but it is difficult, if not impossible, to distinguish between or among causes based on the data available in the database. Initial attempts to make this distinction were abandoned.

   - 96/MNB/2/I: Interpreted failure of engine to spool up from flight idle as engine flameout. Autothrottle engaged, no. 2 engine throttle advanced while no. 1 engine throttle at idle; no. 1 engine EPDB indicating flight idle not flameout/failure.

   - 95/EWB/2/HF: At one point, large left roll input made into engine with low thrust while bank angle in that direction was already at least 30 degrees.

   - 95/MWB/2/I-2: No. 1 engine EPDB interpreted as engine failure rather than as the result of autothrottle inputs.

   - 94/MWB/4/I: No. 3 engine surged, no. 2 engine shut down; commanded thrust rollback on no. 2 interpreted as result of surges.

   - 93/EWB/2/I: Misidentified affected engine and retarded good engine throttle at very low altitude (100 feet).

   - 93/MNB/2/I: Autothrottle actions in retarding throttle to maintain approach speeds interpreted as engine failure.

   - 92/MNB/2/HF: Large aileron input in the wrong direction during attempt to recover created an unusual attitude condition possibly due to misinterpretation of ADI. Attempt to engage autopilot heading-select mode to correct drift. Large aileron input toward the low wing (opposite of what autopilot was holding). ADI may have been misread due to negative transfer.

   - 91/2ND/3/I: Cues misinterpreted as tire problem when actually an engine turbomachinery damage problem.

   - 89/MNB/2/HF: Comparison of engines' N_1 done intermittently at just the wrong time when both values were fairly close together, thus misinterpreting relative N_1 behavior of the two engines. Misinterpreted EPDB as indicating no. 2 engine malfunctioning when no. 1 engine was bad. Vibration and erratic N_1 behavior of no. 1 engine not considered.

   - 88/MNB/2/S: Two bangs and yaw were a surge misinterpreted as blown tire(s). RTO initiated because captain thought airplane had blown tire(s). Absence of EPDB indicating engine failure.

   - 85/2ND/2/HF: Affected engine misidentified by at least one crewmember (based on first correct then incorrect rudder inputs). Yaw plus EPDB cues would establish what was happening and where.

   - 85/MWB/2/I: Deliberate shutdown of wrong engine assumed to be based on misinterpretation of EPDB observed. Lower EGT on no. 1 engine interpreted as indicating affected engine whereas higher EGT on no. 2 engine actually indicated affected engine. Buffet continued after no. 1 engine was shut down.

   - 85/EWB/4/I-2: Drop in fuel flow on no. 4 engine attributed to engine failure instead of thrust reduction.

   - 81/EWB/4/I: EPDB may have been misinterpreted.

   - 81/EWB/4/S: EGT limit light misinterpreted to indicate engine fire by FE.

   - 81/2ND/3/S: Loud bang of engine surge interpreted as a (possible) uncontained engine failure with extensive collateral damage.

   - 81/2ND/2/I: EPDB data on no. 2 engine misinterpreted by crew as engine failure.

   - 75/2ND/3/S: Perceived "marked deceleration" caused by standing water on the runway misinterpreted as engine failure.

   - 75/EWB/4/I-1: Misinterpreted decreasing N_1 as engine failure (also I-1 error).

   - 72/EWB/4/I-2: Quick action to shut down no. 2 engine based on misinterpretation of poorly integrated data.

   - 72/2ND/2/S: Loss of acceleration and directional control problems misinterpreted as loss of thrust and RTO initiated.

    - 70/2ND/2/H: Captain misinterpreted FO rudder overcorrection to right as no. 2 engine failure and incorrectly “perceived” no. 2 engine instruments spooling down.

    - 69/2ND/2/H: PIC misinterpreted EPDB and erroneously identified no. 1 engine as the affected engine.

4. Failure to obtain relevant data/information from crewmembers (D-1): Errors classified under this category might also be classified as being of the “partially or poorly integrated data” type. However, the separate call-out of failing to integrate input from crewmembers into the pattern of cues is considered important for developing recommendations. These errors are different from “not attending to inputs from crewmembers” which would be classified as detection errors.

- Failure of captain to obtain all relevant inputs from crew:

    - 91/MNB/2/H: Crew unaware of clear ice on wings (input from ground crew).

    - 89/MNB/2/HF: Failed to ask cabin crew for help in identifying affected engine.

    - 85/EWB/4/I-2: Failed to check among flight crewmembers for actions that would account for fuel flow reduction in no. 4 engine.

    - 85/EWB/4/I-1: Captain failed to obtain EPDB interpretation from FE.

    - 75/2ND/3/S: Captain failed to obtain status of propulsion system from FE.

    - 70/2ND/2/H: Captain failed to obtain input from FO who was PF as to what he thought was happening.

- Failure of crewmembers to provide relevant data or failure to cross-check erroneous data:

    - 88/EWB/3/I: FE failed to report status of reverser unlock lights.

    - 81/EWB/4/S: Captain based abort decision on incorrect diagnosis of engine fault made by FE.

    - 69/2ND/2/H: Failure to verify the PIC’s identification of the affected engine.

5. Failure to interpret condition (event and context) as abnormal: This error classification is used when crews failed to realize that the airplane was in an unsafe or abnormal condition.

    - 95/EWB/2/HF: Airplane in a climbing left turn as required for departure being flown; failed to recognize that combination of stuck throttle and autothrottle system behavior was producing desired flight path and not pilot inputs.

    - 85/EWB/4/S: Crew failed to note subidle condition of no. 4 engine.

6. Nature of relationships among cues/annunciations not understood: The behavior that would dictate a classification difference between this category and “data pattern misinterpreted” will be hard to come by from the database as it exists. The “bewilderment” aspect of the behavior would support this error classification. It may simply not be meaningful to break the classification down to this level.

7. Knowledge of system operation under abnormal conditions lacking or incomplete: These errors are based on erroneous or incomplete mental models of system performance under abnormal conditions. There is some apparent overlap with the I-3 category, but the link to faulty mental model is clearer.

- Faulty mental model at the system level:

    - 88/2ND/2/HF: Simultaneous or alternate (as appropriate) reduction of power on the engines may extend their operating life somewhat under these circumstances.

    - 86/EWB/2/H: PF not aware of (or did not believe) information about engine capabilities following bird strike.

    - 86/2ND/2/I: PF not aware of (or did not believe) information about engine capabilities following bird strike.

    - 85/EWB/4/I-1: PF not aware of (or did not believe) information about engine capabilities following bird strike.

    - 72/2ND/2/S: Decision to reject takeoff based on incorrect assessment of thrust producing capability of the engines.

- Faulty mental model at the airplane level:

    - 89/MNB/2/HF: Major factor in shutdown of no. 2 engine was erroneous assumption as to source of smoke and smell.

    - 83/EWB/4/S: FE apparently not aware of effect of gradually reducing throttle on V_1 speed/distance relationship.

- 83/1ST/2/HF: Lowered gear and flaps simultaneously, causing loss of airspeed at critical time.

- 78/EWB/3/I-2: Abort decision triggered by onset of “engine fail” light when crew had a flyable airplane.

- 77/2ND/3/I: “Engine fail” light interpreted as not having flyable airplane.

- 77/EWB/3/I: “Engine fail” light interpreted as not having flyable airplane.

Establish Goal (EG)

Errors classified under this general heading are knowledge-based errors.

1. Established an inappropriate goal: RTO events would be listed here only if there were no airline published policy or procedure and pilots were never exposed to the Boeing Takeoff Safety Training Aid. Otherwise, the RTO events are rule-based errors.

2. Failure to properly prioritize goals: (selection of a goal for first action blocks achievement of other important goals).

3. Failure to recognize conflicting goals.

Strategy/Procedure (S/P)

1. Improper strategy/procedure chosen: These are rule-based errors where the crew chose to execute an inappropriate procedure for the conditions or a strategy which deviated from “best practices.” Aborting a takeoff above V_1 is an example of the former; reducing power on engines below safe altitude is an example of the latter.

- Execute RTO procedure when airplane has achieved V_1 speed or higher:

  - 96/MWB/4/I: Chose to abort takeoff above V_1 for surge.

  - 93/MWB/3/I: FO chose to abort takeoff for surge at or above V_1; captain intervened and continued takeoff.

  - 93/EWB/4/I-2: FO chose to abort takeoff for surge at or above V_1 and assumed foreign-object damage (FOD) had occurred.

  - 92/EWB/4/I: Chose to execute an RTO for surge at a speed above V_1.

  - 91/MNB/2/I: Chose to execute RTO for surge at V_R (with plenty of runway).

  - 91/EWB/2/I: Chose to execute RTO for vibration and perceived power loss well above V_1.

  - 88/MNB/2/S: Attempted RTO above V_1. Takeoff should not have been aborted for either surge or blown tire.

  - 88/EWB/4/S: FO initiated RTO well above V_1 on own initiative following engine-fire warning.

  - 88/2ND/2/I: Chose to initiate RTO well above V_1 when potential for bird strikes was obvious well before V_1.

  - 86/EWB/2/H: Chose to initiate RTO at V_R following bird strike.

  - 86/2ND/2/I: Chose to initiate RTO at V_R following bird strike.

  - 85/EWB/4/I-1: Chose to initiate RTO 19 knots above V_1 on wet runway following a bird strike with two thrust reversers inoperative.

  - 81/2ND/3/S: Chose to initiate RTO above V_R with nose gear off the ground.

  - 78/EWB/3/I-2: Given runway conditions and two good engines, an RTO initiated at V_1 would not have been the correct procedure to chose. Although RTO purported to have been initiated at V_1, snow pack over ice at stopping end of runway reduced braking efficiency. Airplane could not be stopped on the runway under these conditions.

  - 78/EWB/4/S: Chose to initiate RTO well above V_1.

  - 77/2ND/3/I: Chose to initiate RTO at V_R with flyable airplane. Airplane could not be stopped on the runway under these conditions.

  - 77/EWB/3/I: Chose to initiate RTO above V_R with flyable airplane. Airplane could not be stopped on the runway under these conditions.

  - 76/EWB/3/I: Chose to initiate RTO above V_R with flyable airplane on contaminated runway. Airplane could not be stopped on the runway under these conditions.

  - 75/2ND/3/S: Chose to initiate RTO near V_R with flyable airplane on wet runway. Airplane could not be stopped on the runway under these conditions.

  - 72/2ND/2/S: Chose to initiate RTO above V_1 with flyable airplane on a wet runway. Airplane could not be stopped on the runway under these conditions.

  - 70/2ND/2/H: Captain chose to assume control of airplane and initiate an RTO 50–100 feet off the ground and above V_2. Airplane could not be stopped on the runway under these conditions.

- Power reduction below safe operating altitude:
  - 94/MWB/2/I-1: Chose to reduce thrust on both engines at very low altitude (290 feet) following surge in left engine.
  - 94/MWB/2/I-2: Chose to reduce thrust on one engine near V_R to clear surge.
  - 93/MWB/2/I-3: Chose to reduce thrust on both engines at low altitude (500 feet) during takeoff.
  - 93/EWB/2/I: Chose to retard throttle below 400 feet.
  - 69/2ND/2/H: Pilot-in-charge rapidly closed identified throttle below 200 feet.

- Other strategies which deviate from “best practice”:
  - 96/1ST/4/HF: Continued takeoff after losing one, possibly two, engines before V_1.
  - 96/MNB/2/I: Chose to close fuel shutoff lever when engine at flight idle because of malfunctioning autothrottle.
  - 95/EWB/2/HF: Tried to engage autopilot while in a 45-degree bank as a recovery strategy.
  - 93/MNB/2/I: Chose to shut down good engine.
  - 91/MNB/2/H: Crew chose to take off with clear ice on wings. During takeoff, the ice came loose and was ingested into both engines causing FOD and unrecoverable surging.
  - 92/MNB/2/HF: Actions taken created an unusual attitude at night.
  - 89/MNB/2/HF: Chose to shut down good engine and leave it shut down on final approach, thus relying on power from severely damaged engine.
  - 88/2ND/2/HF: Applying continuous maximum power with heavy FOD is not conducive to sustained engine operation.
  - 85/1ST/4/H: RTO initiated at high speed with insufficient runway remaining.
  - 5/MWB/2/I: Strategy to reduce vibration and save engine not achieved because of wrong engine shut down.
  - 83/1ST/2/HF: Chose to execute downwind landing. Gear and flaps down simultaneously caused reduced airspeed. Did not immediately select takeoff power.
  - 83/EWB/4/S: FE attempted to control EGT by gradually reducing throttle on affected engine instead of calling for an abort fairly early in the takeoff run (80 knots). No V_1 call.
  - 82/EWB/4/I: Captain reduced then restored power to malfunctioning engine until engine failed. Procedure is to shut it down for high vibration.
  - 81/1ST/4/I: ATB procedure executed inappropriate for the conditions. Attempted landing overweight, 25 knots fast onto wet runway, with tailwind.
  - 81/1ST/4/H: PF Created thrust imbalance at low speed by bringing in no. 2 engine reverser with no. 3 engine shut down.
  - 81/EWB/4/S: FE’s failure to set full takeoff power prior to 80 knots moved V_1 distance point further down the runway making a successful RTO more difficult if not impossible. Takeoff roll started 150 meters down the runway also moved calculated V_1 point. (Overrun was 20 meters.)
  - 79/2ND/2/S: Captain shut down both engines and descended 15,000 feet before restarting good engine.

2. Strategy/procedure could not be achieved due to lack of appropriate skill/knowledge: These errors are knowledge-based. The goal selected may have been appropriate but the crew did not have the knowledge or skill to implement an appropriate strategy.
   - 88/2ND/2/HF: ATB would not be successful without careful management of thrust applications.
   - 83/1ST/2/HF: Crew committed several piloting errors in addition to loss of control.

3. Choosing not to implement appropriate procedure: These are rule-based errors where correct procedures or strategies were clearly available but disregarded. They are often the flip side of choosing an improper procedure/strategy.
   - 96/1ST/4/HF: Did not execute RTO with engine failure below V_1.
   - 83/EWB/4/S: FE chose to reduce power on affected engine rather than call “engine fail.”

4. Failure to reconcile conflicting strategies/procedures: No errors recorded so far that could serve to operationally define this type of error.

Execute (E)

1. Carry out unintended action: These are the classic “slip” errors as defined by Reason (1990).
    - 94/MWB/2/I-1: No. 2 engine throttle reduced inadvertently when no. 1 throttle pulled back in response to surge.
    - 94/MWB/4/I: Intention aspect inferred; reached for no. 3 and shut down no. 2 (or see E-1).
    - 94/MWB/2/I-2: No. 1 engine reported as having surged, no. 2 engine throttle reduced 30 percent at rotation.
    - 85/2ND/2/HF: Assume wrong rudder inputs not intentional.
    - 82/EWB/4/I: FE pulled fire handle on no. 1 engine instead of no. 2 engine as ordered.
    - 81/EWB/4/I: Engine shutdown could have been a slip.
    - 80/EWB/3/I: Possible inadvertent shutdown of no. 2 engine during shutdown of no. 3 engine. Nobody admitting it.
    - 79/EWB/4/I-1: Possible inadvertent shutdown of no. 3 engine while executing shutdown procedure on no. 2 engine.
    - 78/EWB/4/I: No. 3 engine inadvertently shut down in process of shutting down no. 4 engine.
    - 78/2ND/3/I-1: No. 1 engine shut down inadvertently while trying to shift essential power source to no. 2 engine after first trying to select no. 1 engine.
    - 77/EWB/4/I: Possible inadvertent shutdown of no. 1 engine when no. 2 engine failed. Inability to restart no. 1 makes this questionable.
    - 75/EWB/4/I-2: Inadvertent cutoff of fuel to no. 4 engine (fire handle or fuel shutoff valve) while shutting down no. 3 engine following compressor surge.
    - 72/EWB/4/I-1: Fuel valve for no. 2 engine inadvertently closed during shutdown procedure being executed for no. 3 engine.
    - 70/EWB/4/I: Fuel cutoff valve on no. 1 engine inadvertently closed when engine-fire warning occurred in no. 2 engine.
    - 69/2ND/2/H: In process of reducing no. 1 throttle to idle, no. 2 throttle partially closed.
2. Failure to complete action: These errors are typical “lapse” errors or errors of omission where all steps in a procedure are not carried out, usually because of workload or interruptions.
    - 95/MWB/2/I-2: No. 1 engine shut down with fire handle. Fire handle not returned to “off” position before attempting to restart no. 1.
    - 83/1ST/2/H: Crew failed to discharge fire extinguishers as part of shutdown procedure.
    - 68/1ST/4/HF: Failed to close fuel shutoff valve in pylon; failed to shut off booster pumps.
3. Poor execution of action: These are errors of technique rather than omission. The action taken was poorly executed.
    - 90/1ST/4/H: Failed to execute RTO procedure adequately; poor braking technique.
    - 88/MNB/2/S: Slammed nose gear back on runway while both pilots applied maximum braking causing nose gear to collapse.
    - 88/2ND/2/I: Failed to deploy spoilers as part of RTO procedure.
    - 88/EWB/4/I: Allowed airplane to overrotate by 11 degrees; right wing dropped when surge in no. 4 engine occurred at rotation.
    - 85/2ND/2/HF: Control inputs resulted in high-speed stall and rudder into the dead engine.
    - 83/1ST/2/HF: Did not select takeoff power immediately. Gear and flaps lowered simultaneously.
    - 81/1ST/4/H: Unstable approach; landed long.
    - 81/EWB/4/S: FE did not bring engines up to full takeoff power before 80 knots. Captain did not apply maximum continuous braking during RTO. No indication of reversers being used.
    - 78/EWB/4/S: PF delay in applying brakes; reversers on no. 3 and no. 4 engine not deployed.
    - 78/EWB/4/I: Engine shutdown procedure not properly executed (fire handle or fuel switch for

no. 3 engine inadvertently moved during shutdown of no. 4 engine).

   - 69/1ST/4/S: Overload, delay in applying brakes, rolling takeoff and a reduction in reported head wind led to overrun.
   - 69/2ND/2/H: Poor execution of engine shutdown procedures resulted in fire and fatalities.
   - 68/1ST/4/HF: Poor execution of engine shutdown procedures resulted in fire and fatalities.

4. Failure to initiate action: These errors may be caused by inattention or a failure to recognize a cue pattern as indicating an abnormal condition. They are the action side of failure to recognize.

   - 95/EWB/2HF: Stuck throttle condition existed for 42 seconds with no action taken to correct problem; no rudder input throughout entire event.

5. Poor/no crew coordination in carrying out action: There is some ambivalence as to whether this is an error type or contributing factor at this point. There is also a “poor/no crew coordination” category under contributing factors. The event lists do overlap to some extent, but the distinction is between poor/no crew coordination in executing a particular action (here) vs. lack of crew coordination in general (contributing factor).

   - 93/MWB/3/I: No evidence of formal transfer of control from FO to captain.
   - 89/MNB/2/HF: Failed to coordinate with cabin crew; captain and FO working independently; captain did not cross-check and verify FO identification of affected engine.
   - 88/MNB/2/S: Captain took control of airplane during RTO without verbal call for control, resulting briefly in conflicting control inputs.
   - 88/EWB/3/I: FE failed to advise captain immediately of status of reverser unlock lights.
   - 88/EWB/4/S: Captain did not call for RTO, FO assumed captain hand movement toward throttles a signal to abort takeoff.
   - 88/2ND/2/I: No cross-check to assure proper execution of procedure.
   - 85/2ND/2/HF: Assume two pilots making control inputs or giving directions for control inputs which are not correlated with required control inputs for the situation.
   - 85/EWB/4/I-2: Coordination among crew on thrust reduction and apparent failure of no. 4 engine did not occur.
   - 83/EWB/4/S: FE did not advise captain of actions/intentions. No V_1 call-out made. No V_1 speed bug used.
   - 83/1ST/2/H: No cross-check by crew on proper and complete execution of shutdown procedure.
   - 81/EWB/4/I: Poor coordination between captain and FE in accomplishing engine shutdown.
   - 81/EWB/4/S: Crew failed to coordinate actions for optimum RTO execution.
   - 81/2ND/3/S: FE failed to advise captain that engine had not failed completely.
   - 81/2ND/2/I: Crew failed to coordinate interpretation of EPDB for correct analysis of event.
   - 78/2ND/2/H: Instructor pilot attempting go-around while student pilot was applying brakes.
   - 78/2ND/3/I-1: Assume action on procedure shared among crewmembers.
   - 72/EWB/4/I-2: Malfunction diagnostic process not well coordinated among crew.
   - 71/1ST/4/H: Total lack of crew coordination during loss-of-control event.
   - 70/2ND/2/H: Captain as PNF did not perform his duties of scanning engine instruments to determine what was happening where; FO stayed on the controls after captain assumed control and called for control verbally.
   - 69/2ND/2/H: PIC should not have intruded into flying the airplane and dealing with the engine malfunction.
   - 68/1ST/4/HF: Poor crew coordination in dealing with malfunction

6. Poor piloting skills (closed-loop control skills): These errors are specifically related to controlling the flight path of the airplane.

   - 92/MNB/2/HF: Poor systems monitoring.
   - 90/1ST/4/H: Poor execution of braking action.
   - 88/EWB/4/I: Poor airplane control during surge at rotation.

- 85/2ND/2/HF: Elevator and rudder inputs were exactly the opposite of what they should have been.
- 83/1ST/4/HF: Poor airplane control on liftoff with no. 4 engine set at reduced power for ferry flight.
- 83/1ST/2/HF: Lost control during final approach, wing tip struck the ground.
- 81/1ST/4/H: Lost control when created imbalance by bringing in no. 2 reverser with no. 3 engine shut down.
- 81/1ST/4/I: Unstable approach.
- 73/1ST/2/HF: Loss of control during go-around. Strange, would have expected plane to go in to the left.
- 71/1ST/4/H: Loss of control during simulated heavyweight takeoff.

7. Failure to initiate action in a timely manner: This is an attempt to capture the timing aspect of errors.
    - 92/MNB/2/HF: Failed to advance no. 2 throttle manually at level off; failure to assume manual control during thrust asymmetry recovery.
    - 92/MWB/2/I: Failed to address rollback to subidle when it occurred (action delayed for over 7 minutes).
    - 88/EWB/3/I: Failed to immediately reduce power on all engines.
    - 88/2ND/2/I: Failed to immediately deploy "lift dumpers" (spoilers).
    - 88/EWB/4/I: Failed to correct properly for surge in no. 4 engine at rotation.
    - 85/EWB/4/S: Failure to recover from unusual attitude before losing 32,000 feet.
    - 83/EWB/4/S: FE failed to advise captain of engine failure in a timely manner.
    - 78/EWB/4/S: Delay in initiating RTO at or very near V_1 when surge occurred.
    - 68/1ST/4/HF: Failure to turn off booster pumps resulted in fuel being pumped onto the ramp for 20 minutes.

Violations (V)

Reason (1990) defines two levels of violations. His terms are used here but the definitions are specific to this application. Crew actions in these events were assigned to the following categories when specific evidence of a violation was documented in the database. Needless to say, this was very rare. Inferred violations were not recorded.

1. Routine: These are the more "minor" violations of company policy or procedures but which can have a major impact on the course of an event.
    - 88/MNB/2/S: RTO procedures not briefed before takeoff.
    - 83/EWB/4/S: FE reduced throttle instead of calling "engine fail." No V_1 call.
2. Exceptional: This category was used when the violation was of a more serious nature and had a direct contribution to the event.
    - 70/2ND/2/H: Company procedures and applicable flight manuals dictate that crew should have continued takeoff with one engine inoperative.
    - 69/2ND/2/H: Pilot-in-charge took action on the throttles below 700 feet in direct violation of company policy (training manual).

Factors that Contribute to Errors

These aspects of the events were identified and categorized for the purpose of providing "context" for the events. Relating contributing factors to the error data offers the possibility of understanding at least some of the conditions which have relevance to or seriously impact human performance and may provide a framework for better understanding the "why" of human error; *particularly* the cognitive errors.

1. Data not present or unreadable:
    - 91/EWB/2/I: Pilot reported vibration so bad couldn't read instruments (however, also reported perceived loss of power).
    - 86/EWB/2/H: Crew reported lateral vibrations so heavy could not read instruments.
    - 85/2ND/2/HF: Outside horizon not visible from this airplane during this phase of flight.
    - 78/EWB/3/I-2: Condition of runway at stopping end may not have been available to the crew although should have been expected given the location and time of year.
2. Workload due to weather, ATC and dispatch interface requirements:

- 89/MNB/2/HF: FO and captain talking to ATC and dispatch several times during the event. These communications interrupted crew's attempt to coordinate on several occasions. FO trying unsuccessfully to reprogram flight management computer in descent and initial approach.

3. Lack training on condition (event and context):

   - 96/MWB/4/I: Inferred from general lack of training across airlines on surges.
   - 96/MNB/2/I: Inferred from general lack of training across airlines on subtle autothrottle failures.
   - 95/EWB/2/HF: Inferred from general lack of training on event across airlines; FO as PF was low time.
   - 92/MNB/2/HF: No unusual attitude recovery training available to crew.
   - 92/EWB/4/I: Boeing Takeoff Safety Training Aid not available.
   - 91/MNB/2/H: Conditions outside crew training experience.
   - 89/MNB/2/HF: Conditions outside crew training experience.
   - 88/2ND/2/HF: Crew lacked training on procedures with multiple-engine FOD.
   - 88/EWB/4/I: PF lacked training for surge at this point in takeoff under adverse wind conditions.
   - 86/EWB/2/H: Crew lacked training on RTO decision criteria; Boeing Takeoff Safety Training Aid not published yet.
   - 85/2ND/2/HF: Extensive review of crew training by U.S. National Transportation Safety Board documented this.
   - 85/EWB/4/I-1: Inferred from general lack of training on event across airlines.
   - 83/1ST/4/HF: Conditions outside crew training experience.
   - 83/1ST/2/HF: Crew had not completed emergency procedures training.
   - 81/EWB/4/S: FE lacked training and/or skill on engine malfunction identification.
   - 81/2ND/3/S: Captain lacked takeoff safety training to counter earlier experience.
   - 78/2ND/2/H: Student pilot not trained on engine loss procedure for takeoff or go-around.
   - 77/2ND/3/I: Crew lacked training on criteria for RTOs (assumed based on time frame).
   - 77/EWB/3/I: Crew lacked training on criteria for RTOs (assumed based on time frame).
   - 76/EWB/3/I: Crew lacked training on criteria for RTOs (assumed based on time frame).
   - 73/1ST/2/HF: Conditions outside crew training experience.

4. Little or no experience with condition(s):

   - 96/1ST/4/HF: Inferred from action taken.
   - 96/MWB/4/I: Inferred from event occurrence frequency.
   - 95/EWB/2/HF: Inferred from action or lack of action taken. Low-time FO as PF. Same event occurred on same airplane on the previous flight.
   - 92/MNB/2/HF: Lack of experience with condition inferred from actions.
   - 89/MNB/2/HF: Low-time crewmembers in both positions.
   - 88/MNB/2/S: First RTO for either pilot.
   - 88/2ND/2/HF: Inferred from action taken.
   - 86/EWB/2/H: Inferred from action taken.
   - 85/2ND/2/HF: Both pilots low time in type.
   - 85/EWB/4/I-1: Inferred from action taken.
   - 83/1ST/4/HF: Inferred from actions taken.
   - 83/1ST/2/HF: Inferred from series of inappropriate actions taken.
   - 78/2ND/2/H: Student pilot's lack of experience caused startle reaction and inappropriate response (applying brakes during go-around).

5. Fatigue:

   - 96/1ST/4/HF: Inferred from night takeoff.
   - 69/2ND/2/H: Fatigue cited as possible factor in poor judgment displayed by PIC.

6. Weather:
   - 5/EWB/2/HF: Departure in snowstorm.
   - 91/MNB/2/H: Clear ice on wings.
   - 88/EWB/4/I: Squall-like crosswinds on takeoff.
   - 86/2ND/2/I: Heavy rain.
   - 85/EWB/4/I-1: Heavy rain showers before event.
   - 81/1ST/4/H: Typhoon conditions for landing, gusty tail wind and crosswinds.
   - 81/1ST/4/I: Unstable?
   - 78/EWB/3/I-2: Blowing snow.
   - 76/EWB/3/I: Rain, sleet, snow, wind.
   - 75/2ND/3/S: Recent rain.
   - 72/2ND/2/S: Raining.
   - 69/1ST/4/S: Shifting winds.
7. Runway conditions:
   - 86/2ND/2/I: Very wet runway (standing water?).
   - 85/EWB/4/I-1: Wet runway.
   - 81/1ST/4/H: Wet runway.
   - 81/1ST/4/I: 7.5-knot tail wind.
   - 78/EWB/3/I-2: Snow pack over ice at stopping end of runway.
   - 77/EWB/3/I: Wet runway.
   - 76/EWB/3/I: Runway contaminated (sleet, rain, snow).
   - 75/2ND/3/S: Wet runway with extensive area of standing water.
   - 72/2ND/2/S: Wet runway with pools of standing water.
8. Loss of situation awareness:
   - 95/EWB/2/HF: Neither member of the crew was aware of why airplane was flying the way it was.
   - 92/MNB/2/HF: Crew not aware of autothrottle and autopilot inputs in response to thrust asymmetry produced by malfunctioning throttle system.
   - 85/EWB/4/S: Captain lost situation awareness while dealing with in-flight malfunction.
9. Poor/no crew coordination:
   - 96/1ST/4/HF: Inferred.
   - 95/EWB/2/HF: No cross-check by PNF of PF actions or inaction.
   - 93/MWB/3/I: Inadequate RTO criteria briefing before takeoff (inferred from actions).
   - 92/MNB/2/HF: No cross-check of airplane system conditions by both pilots.
   - 89/MNB/2/HF: Lack of crew coordination from onset of event to crash.
   - 88/MNB/2/S: Captain as PNF not doing engine instrument scan during takeoff roll; no positive call-out indicating captain was taking control to execute an RTO.
   - 88/EWB/4/S: No clear understanding of criteria or signal for RTO briefed before takeoff. On taxi out, FO had asserted emphatically that if an RTO were required, *he* would execute the procedure.
   - 88/2ND/2/I: No cross-check of procedure items by crew to assure proper completion.
   - 85/EWB/4/I-2: Poor coordination and cross-checking by crew on true status of engines and who was doing what to which engine.
   - 85/EWB/4/S: Crew failed to monitor and cross-check engine and flight instruments.
   - 83/EWB/4/S: FE failed to keep captain advised of his actions/intentions. No V_1 call-out.
   - 83/1ST/2/HF: Crew failed to carry out basic airmanship tasks.
   - 82/EWB/4/I: Procedural errors and slips by captain and FE. Lack of crew coordination.
   - 81/EWB/4/I: Poor coordination of engine shutdown procedure between captain and FE.
   - 81/EWB/4/S: Poor coordination of RTO procedures.
   - 81/2ND/3/S: Captain not advised by FE on affected engine EPDB status.

- 81/1ST/4/I: Crew did not plan effective ATB strategy.
- 78/2ND/2/H: Student pilot not briefed for this event
- 78/2ND/3/I-1: Abnormal procedure execution not coordinated.
- 76/EWB/3/I: Crew failed to coordinate information exchange on propulsion system status.
- 75/2ND/3/S: Crew failed to coordinate information exchange on propulsion system status.
- 72/2ND/2/S: Crew failed to coordinate information exchange on propulsion system status.
- 70/2ND/2/H: Both pilots were on the controls during the RTO; no verification of airplane status between crewmembers.
- 69/2ND/2/H: Affected engine identified by senior pilot in jump seat whose real purpose was to supervise copilot. Senior status of PIC gave too much weight to his "suggestion." Decisions and flying the airplane should have been done by the pilot-in-charge.

10. System(s) fail to operate because of MEL action:
    - 85/EWB/4/I-1: Two outboard thrust reversers could not be used; one inoperative.
11. Bird strike or assumed bird strike:
    - 93/EWB/4/I-2: Two large common buzzards in no. 2 engine.
    - 92/EWB/4/I: Bird strike initiated surge; no fan blade damage.
    - 88/2ND/2/HF: Multiple bird strikes in both engines.
    - 88/2ND/2/I: Assumed multiple bird strikes from flock of birds on runway.
    - 86/EWB/2/H: Ingested black kite bird in no. 2 engine.
    - 86/2ND/2/I: Bird strike in no. 1 engine, at least one sea gull.
    - 85/EWB/4/I-1: Feathers present but no fan blade damage.
    - 78/2ND/2/H: Bird strike on no. 1 engine during go-around.
    - 69/1ST/4/S: Bird strikes in three of four engines, one with FOD.
12. Conditions not as calculated (weight, wind speed/direction, etc.):
    - 69/1ST/4/S: Fuel overload due to faulty hydrometer.
13. Night:
    - 92/MNB/2/HF.
14. Equipment failure:
    - 95/EWB/2/HF: No. 2 throttle stuck at high power setting with autothrottle engaged.
    - 93/MNB/2/I: Defective torque switch in autothrottle system suspected; turbomachinery damage.
    - 93/EWB/4/I-1: Turbomachinery damage and collateral damage to second engine.
    - 92/MNB/2/HF: No. 2 engine throttle failed to respond to autothrottle inputs.
    - 92/MWB/2/I: No. 1 engine went to subidle at level-off to cruise.
    - 91/EWB/2/I: Tire tread ingested into no. 1 engine, FOD and heavy vibration.
    - 89/MNB/2/HF: Turbomachinery damage on no. 1 engine.
    - 88/MNB/2/S: Turbomachinery damage on no. 1 engine.
    - 85/EWB/4/H: Throttle cable parted at just the wrong time, resulting in full forward thrust just as other three engines went into reverse on landing.
    - 85/2ND/2/HF: Uncontained engine failure.
15. Maintenance error(s):
    - 72/EWB/4/I-1: Maintenance error produced leaking O-rings; fuel ignited and caused engine fire no. 3 engine.
16. Design:
    - 96/MNB/2/I: No alert for thrust asymmetry.

  - 95/EWB/2/HF: No alert for thrust asymmetry.
  - 92/MNB/2/HF: No alert for thrust asymmetry.
  - 92/MWB/2/I: No alert for thrust asymmetry.

17. Negative transfer:
  - 92/MNB/2/HF: Previous planes flown by pilots were built in Russia with ADI horizon indication the opposite of airplane being flown.
  - 85/EWB/4/S: Failure to recover from unusual attitude before so much altitude was lost may be due to negative transfer from Russian to U.S. ADIs.
  - 95/EWB/2/HF: Low-time FO as PF. Possible Eastern Bloc ADI experience involved.

18. Inadequate/inappropriate procedures in place for conditions:
  - 91/MNB/2/H: Company policy and procedures for dealing with clear ice removal were inadequate.
  - 72/2ND/2/S: No policy or procedures in operators manual to provide guidance for pilots with regards to isolated pools of standing water on the runway.

19. Procedure not available (no formal procedure exists).♦

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3. Shontz, W.D. “Crew Information Requirements Analysis (CIRA).” Boeing Document D6-82110. 1997.
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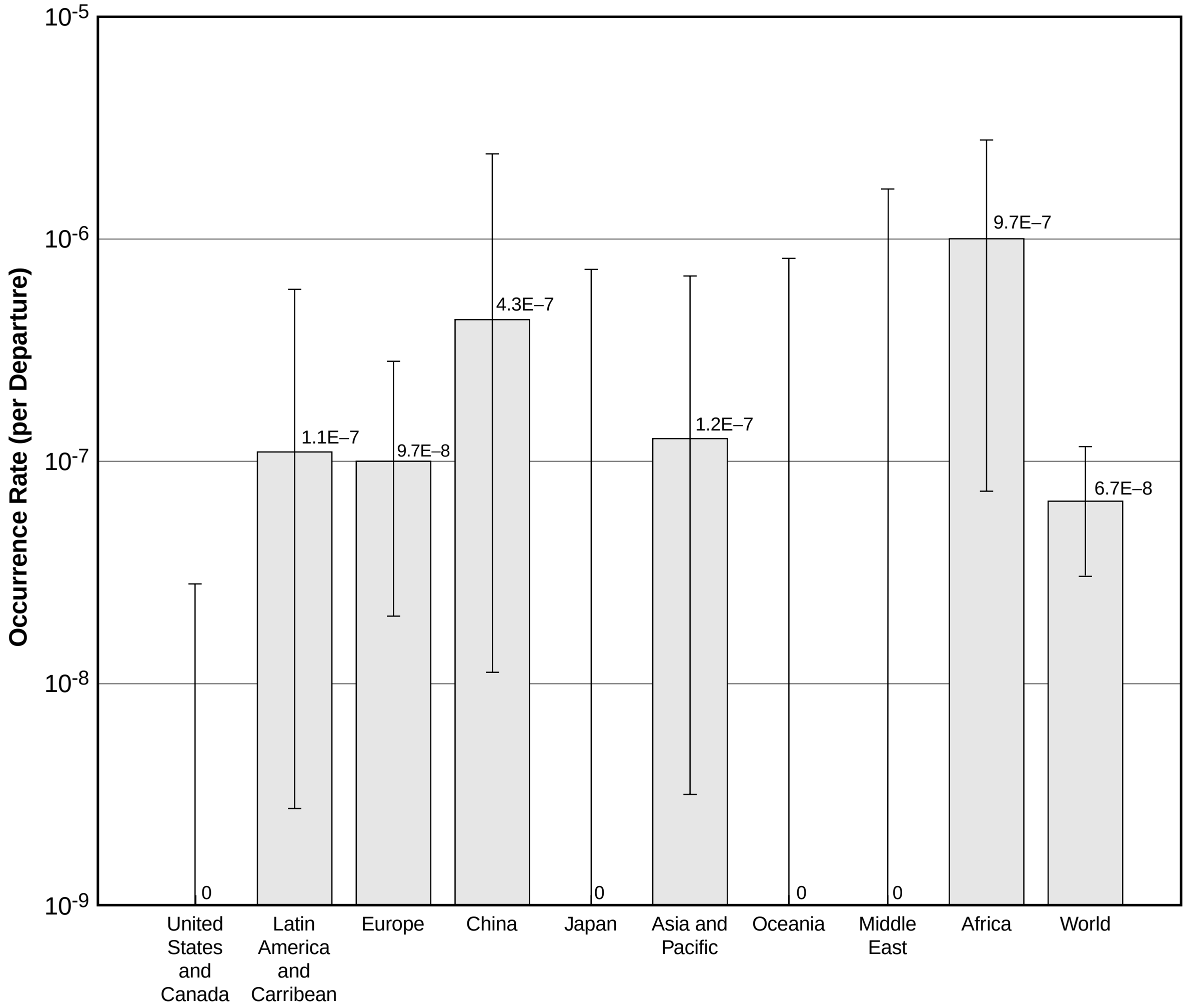
Appendix P

Turbofan Statistical Difference Assessment



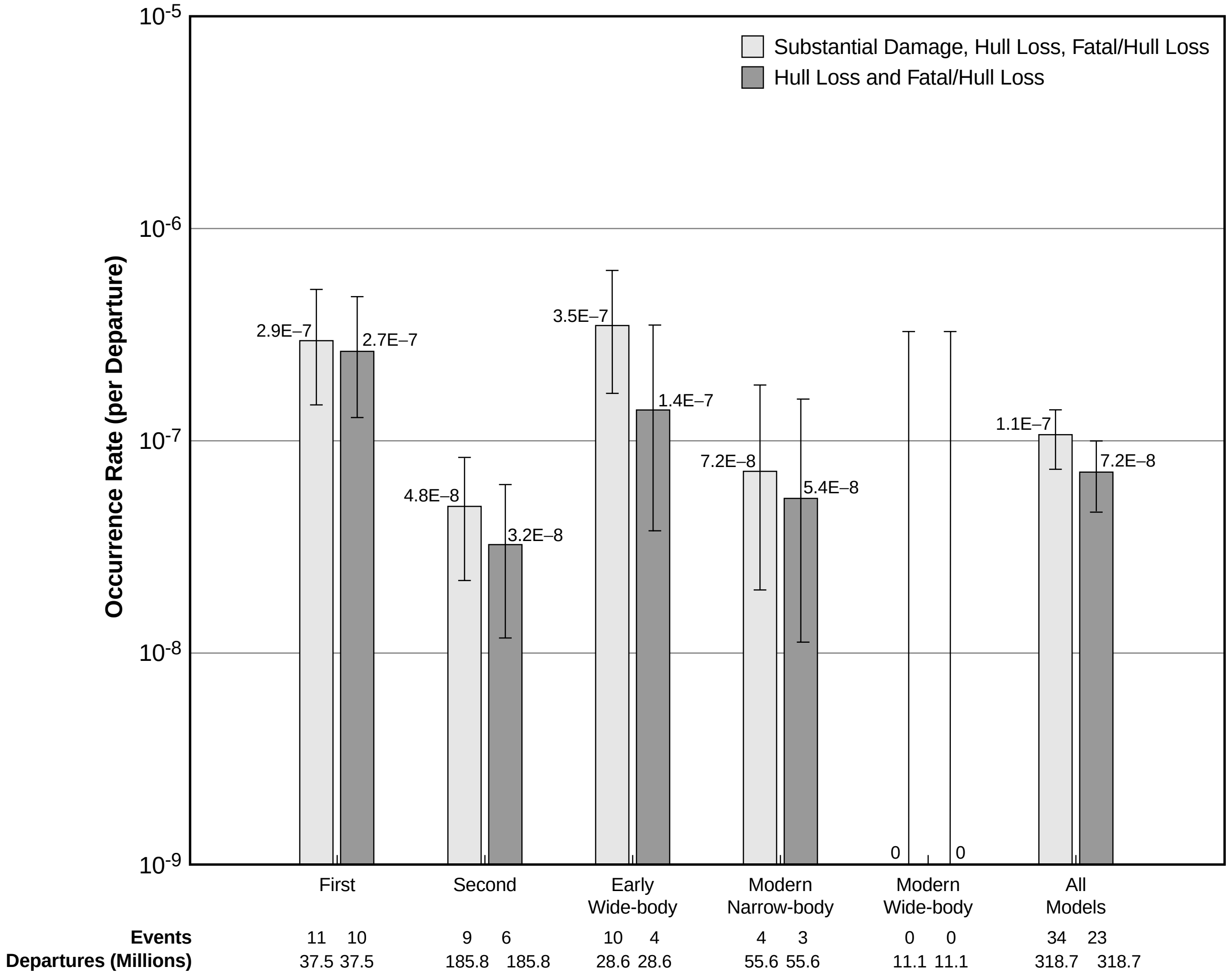
PSM+ICR* Regional Differences; Turbofan Airplanes for Last Ten Years (1987–1996); Hull Loss Accidents Only

	United States and Canada	Latin America and Carribean	Europe	China	Japan	Asia and Pacific	Oceania	Middle East	Africa	World
Events	0	1	3	1	0	1	0	0	3	9
Departures (Millions)	69.8	9.2	30.8	2.3	5.0	8.0	4.5	2.2	3.1	134.9

*PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: Reprinted with minor changes from G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

PSM+ICR* Differences by Airplane Generation; Turbofan Airplanes Since Start of Service Through End of 1996



*PSM+ICR = Propulsion system malfunction plus inappropriate crew response

Source: Reprinted with minor changes from G.P. Sallee and D.M. Gibbons, “AIA/AECMA Project Report on Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR),” Aerospace Industries Association and The European Association of Aerospace Industries, November 1998.

Controlled-flight-into-terrain Accidents Decline in First 11 Months of 1999

Boeing data show one CFIT hull-loss accident involving a large, Western-built commercial jet airplane.

FSF Editorial Staff

One large Western-built airplane in the worldwide commercial jet fleet was destroyed in the first 11 months of 1999 in a controlled-flight-into-terrain (CFIT) accident (Figure 1, page 195), showed data compiled by The Boeing Co.

The accident involved a Lufthansa Cargo India Boeing 727 (B-727) that struck terrain shortly after takeoff from an airport in Katmandu, Nepal, on July 7. The accident killed all five people in the airplane.

At least two CFIT accidents have been reported among Western-built commercial jet airplanes weighing more than 60,000 pounds (27,216 kilograms) maximum gross weight every year since 1984, when Boeing data showed that there were no CFIT accidents in that category.

Boeing data also showed that five airplanes in the Western-built worldwide commercial jet fleet were destroyed in CFIT accidents in 1998, and that one airplane was substantially damaged in a CFIT accident. Other 1998 data compiled by Donald Bateman, chief engineer at AlliedSignal and an authority on CFIT accidents, included two additional CFIT accidents in which the airplanes were classified as hull losses.

The five hull losses included in Boeing's 1998 data represented an increase from 1995, 1996 and 1997, when there were three hull losses worldwide each year as a result of CFIT accidents. Boeing defines a hull loss as damage to an airplane that is substantial and beyond economic repair. Boeing also classifies an airplane as a hull loss if the aircraft is missing, if the wreckage has not been found and the search has been terminated, or if the aircraft is substantially damaged and is inaccessible.

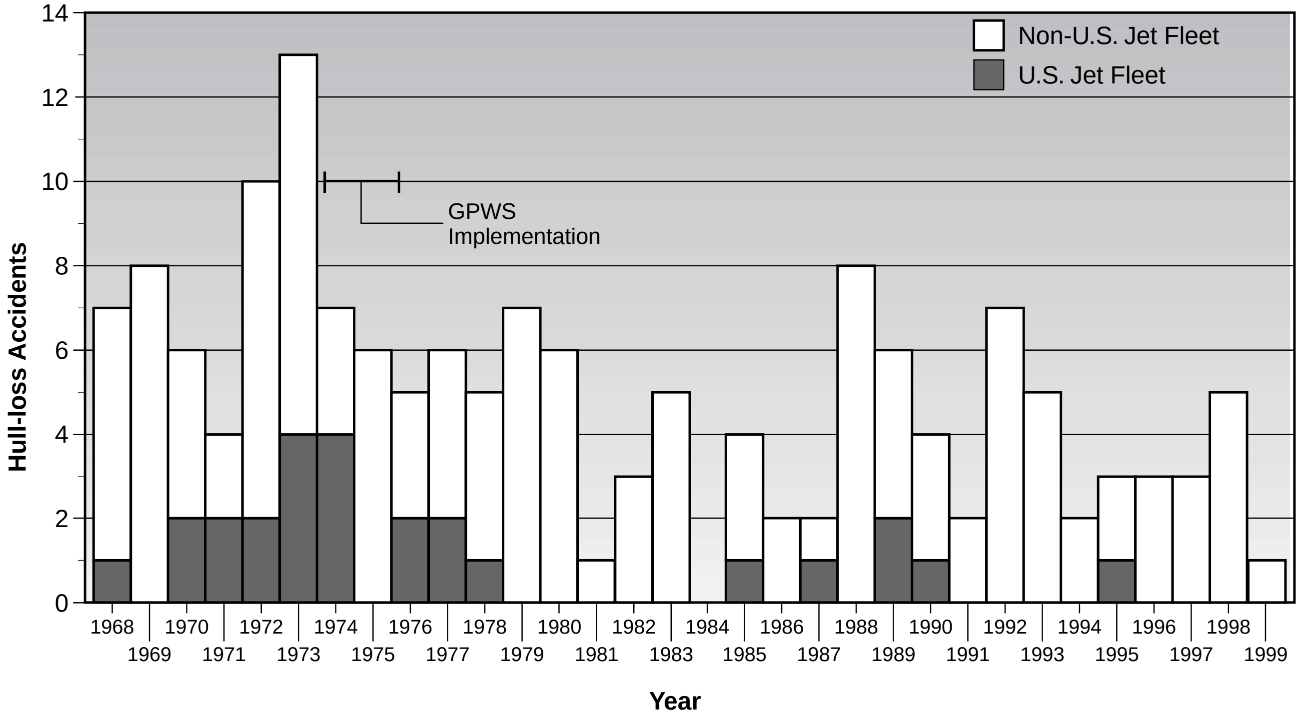
Flight Safety Foundation defines a CFIT accident as one that occurs when an airworthy aircraft under the control of the flight crew is flown unintentionally into terrain, obstacles or water, usually with no prior awareness by the crew. This type of accident can occur during most phases of flight, but CFIT is more common during the approach-and-landing phases, which typically comprise about 16 percent of the average flight duration of a large commercial jet.

Boeing's definition differs slightly and describes a CFIT accident as "an event where a mechanically normally functioning airplane is inadvertently flown into the ground, water or an obstacle (not on airport property while attempting to land)."

The Boeing data include worldwide commercial jet airplanes that are heavier than 60,000 pounds maximum gross weight; the data exclude airplanes manufactured in the Commonwealth of Independent States, because of a lack of operational data, and commercial airplanes that are used in military service.

The five CFIT hull-loss accidents on Boeing's list for 1998 were:

- An Iran Air Fokker 100 that struck desert terrain Jan. 5 in Isfahan, Iran. There were no fatalities;



Hull Losses Resulting from Controlled-flight-into-terrain Accidents

Note: Data are for commercial jet airplanes with maximum gross weights of more than 60,000 pounds (27,216 kilograms), excluding airplanes manufactured in the Commonwealth of Independent States and airplanes used in military service.

GPWS = Ground-proximity warning system

Source: The Boeing Co.

Figure 1

- A Cebu Pacific Air McDonnell Douglas DC-9 that struck a mountain Feb. 2 in Cagayan de Oro, Philippines. The accident killed all 104 people in the airplane;

- An Ariana Afghan Airlines B-727 that struck a mountain March 19 near Kabul, Afghanistan. The accident killed all 45 people in the airplane;

- A Tame B-727 that struck a mountain April 20 near Bogota, Colombia. The accident killed all 53 people in the airplane; and,

- A Paukn Air British Aerospace BAe 146 that struck a hill Sept. 25 in Melilla, Morocco. The accident killed all 38 people in the airplane.

The CFIT accident in which the airplane was substantially damaged involved an Azerbaijan Airlines B-727 that struck an electrical pylon while on a go-around at the airport in Baku, Azerbaijan, on Dec. 10. The airplane subsequently was landed, and none of the 72 people on board was injured.

Besides the six CFIT accidents, 39 other commercial jet accidents occurred in 1998, including nine other hull-loss accidents, 29 accidents in which damage was substantial and one accident in which damage was minor, Boeing said.

The two 1998 accidents not classified by Boeing as hull-loss CFIT accidents but placed in that category in the data compiled by Bateman were:

- An American Airlines B-727 that touched down 200 feet (61 meters) short of a runway at O'Hare International Airport in Chicago, Illinois, U.S., on Feb. 9. (Boeing classified the accident as a landing accident rather than a CFIT accident.) None of the 121 people in the airplane was injured; and,

- A Peruvian Air Force Boeing 737 operating as a charter flight on behalf of Occidental Peruana that struck the ground during an approach about five kilometers (three miles) from a runway near Andoas, Peru, on May 5. (Boeing's data did not include the accident because it involved a military aircraft flown by a military crew.) The accident killed 75 people in the airplane; the other 13 people on board were injured.♦

FAA Publishes Guidelines For Aircraft Data Communications Systems

Advisory circular outlines standards developed in cooperation with international civil aviation authorities.

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Advisory Circulars

Guidelines for Design Approval of Aircraft Data Communications Systems. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 20-140. Aug. 16, 1999. 20 pp. Available through GPO.*

This AC is issued to support the introduction of data communications applications for air traffic services. The International Civil Aviation Organization (ICAO) intends to use data communications applications to implement the communication, navigation and surveillance concepts that describe the future air navigation system. This AC provides guidelines for design approval of aircraft data communications systems and applications used primarily for air traffic services. These guidelines outline a method of compliance with airworthiness standards contained in the U.S. Federal Aviation Regulations (FARs) and will ensure standardization among the aircraft certification offices when assessing aircraft data communications systems and applications for design approval. This AC was developed in consideration of ICAO standards and recommended practices and in cooperation with international civil aviation authorities.

Appendix 5 of this AC contains a comment form to allow aircraft certification offices and other users to offer comments during the use of this AC. [Adapted from AC.]

Announcement of Availability: FAA Certificated Air Carriers Directory. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 135-13G. Aug. 12, 1999. 1 p. Available through GPO.*

This FAA AC announces the availability of AC 135-13G, *FAA Certificated Air Carriers Directory*. The air carriers are certificated under the provisions of the U.S. Federal Aviation Regulations Part 135. The list is current as of May 18, 1999. [Adapted from AC.]

Reports

Air Traffic Control Specialist Age and Cognitive Test Performance. Heil, Michael C. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine. Report DOT/FAA/AM-99/23. August 1999. 20 pp. Available through NTIS.**

Keywords:
1. Air Traffic Control Specialist
2. Age
3. Personnel Selection
4. Cognitive Abilities

The effect of air traffic control specialists' age on their job performance has been studied extensively during the past three decades. This research consistently has found that, as air traffic controllers get older, their training success ratings and job performance ratings decline. The purpose of the study was to investigate the relationship between age and performance on tests of cognitive ability for air traffic controllers. A total of 1,083 air traffic controllers from 12 air route traffic control centers participated in the study. Tests were administered to measure knowledge, skills, abilities and other characteristics relevant to providing air traffic control services. Results supported the hypothesis that declines in performance may be associated with age-related declines in cognitive ability and processing speed. [Adapted from Introduction and Discussion.]

Books

A Passenger's Guide to Airline Flying. Coy, Larry. Raleigh, North Carolina, U.S.: Pentland Press, 1998. 146 pp.

The author, a retired airline captain, draws on his more than 40 years of flying experience to help passengers understand airplanes, pilots, airports, flight attendants and other factors involved in flight on modern commercial airplanes. Using descriptions, personal narratives and humor, he answers the more serious questions about today's airplanes and explains how in-flight meals are prepared and why large airplanes are capable of flying on one engine.

Contains a glossary of technical terms. [Adapted from Introduction.]

Aviation & Aerospace Abbreviations, Acronyms and Glossary 1999. Lampl, Richard, Executive Editor. Washington, D.C., U.S.: *Aviation Week*, 1999. 128 pp.

This reference work combines definitions selected by the editors of *Aerospace Daily* and *Aviation Daily* from lists originated by the U.S. Department of Transportation, the U.S. National Aeronautics and Space Administration, the U.S. Department of Defense, aviation associations and aircraft manufacturers. The book contains terms covering basic principles of air traffic control, flight regulations, U.S. Federal Aviation Administration rules and aircraft engineering. International aeronautical definitions and astronomical terms also are included. More than 2,200 abbreviations and acronyms are included, and the glossary contains more than 1,100 terms. [Adapted from Introduction.]♦

Sources

* Superintendent of Documents
U.S. Government Printing Office (GPO)
Washington, DC 20402 U.S.

** National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161 U.S.
+1(703) 487-4600

Updated U.S. Federal Aviation Administration (FAA) Regulations and Reference Materials

Advisory Circulars (ACs)

AC No.	Date	Title
25-7A	June 3, 1999	*Change 1: Flight Test Guide for Certification of Transport Category Airplanes.*
120-28B	July 13, 1999	*Criteria for Approval of Category III Weather Minima for Takeoff, Landing, and Rollout.* (Cancels AC 120-28C, *Criteria for Approval of Category III Landing Weather Minima*, dated March 9, 1984, and AC 20-57A, *Automatic Landing Systems (ALS)*, dated Jan. 12, 1971.)
65-25B	Aug. 26, 1999	*Aviation Maintenance Technician Awards Program*. (Cancels AC 65-25A, *Aviation Maintenance Technician Awards Program*, dated Nov. 6, 1993.)

International Reference Updates

Joint Aviation Authorities (JAA)

Date	
Oct. 1, 1999	Revision to JAA Administrative and Guidance Material, Section One: General Guidance and Reference Material.
Oct. 1, 1999	Revision to JAA Administrative and Guidance Material, Section Two: Maintenance.
Oct. 1, 1999	Revision to JAA Administrative and Guidance Material, Section Three: Certification.
Oct. 1, 1999	Revision to JAA Administrative and Guidance Material, Section Four: Operations.

Aeronautical Information Publication (A.I.P.) Canada

Amendment No.	Date	
4/99	Oct. 7, 1999	Updates the General, Communications, Meteorology, Rules of the Air and Air Traffic Services, Search and Rescue, Aeronautical Charts and Publications, Licensing, Registration and Airworthiness, and Airmanship sections of the A.I.P.

Accident/Incident Briefs

Boeing 727 Strikes Runway During Missed Approach

Airplane was not aligned with runway after descending below decision height. Right main landing gear touched the runway after the captain commanded a go-around.

FSF Editorial Staff

The following information provides an awareness of problems through which such occurrences may be prevented in the future. Accident/incident briefs are based on preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be entirely accurate.

Air Carrier

Aircraft Damaged on Approach in Instrument Meteorological Conditions

Boeing 727. Minor damage. No injuries.

Instrument meteorological conditions prevailed at an airport in the United States as the pilots conducted an instrument landing system (ILS) approach with the autopilot engaged. The flight engineer called the approach lights "in sight," and the pilots continued the approach below decision height. As the descent continued, the pilots decided that the airplane was not aligned properly with the runway centerline, and the captain called for a go-around. They felt the right main landing gear touch the runway, but the go-around was otherwise uneventful, the report said. A second ILS approach also ended in a go-around. On the third approach, the pilots landed the airplane.

A subsequent examination of the aircraft revealed damage on the outer part of the outboard leading edge slat of the right wing, the right wing logo light, the right wing outer jackscrew fairing and the trailing edge outboard flap.

Misplaced Clipboard Cited in Loss of Steering

Boeing 767. No damage. No injuries.

The first officer was positioning the airplane on the runway at an airport in Japan in preparation for takeoff when the steering tiller stuck. The first officer applied full right rudder, but the aircraft continued to turn left. The captain took the controls, and he also was unable to move the tiller, so he stopped the aircraft.

The first officer said, "As I regained a measure of composure, I looked over the tiller and found that the tip of a [small] clipboard was [stuck] in it. I had casually left the clipboard alongside a Jeppesen chart on my flight bag. The board somehow found its way into the tiller."

The clipboard was removed, and the pilots proceeded with the takeoff.

Stuck Flaps Blamed for Flight Delay

McDonnell Douglas MD-11. No damage. No injuries.

The airplane had just departed from an airport in Switzerland when the pilots attempted to retract the wing flaps, which had been extended for takeoff. The flaps failed to retract, and the pilots returned to the airport for an uneventful landing about one hour after their departure. The problem was corrected, and the airplane took off again.

Aircraft Led Astray By 'Follow-Me' Vehicle

Fokker 27. No damage. No injuries.

Night instrument meteorological conditions prevailed when the crew, which was about to begin the final segment of a three-segment flight, obtained clearance about 0100 local time to taxi behind a "follow-me" vehicle to the runway at an airport in England.

Construction was under way in the maneuvering area, and the pilot decided that the "follow-me" vehicle was traveling too fast. Distance between the aircraft and the vehicle increased to about 165 feet (50 meters), and at that point, the vehicle stopped momentarily and then drove out of sight. The pilot followed the wheel tracks left by the vehicle, and the left main landing gear stuck in soft ground. The pilot notified air traffic control and shut down the engines.

There were no lights or edge markings to indicate the end of the maneuvering area, and the soft ground had been covered with a thin layer of asphalt. Photographs showed that the "follow-me" vehicle had been driven across the asphalt, which supported its weight.

Air Taxi Commuter

Aircraft Vibration Traced to Faulty Microswitch

British Aerospace ATP. Minor damage. One serious injury; three minor injuries.

After a routine flight from one airport in England to another, the airplane touched down with a 13-knot, 60-degree right crosswind. The first officer, who had been flying, turned over control of the airplane to the captain. (The left-seat pilot taxis this type of aircraft, because the right-seat pilot has no nosewheel steering tiller and because the steering system is not connected to the rudder pedals.)

The rollout continued normally for several seconds, but then the airplane began to vibrate. The vibration, which lasted about 15 seconds, was severe enough to send objects on the flight deck into the air and to open some overhead lockers. As the captain tried to steer the airplane toward a runway exit, he lost nosewheel steering authority, and the nose landing gear collapsed. The 58 passengers evacuated the aircraft using all doors except the forward door slide, which did not inflate. One passenger was injured when he jumped off a wing, and three other passengers received minor cuts and bruises; the rest of the passengers and the four crewmembers were not injured.

An examination of the aircraft revealed that the nose gear pintle mounting structure had been torn from the nose gear bay. The nosewheel tires had left a chevron pattern along 820 feet (250 meters) of the runway, and the marks were typical of those caused by torsional oscillation of the nose leg, the report said. A subsequent examination of the failed pintle mounting structure revealed no evidence of previous damage and concluded that "the failure of the various structural elements occurred due to pure overload with no direct indications of load cycling."

Further inspection revealed two broken steering cables between the steering tiller and the landing gear leg. Inspectors theorized that one cable or both cables had broken before or during the landing roll and that the break may have caused the shimmy, the report said. The incident also prompted the aircraft manufacturer to require a fleet-wide inspection of the cables.

Later tests revealed that the steering compensator's leak rate was out of limits "by a considerable margin" and that excess moisture and resulting corrosion — probably the result of a damaged "O" ring seal — had caused the apparent failure of a landing gear microswitch. The apparent microswitch failure deprived the steering system of main hydraulic system pressure.

As a result of the investigators' findings, British Aerospace told all ATP operators to replace nosewheel landing gear weight-on-wheels microswitches by December 1998 and to replace them again after four years. The possibility of substituting a different type of microswitch was under investigation.

Engine Failure Prompts Emergency Landing on Beach

Britten-Norman Trislander. No damage. No injuries.

The aircraft had been refueled, bringing the total fuel on board to 575 pounds (261 kilograms), for the fifth flight of the morning between two airports in England, all flown by the same pilot. There were 16 passengers on the airplane, and the pilot signed a load manifest. A handling agent's mathematical error resulted in the airplane leaving the ramp weighing 51 pounds (23 kilograms) more than its maximum takeoff weight of 10,500 pounds (4,763 kilograms). The takeoff and initial climb appeared to be normal, but when the airplane reached 200 feet, the pilot determined that the left engine had failed.

The pilot feathered the propeller on that engine, increased to maximum power on the other two engines and adjusted the airplane's pitch attitude to maintain 80 knots, the speed recommended after an engine shutdown. The pilot then landed the airplane on a beach, and the passengers were evacuated without injury. The aircraft was not damaged.

Flight tests conducted on the operator's fleet of Trislanders two years before the incident had determined that, at maximum takeoff weight under these conditions, the aircraft should have climbed at 140 feet per minute (FPM) to 160 FPM. In a similar test conducted after the incident using the incident aircraft, the rate of climb was 120 FPM.

The pilot recently had been hired by the company and had completed training less than one month before the incident. During training, simulated engine failures were practiced but not at maximum takeoff weight. Training procedures have been revised to add a phase of training with the aircraft carrying ballast to simulate operations at "realistic weights," the report said.

The report said that the aircraft overloading error was too small to have affected the airplane's overall performance; nevertheless, the operator changed procedures to require the pilot to verify the handling agent's weight-and-balance calculations.

Corporate
Business

Truck Cited in Collision With Airplane on Taxiway

Beech C90A King Air. Substantial damage. Two minor injuries.

The pilot was following taxi instructions from the ramp to the runway at an airport in the United States. As the airplane came to a taxiway intersection, an airline's lavatory service truck struck the airplane's right engine and right propeller. The impact pushed the airplane about 10 feet (3 meters) off the runway centerline. Airport law enforcement authorities issued a citation to the driver of the truck for failing to give way to the aircraft.

Approach Ends in Gear-up Landing

Learjet 31. Airplane destroyed. No injuries.

Visibility was restricted because of haze as the pilot flew an approach to an airport in the United States. The airplane was high and fast on final approach, and the pilot executed a go-around.

Neither the pilot nor the copilot recalled retracting the landing gear, and the pilot said that, in the second approach, he did not extend the gear because he was sure that it was already down. The airplane landed with the gear retracted and slid about 3,000 feet (915 meters). A fire began under the right wing root and could not be extinguished with hand-held fire extinguishers. The pilots evacuated the airplane safely.

Airplane's Fuel Tanks Found Empty After Off-airport Landing

Cessna 425. Substantial damage. One minor injury.

During his preflight inspection at an airport in the United States, the pilot noticed a discrepancy between his requested fuel load and the reading on the airplane's fuel-quantity gauges. He based his flight planning for a multiple-leg flight on his decision that the right fuel-quantity gauge was accurate and that the left fuel-quantity gauge was inaccurate.

Later, at another airport, he decided — based on the reading on the right fuel-quantity gauge — not to refuel before beginning his return flight. About 50 miles (80 kilometers) from the destination airport, the left low-fuel-quantity light and the right low-fuel-quantity light illuminated; the right fuel-quantity gauge indicated that the tank held 390 pounds (177 kilograms) of fuel. The pilot continued to his destination until both engines lost power, then he landed the airplane in an open school field. The left wing struck football-training equipment, and the outboard four feet of the wing separated from the airplane. One of the airplane's eight occupants received minor injuries; the others were not injured.

A subsequent investigation found no fuel in the main fuel tanks, the collector tanks, the fuel lines or the filters. The left fuel-quantity gauge indicated "0," and the right fuel-quantity gauge indicated that the right fuel tank held 290 pounds (132 kilograms) of fuel.

Other
General
Aviation

Contaminated Fuel Blamed for Fatal Accident

Fairchild M-62A Cornell. Airplane destroyed. One fatality; one serious injury.

Visual meteorological conditions prevailed for the flight from an airport in England to the farm airstrip where the airplane was based. The pilot performed a preflight inspection and a run-up. During the run-up, an aircraft engineer who was standing nearby noticed a light haze emanating from the engine exhaust. The subsequent takeoff and the earliest stages of the climb-out appeared to be normal, but when the airplane reached about 150 feet, the engine began misfiring, dark smoke appeared from the engine exhaust system and there was a reduction in power. A radio operator on the ground asked the pilot twice if there was a problem, "and the pilot eventually responded by saying words to the effect of 'Stand by; I'm busy.'"

The sole passenger said that the pilot had initiated a left turn and that the pilot had told him that they would return to the airport. Soon afterward, the engine stopped, and the aircraft began descending, apparently entering an incipient spin at less than 100 feet above ground level.

The pilot was killed and the passenger was seriously injured in the accident, which destroyed the airplane.

The passenger later said that, when he arrived at the farm airstrip for the flight to the larger airport, he saw several empty fuel cans near the aircraft. The pilot generally bought fuel for the aircraft from a local motor vehicle service station, but he used aviation-grade gasoline (avgas) when he flew into airports where it was available.

An investigation revealed combustion deposits in two engine cylinders. The report said, "The use of motor fuel, with its high volatility relative to avgas, could have increased the vulnerability of the fuel lines to vapor lock." The report cited a similar incident, in which the aircraft's engine lost power and then recovered, noting, "On both occasions, the aircraft had flown earlier in the day and had then been parked in warm sunshine for a few hours before taking off again, with the loss of power occurring shortly after takeoff. … These vapor bubbles may have been interspersed with liquid fuel, which could have caused the observed puffs of smoke from the exhaust due to the … unstable running conditions."

Pilot Fails in Attempt to Patch Punctured Float with Rags

Cessna A185F. Substantial damage. No injuries.

The amphibious-float-equipped airplane had been flown to a lake in Canada on a fishing trip. While taxiing to shore, one of the airplane's floats was punctured. The pilot tried to patch the puncture hole with rags and planned to fly to a nearby airport for more permanent repairs. As the pilot attempted to depart from the lake, he applied full engine power, but the aircraft slowed and sank into the water. The pilot, who was the only occupant of the airplane, was not injured. A salvage team was called to recover the aircraft.

Unchocked, Hand-propped Airplane Rolls Without a Pilot

Piper J3C-65 Cub. Minor damage. No injuries.

The pilot forgot to load the airplane's wheel chocks before departing from an airport in England for a farm airstrip. When he was ready to leave, he hand-propped the airplane, and when the engine started, the aircraft moved forward. The pilot tried to reach into the cockpit to turn off the magnetos, but he tripped and fell. The aircraft continued across the airstrip, coming to a halt when it struck a fence.

"The pilot considered that the cause of the incident was his decision to start the engine while the aircraft was parked on a hard surface with the wheels unchocked," the report said.

Investigators Focus on Training of Pilot for Sheep-mustering Flights

Cessna A150M. Airplane destroyed. One fatality.

The pilot was working with a ground crew in a sheep-mustering (sheep-herding) operation in Australia. One member of the ground crew said that the pilot flew the aircraft about 80 feet to 100 feet above ground level and then turned sharply to the right. During the turn, the aircraft descended, struck the ground and burned. The airplane was destroyed, and the pilot was killed.

There was no indication of any mechanical problem with the airplane before the accident. An investigation disclosed that about two months before the accident, the pilot's employer had arranged for the pilot to receive training for an aerial stock-mustering endorsement. The firm that conducted the training told the pilot's employer that only the low-flight portion of training had been completed and that the mustering training could not be conducted. The report said that the low-flying approval certificate issued by the training firm might have been inappropriate "because it was not derived from the [Civil Aviation Order] current at the time." The certificate made no mention of stock-mustering training.

The report said that the cause of the airplane's descent could not be determined, and an investigation was continuing into aspects of the pilot's license, training and employment.

Rotorcraft

Loss of Power Lands Helicopter in Lake

Robinson R44. Substantial damage. No injuries.

The aircraft took off from an airport in Canada on a midmorning flight to conduct a survey of moose and aquatic wildlife. The pilot flew two passengers to an exploration camp and landed on a pad there, then lifted off into a hover and began to hover-taxi backward. Main-rotor revolutions per minute decayed, and the pilot was unable to hover-taxi back to the pad, the report said. Instead, he maneuvered the aircraft over downsloping terrain to the lake. The helicopter came to rest in the lake, with only its main-rotor blades above the water. The pilot and the two passengers left the helicopter without injuries.

Pilot Cites Airframe Vibration in Helicopter Accident

Robinson R22. Helicopter destroyed. Two serious injuries.

The flight instructor and the commercial-rated student pilot had departed from an airport in the United States for an instructional flight in visual meteorological conditions. The instructor said that he was demonstrating a 180-degree autorotation and had begun the maneuver at an altitude of 500 feet and an airspeed of 60 knots.

"He then lowered the collective pitch to the full-down position, applied right anti-torque pedal, reduced the throttle to split the needles, adjusted the airspeed to a 60-knot attitude and began a right turn towards his touchdown point," the report said. When the airspeed decreased, he lowered the helicopter's nose, and as the helicopter descended through 100 feet, he began to level the aircraft. With the airspeed at 60 knots and the rotor revolutions in the green arc, the helicopter was descending rapidly and its airframe began to vibrate. The helicopter then struck the ground in a nose-low attitude.

The pilot said that he did not begin a power recovery because of the airframe vibration, which began about three seconds after the helicopter came out of the turn. He also said that the helicopter experienced "very high control forces as he attempted to pull aft cyclic and up collective."

Broken Strut Restricts Flight Controls

Eurocopter AS365N2. Minor damage. No injuries.

As the helicopter climbed away from an offshore satellite in the North Sea, the pilots felt a control restriction. When they manipulated the controls to assess the extent of the restriction, they determined that the cyclic and the collective both were severely restricted and that the helicopter was difficult to control. The pilots decided to land the helicopter at a nearby offshore platform, and as they flew the helicopter toward the platform, the restriction increased. Both pilots were needed to overcome the restriction on the controls to accomplish the landing.

After they shut down the engines, the pilots found that the gas strut at the right rear door was detached at the front end and that the strut had pierced the "nine-degree frame" trim.

"The trim base also forms part of the heater diffuser for the rear of the cabin and has an inner wall, which forms the back of the diffuser box," the report said. "The strut was restrained by the inner wall, which was displaced and had contacted the roll-control rod that is routed in close proximity. Contact pressure was sufficient to impair control harmonization by increasing the friction in the roll-control channel."

Records indicated that a similar incident had occurred about one year earlier. After the second incident, the operator installed a protective plate to prevent the gas strut from piercing the trim panel and planned to take other steps to prevent the door-restraint strut from disconnecting.

Sightseeing Helicopter Loses a Window

Aerospatiale AS350B. Minor damage. No injuries.

The helicopter was on a sightseeing flight, descending over the Grand Canyon National Park in Arizona, United States, when the left-side passenger window separated. The window struck a tail-rotor blade, causing substantial damage. The pilot landed the helicopter without further difficulty, and none of the seven people on board was injured.

The pilot said that he had not detected damage to the window during his preflight inspection, and he had not noticed the passenger seated next to the window leaning on the window during flight. The operator said that the window had been replaced several months earlier and that the helicopter manufacturer was not the manufacturer of the window. The window and its retention gasket (seal) were missing, the report said.♦

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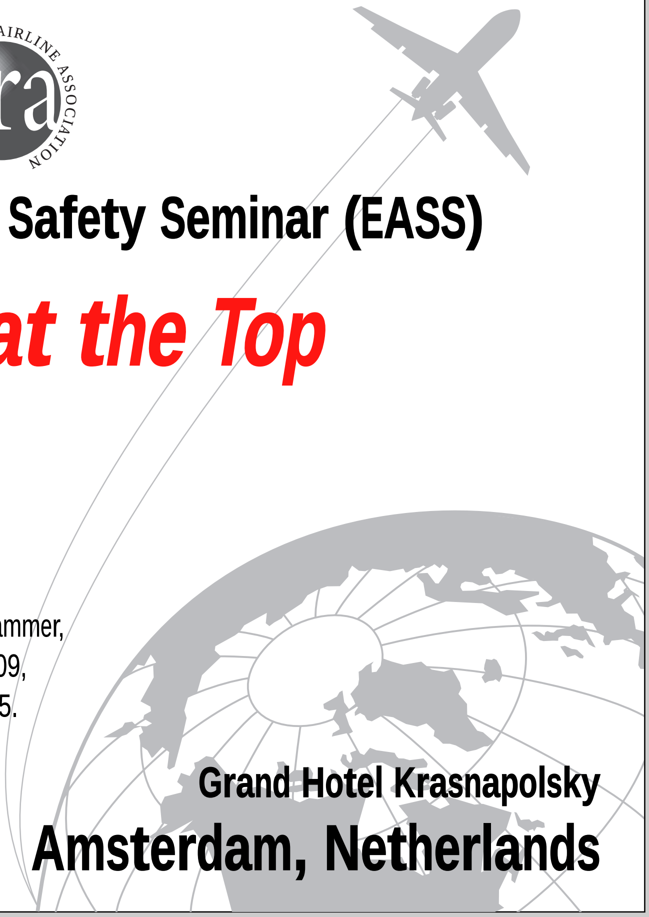

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