FLIGHT SAFETY FOUNDATION

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FLIGHT SAFETY
DIGEST

A Review of Transport Airplane Performance Requirements Might Benefit Safety

PERFORMANCE

JAR 25.101 General (See ACJ 25.101)

(a) Unless otherwise prescribed, aeroplanes must meet the applicable performance requirements of this Subpart for ambient atmospheric conditions and still air.

(b) The performance, as affected by engine power or thrust, must be based on the following relative humidities:

(1) 80%, at and below standard temperatures; and

(2) 34%, at and above standard temperatures plus 50°F.

Between these two temperatures, the relative humidity must vary linearly.

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§ 25.101 General

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(b) The performance, as affected by engine power or thrust, must be based on the following relative humidities:

(1) For turbine engine powered airplanes, a relative humidity of—

(i) 80 percent, at and below standard temperatures; and

(ii) 34 percent, at and above standard temperatures plus 50 degrees F.

Between these two temperatures, the relative humidity must vary linearly.

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In This Issue

About the cover: Transport airplane certification performance requirements are contained in European Joint Aviation Requirements (JARs) 25 and in U.S. Federal Aviation Regulations Part 25. (Illustration by FSF Production Staff)

Flight Safety Foundation is an international membership organization dedicated to the continuous improvement of aviation safety. Nonprofit and independent, the Foundation was launched officially 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.

A Review of Transport Airplane Performance Requirements Might Benefit Safety

Most current performance requirements for the certification and operation of transport category airplanes were established at the beginning of the jet age. Today, operating experience and data provide the most accurate means to further improve the performance requirements of modern transport airplanes.

Joop H. Wagenmakers

The performance requirements of U.S. Federal Aviation Regulations (FARs) Part 25[1] and European Joint Airworthiness Requirements (JARs) 25[2] have a substantial effect on the design, operating economy and safety of transport category airplanes.

Performance requirements are minimum standards that must be met during airplane certification and operation. The requirements affect variables such as stall speeds, takeoff and landing speeds, takeoff and landing distances, climb gradients, etc. The performance requirements determine, for example, the permissible takeoff weight for conditions that include runway length, obstacles, field elevation and air temperature, thereby setting the airplane's payload and range. Airplane design features and specific airplane operating procedures usually are optimized by airframe manufacturers within the constraints of the performance requirements.

The performance requirements have evolved from rudimentary standards established before World War II to relatively comprehensive standards that are similar in the United States and in Europe (see " Summary of Transport Category Turbine Airplane Performance Standards and Operating Standards," page 10).

Most of the currently applicable performance requirements were established in the late 1950s, at the beginning of the large-scale introduction of turbine airplanes into commercial service. In the period since the current performance requirements and operating requirements for turbine-engine transport airplanes were adopted, considerable operational experience has been gained, and significant improvements have occurred, for example, in engines, airplane systems, maintenance procedures and runway surfaces. Moreover, the minimum operating safety level that the industry, the regulators and the public currently regard as acceptable is higher than it was in the 1950s.

The industry might be resistant to change current performance requirements, which are working reasonably well. Nevertheless, the industry should consider the long-term benefits to safety and to operating economy that could be derived from a review to fine-tune the performance requirements.

Jet Age Brings Changes

The transport airplane performance requirements in U.S. Civil Air Regulations (CARs) Part 4b[3] were applied during the certification of the Convair 240 and 340; the Douglas DC-4, DC-6 and DC-7; the Lockheed Constellation series; and other U.S. reciprocating-engine airplanes that transported most passengers and cargo during the 20 years after World War II. The performance requirements in CARs 4b and the performance requirements established by the United Kingdom also were used to certify transport airplanes designed and built in many other countries.

These performance requirements were unsuitable for certifying jet aircraft. Work to revise the performance requirements was conducted initially in the United Kingdom, and the work was continued by the International Civil Aviation Organization (ICAO) Standing Committee on Performance (SCP). Many of the SCP's ideas[4] were used in the development of FARs 25 and JARs 25.

The statistical database used in the SCP studies now is outdated, and experience in the past 40 years with the operation of turbine-engine transport aircraft has taught the aviation community many lessons.

Lessons Learned from Accidents

The investigations of many performance-related airplane accidents in the late 1940s revealed that the unreliability of some engines was a major factor in the accidents.

Another major factor involved in accidents during the period was performance degradation caused by high outside air temperature. Adjustment of takeoff weight to compensate for performance degradation caused by high temperature was not required then, because regulators and manufacturers believed that the performance requirements included margins adequate to compensate for performance losses caused by temperature.

The accidents showed the need to correct for the effects of high temperature. A requirement for *temperature accountability* was added to CARs 4b in the early 1950s. The rule required manufacturers to determine the effects of all expected operating temperatures on airplane aerodynamic characteristics and on engine power, and to include in the airplane flight manual (AFM) correction factors for airplane operating weight and takeoff distances.

Rather than requiring full temperature accountability, however, CARs 4b.117 said, "The operating correction factors for the airplane weight and takeoff distance shall be at least one-half of the full [temperature] accountability values."

A requirement for *humidity accountability* subsequently was added to CARs 4b. Humidity has a significant adverse effect on the achievable takeoff power of a reciprocating engine operating at a rich mixture — such as during takeoff and landing. As humidity (water vapor in the air) increases, there is a decrease in the oxygen available for combustion. Humidity significantly reduces power output from a reciprocating engine, which uses all intake air in the combustion process; the effect of humidity is insignificant for a jet engine, which uses only a portion of intake air for combustion.

Some reciprocating-engine airplanes that were certified to CARs 4b requirements, including the temperature-accountability requirement and the humidity-accountability requirement, remain in operation today. The airplanes include Constellations, DC-4s and DC-6s. Today, operating requirements for reciprocating-engine airplanes are in FARs 121.175 through 121.187, and are in the JARs commercial-airplane-operating requirements (JAR–OPS 1).

CARs 4a, the U.S. certification requirements adopted in 1950 for normal, acrobatic and transport category airplanes, specified a maximum stall speed.[5] The premise for the maximum-stall-speed requirement was that airplanes with higher stall speeds — thus, higher takeoff speeds and higher landing speeds — would have longer takeoff distances and longer landing distances, and would have a greater risk of an accident during takeoff or landing. This premise is the basis for the 61-knot maximum stall speed incorporated in FARs 23 and JARs 23, the certification standards for normal, utility, acrobatic and commuter category airplanes.

CARs 4b, which in 1953 superseded the CARs 4a certification requirements for transport category airplanes, did not specify maximum stall speeds. CARs 4b, however, retained minimum-climb-performance requirements that caused airplane manufacturers to use relatively low stall speeds when optimizing their designs. The minimum-climb-performance requirements were expressed as: *required rate of climb = constant x (stall speed)*^{2}. Different values for the constant were specified for different airplane configurations and phases of flight.

Some ICAO delegates in the early 1950s said that the rate-of-climb requirements were not suitable for jet airplanes, and they recommended a review of the climb-performance requirements. Climb-gradient requirements were regarded as more appropriate and logical, because climb-gradient requirements would ensure that specific heights would be reached at given distances.[6]

To prepare for the large-scale introduction of turbine-powered airplanes, the United Kingdom developed *rational* (statistically founded) performance requirements. This approach was adopted by the ICAO SCP.

The SCP final report in 1953 included proposed amendments to the transport-airplane performance requirements in ICAO Annex 6[7] and ICAO Annex 8[8]. ICAO adopted Annex 6 and Annex 8 in 1949.

Between 1958 and 1960, the United States adopted Special Regulations 422, 422A and 422B, which established new standards for the performance certification of turbine-powered airplanes. The special regulations were incorporated later in FARs 25 and in the associated operating rules, including FARs 121.

The ICAO Airworthiness Committee was established in the late 1950s as an international forum for the discussion of airplane-performance issues. The committee comprised representatives from several countries and international organizations such as the International Air Transport

Association, the International Federation of Air Line Pilots' Associations and the International Coordinating Council of Aerospace Industries Associations. Conclusions and recommendations of the ICAO Airworthiness Committee were published in Section 1 of the ICAO *Airworthiness Technical Manual*, a noncompulsory guidance document.[9]

In the 1960s, France, the United Kingdom and the United States began designing supersonic transport airplanes. A task group from these countries developed a separate set of performance-certification requirements for supersonic airplanes, and the Aerospatiale/British Aerospace Concorde was certified to these standards.

Joint European Standards Established

Minor differences between U.K. certification criteria and U.S. certification criteria necessitated the establishment of special conditions for certification of transport airplanes and resulted in significant re-certification costs for manufacturers. In 1970, several European countries began working together to develop the JARs. JARs 25 is similar to FARs 25, except for some changes that were essential to the Europeans. Other JARs affecting transport-airplane certification include JARs 33 (engines) and JARs AWO (all-weather operations).

In 1990, the JARs 25 development initiative led to the creation of the Joint Aviation Authorities (JAA), which operates in association with the European Civil Aviation Conference.

JARs 25 performance requirements (mainly JARs 25 Subpart B) have been developed by the JAA Flight Study Group, which consists of representatives of the JAA member countries, The European Association of Aerospace Industries, the Association of European Airlines and Europilote (a pilots' association).

JAA representatives and U.S. Federal Aviation Administration (FAA) representatives participate each year in a JARs/FARs harmonization conference to coordinate transport category airplane certification and operating requirements.

In June 1998, European Union transport ministers agreed to establish the European Aviation Safety Agency (EASA), which might, among other things, supersede JAA's responsibilities for aircraft certification and create a legal framework that will require all EASA countries to comply with the certification requirements.

SCP Report Sets Good Example

The final report by the SCP in 1953 includes substantial documentation and could serve as a useful example for conducting a new review of performance requirements.

The work performed by the SCP was based on the following principles established by the committee in 1951:

- "That in each flight stage, it is possible to establish a datum performance below which undesirable conditions exist;
- "That the standards be such that the probability of the performance of an aeroplane falling below values of the datum … does not exceed an agreed numerical value; [and,]
- "That the above standards be determined by a statistical assessment of the performance margins, above the specified datum values, needed to allow for specific contingencies and variations."

The SCP developed mathematical methods and statistical methods to derive airworthiness standards for various phases of flight. The committee also collected data on numerous performance variables for various phases of flight and determined standard deviations.[10] The SCP considered factors such as engine failure and failure of the landing gear to retract. The committee also considered variables such as engine power, thrust, drag and airplane gross weight.

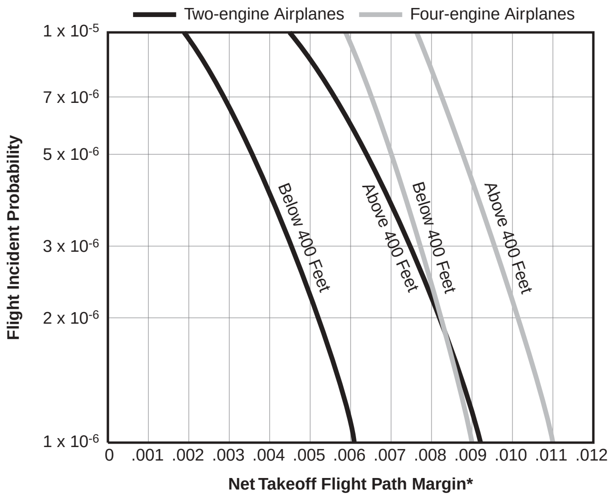
The SCP studies applied the concept of *incident probability* to establish safety objectives. Incident probability was defined as the probability of airplane performance falling below a defined performance datum on any given flight. The performance datum was defined as the minimum performance required under specific conditions — for example, the minimum performance required for an airplane to maintain level flight. The concept does not assume that a flight incident necessarily leads to a performance-related accident, but that the rate of accidents caused by insufficient performance should be significantly lower than the incident probability selected as a target.

Figure 1, page 4, is an adaptation of SCP study results about incident probabilities of twin-engine airplanes and four-engine airplanes. The SCP did not select a target incident probability; the committee presented proposals for two incident probabilities — $2x10^{-6}$ and $7x10^{-6}$ — with the understanding that ICAO subsequently would select a target incident probability.[11]

Over the years, the concept of incident probability and accident probability has been an integral part of transport airplane design analysis.

FARs 25.1309 and JARs 25.1309, for example, require that equipment, systems and installations be designed to ensure that they perform their intended functions under any foreseeable operating condition. Several methods may be used to show compliance with this requirement. Guidance on system-safety analysis, failure-conditions analysis, qualitative assessment and quantitative assessment is provided in FAA Advisory Circular (AC) 25.1309-1A[12] and in JAA Advisory Material–Joint (AMJ) 25.1309.[13]

International Civil Aviation Organization Standing Committee on Performance In-flight Incident Probabilities



* The net takeoff flight path is derived by subtracting performance margins from the one-engine-inoperative flight path demonstrated during certification of takeoff obstacle-clearance performance. The margins correct for factors such as average pilot skill and average airplane performance.

Source: Joop H. Wagenmakers

Figure 1

Figure 2 shows a summary of the terminology and the numerical information that are applied in AC 25.1309-1A and AMJ 25.1309. For reference purposes, a standard deviation scale — based on a normal (Gaussian[14]) single-sided frequency distribution — has been added to the probability scale. Figure 2 shows that the probability of a catastrophic accident[15] caused by a system failure or by a performance problem should be less than 1×10^{-9}, with the unit of risk expressed as a rate of occurrence per flight hour.

Statistically founded performance concepts were applied extensively in the 1980s for the development of airplane performance requirements for extended-range twin-engine operations (ETOPS).[16] The rational performance concepts were used to determine the maximum threshold time (i.e., the maximum diversion time to an en route alternate airport).

ETOPS criteria are compatible with an overall all-causes safety-target probability of 0.3×10^{-6} fatal accidents per flying hour, which corresponds with the JAA-identified rate of fatal accidents among turbine airplanes in a recent six-year period.[17] ETOPS requires that the probability of a catastrophic accident caused by a total thrust loss from independent causes must not be greater than 0.3×10^{-8} per hour.

The ETOPS criteria use the following relationship (originally proposed by the U.K. Civil Aviation Authority) between risk per hour and risk per flight: *risk/flight = (0.6 + 0.4T) x risk/hour* (in which T is the intended flight duration in hours).

Safety Targets Become More Demanding

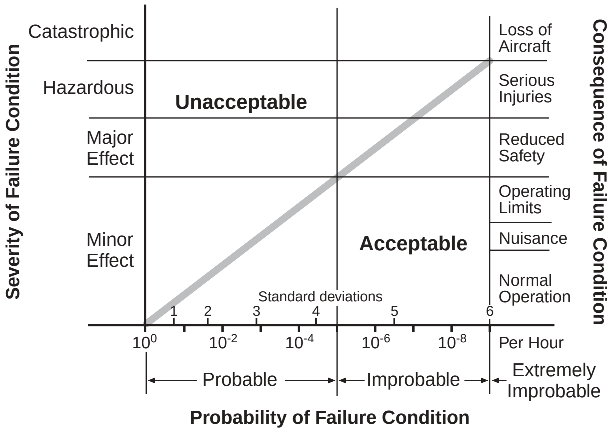
The following summary of performance certification safety targets — all converted to a factor of 10^{-8} for comparison purposes — shows that the current targets are more demanding than the targets established in the 1950s:

- The SCP proposed two incident probability targets, with the understanding that ICAO would adopt one of the targets. The targets proposed by SCP were 200×10^{-8} incidents per flight and 700×10^{-8} incidents per flight. The SCP did not establish an accident probability objective, but an accident probability target one order of magnitude (i.e., a factor of 10) lower than the incident probability target would correspond with approximately 50×10^{-8} accidents per flight;

- AC 25.1309-1A and AMJ 25.1309 said that the probability of a catastrophic accident caused by a system failure or a performance problem should be less than 0.1×10^{-8} per flight hour; and,

- ETOPS established an all-causes accident probability target of 30×10^{-8} accidents per flight hour. The associated probability target for a total loss of thrust from independent causes is 0.3×10^{-8} per flight hour.

U.S., European Certification Guidance For System Design and Analysis*



* Terminology and numerical information are adapted from U.S. Federal Aviation Administration Advisory Circular (AC) 25.1309-1A, *System Design and Analysis,* and Joint Aviation Authorities Advisory Material–Joint (AMJ) 25.1309, *System Design and Analysis.*

Source: Joop H. Wagenmakers

Figure 2

Engine Reliability Improved

The SCP report included data through July 1952 on the failure rates of reciprocating engines installed in 23 types of airplanes that were in operation at that time. Because the Douglas DC-3 fleet had accumulated a disproportionate amount of engine hours and had relatively reliable engines, the report included data for all 23 airplane types and data for 22 airplane types — not including the DC-3 — (Table 1). The data showed a rate of 3.59×10^{-4} engine failures per engine flight hour among the 22 airplane types (excluding the DC-3). This led the SCP to select for its analysis an overall power-loss rate of 3.5×10^{-4}.

The large and complex reciprocating engines that were used in the late 1950s on the Boeing Stratocruiser, Douglas DC-7C and Lockheed Super Constellation were less reliable than the less-complex reciprocating engines used in many airplanes developed in the 1940s and early 1950s and the turbine engines that were used in airplanes developed in the 1960s.

Data from engine manufacturers and data from airplane manufacturers indicate that the rate of in-flight shutdowns (IFSDs) of current turbofan and turboprop engines of mature design is 0.03×10^{-4} engine shutdowns per hour. Thus, modern turbine engines have an IFSD rate that is approximately 10 times lower than the failure rate of the reciprocating engines used in the 1950s.

Engine reliability is a primary concern for ETOPS certification. The safety level of twin-engine airplanes must be equivalent to the safety levels achieved by current three-engine wide-body airplanes and by four-engine wide-body airplanes. To qualify for a threshold time of 120 minutes, a twin-engine airplane must have a demonstrated IFSD rate of less than 0.05 engine shutdowns per 1,000 engine hours (0.05×10^{-3} engine shutdowns per engine hour); to qualify for a threshold time of 180 minutes, a twin-engine airplane must have a demonstrated IFSD rate of less than 0.02 engine shutdowns per 1,000 engine hours (0.02×10^{-3} engine shutdowns per engine hour). Many current turbofan engines comply with these requirements; new engines usually achieve such low rates only after a period of additional in-service development.

One method of reducing IFSD rates is the use of reduced takeoff thrust or derated takeoff thrust, because the temperatures (turbine inlet temperature and exhaust gas temperature) developed in turbine-engine hot sections at maximum takeoff power greatly affect engine reliability. The use of reduced takeoff thrust or derated takeoff thrust significantly improves engine reliability and reduces engine IFSD rates.

The following summary of engine failure and engine IFSD rates (using a factor of 10^{-3}) provides useful comparative data:

- The SCP adopted, based on data for 23 airplane types, an overall reciprocating-engine-failure rate of 0.35×10^{-3} engine failures per flight hour and found that the rate for the DC-3 was 0.09×10^{-3} engine failures per flight hour;
- The current IFSD rate for Western-built turbine engines (turbofan and turboprop) of mature design is approximately 0.03×10^{-3} engine shutdowns per flight hour; and,
- ETOPS certification criteria require engine IFSD rates to be no more than 0.05×10^{-3} engine shutdowns per engine hour to qualify for a 120-minute minimum threshold time, and no more than 0.02×10^{-3} engine shutdowns per engine hour to qualify for a 180-minute minimum threshold time.

Table 1
International Civil Aviation Organization Reported In-flight Engine Failures Among 23 Reciprocating-engine Transport Airplanes Through July 1952*

Airplane Types**	Engine Flight Hours	Engine Failures	Engine Failures per Engine Flight Hour (Rate)
Excluding DC-3 (22 airplane types)	19,152,460	6,869	3.59×10^{-4}
Douglas DC-3	7,405,451	674	0.91×10^{-4}
Including DC-3 (23 airplane types)	26,557,911	7,543	2.84×10^{-4}

* Collection of the engine-failure data began at various times. The International Civil Aviation Organization (ICAO) began collecting engine-failure data in 1949. At that time, ICAO requested contracting states to report all available engine-failure data.

** ICAO identified the airplanes as the Argonaut, B.377, Boeing 314A, Constellation, Convair 240, DC-3, DC-3S, DC-4, DC-6, G Class, Halton, Hermes IV, Hythe, Lancastrian, Liberator, Martin 202, Plymouth, Scandia, Solent Mark III, Solent Mark IV, S.O.161, Viking and York.

Source: Joop H. Wagenmakers, from *Final Report of the Standing Committee on Performance*, Doc. 7401–AIR/OPS/612, International Civil Aviation Organization, Montreal, Canada, August 1953.

Review of Performance Requirements Involves Several Factors

Current airplane weight restrictions result from requirements to meet certain performance criteria and to consider failure cases. These factors should be reviewed and changed as necessary. New criteria and failure cases might have to be considered, and current criteria and failure cases that prove to be insignificant should be disregarded.

The following items also should be considered in a review of the transport-airplane performance requirements:

- *External factors:* Available takeoff distance, accelerate-stop distance, landing distance, runway slope, obstacle data, field elevation, en route terrain profile, pressure altitude, ambient temperature, wind component, runway surface condition and icing are examples of external factors currently used in performance requirements for airplane certification and operation. These factors have a direct effect and a significant effect on takeoff performance, en route performance, landing performance and the associated airplane weight restrictions; thus, these factors probably would remain valid as operational variables in the review of performance requirements. Other external factors that significantly affect safety — and should be considered in the review of performance requirements — include windshear, temperature inversions, icing, volcanic ash, birds and airplane external damage that causes increased drag, reduced lift or errors in instrument indications;

- *Certification criteria and operational criteria:* The following variables should be reviewed to confirm their validity, and changed as necessary: target flying speeds such as V_2 (takeoff safety speed), climb speeds and V_{REF} (reference speed for final approach); factors applied in takeoff-distance calculations and in landing-distance calculations; takeoff screen height; landing threshold height; and obstacle-clearance requirements for takeoff and en route flight[18]; and,

- *Failure cases:* The expected frequencies of failures should be considered in reviewing performance requirements that account for failures of engines, thrust reversers, propeller-feathering systems, propeller-reversing systems, wing flaps and spoilers. Other types of failures, such as tire failure and brake failure, might warrant new performance accountability. A thorough analysis of accidents and incidents might show aircraft or system problems that should be factored into the review of performance requirements.

Over the years, many airplane systems have been introduced with the primary purpose, or with the sole purpose, of improving performance and/or increasing permissible operating weights. Examples include retractable landing gear, wing flaps, slats and propeller autofeather systems. Malfunction of the systems and improper operation of the systems, however, have caused accidents and incidents. Increased system complexity normally is accepted by airplane-certification authorities without any penalty, provided that the basic certification requirements are met. Nevertheless, each system element might present unique reliability risks and crew-error (human factor) risks that should be identified and should be considered in the review of performance requirements.

Rule Changes Can Affect Economy

The review must recognize that relatively minor changes of performance requirements could have significant economic impact. For example, if the second-segment[19] climb-gradient requirement for airplanes with four turbine engines were changed from 3 percent to either 2.9 percent or 3.1 percent, the permissible takeoff weight of a Boeing 747 would increase or decrease by 3,000 kilograms (6,614 pounds), which is approximately equivalent to the weight of 30 passengers and their baggage.

The permissible takeoff weight of an airplane — and, thus, the airplane's payload/range capability — is affected by several factors, including the following:

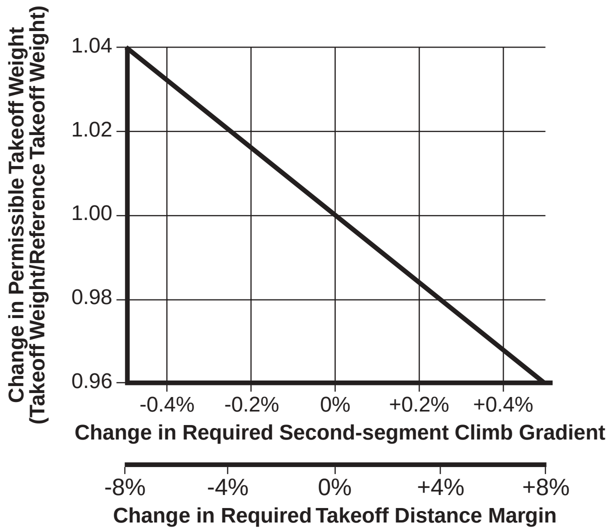
- Available runway length. A variation in runway-length margin of 1 percent results in approximately a 0.5 percent variation in permissible takeoff weight;

- Obstacles in the takeoff flight path area; and,

- Requirements for first-segment climb, second-segment climb and final-segment climb. The second-segment climb requirement usually has the greatest effect on an airplane's permissible takeoff weight. A variation of 0.1 percent in the second-segment climb requirement results in approximately a 0.8 percent variation in permissible takeoff weight (Figure 3, page 7).

Figure 4, page 7 shows the approximate effects of a 4 percent change in the permissible takeoff weight on a typical long-range airplane's payload capability and range capability. The example shows that an airplane with full fuel tanks (i.e., at the typical fuel-tank-capacity limit) and with a reference takeoff weight (RTOW) of 500,000 pounds has a payload capacity of approximately 25,000 pounds (0.05 x RTOW) and a maximum range of approximately 8,100 nautical miles. A 4 percent increase in RTOW (to 520,000 pounds) would result in a payload capacity of approximately 46,800 pounds (0.09 x RTOW) and a maximum range of approximately 7,750 nautical miles. A 4 percent decrease in RTOW (to 480,000 pounds) would result in a payload capacity of approximately 9,600 pounds (0.02 x RTOW) and a maximum range of approximately 8,450 nautical miles. (With the same fuel load, the lighter airplane would have a greater range than the heavier airplane.)

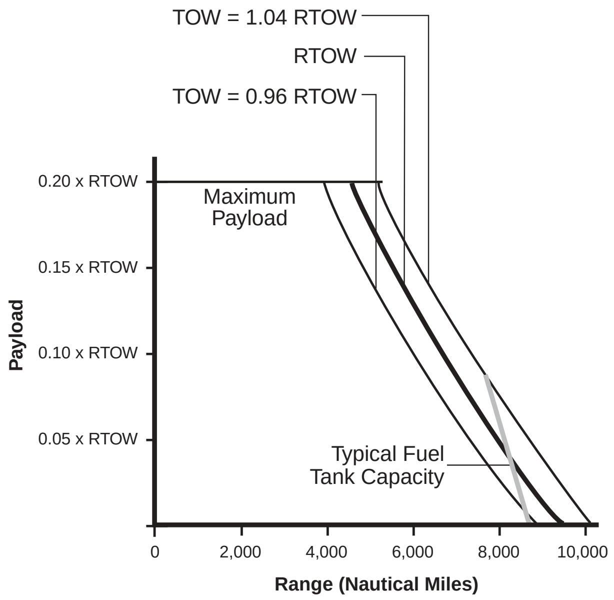
Effect of Change in Required Second-segment Climb Gradient and Required Takeoff Distance Margin on Permissible Takeoff Weight



Source: Joop H. Wagenmakers

Figure 3

Effects of Change in Permissible Takeoff Weight on Payload Capability and Range

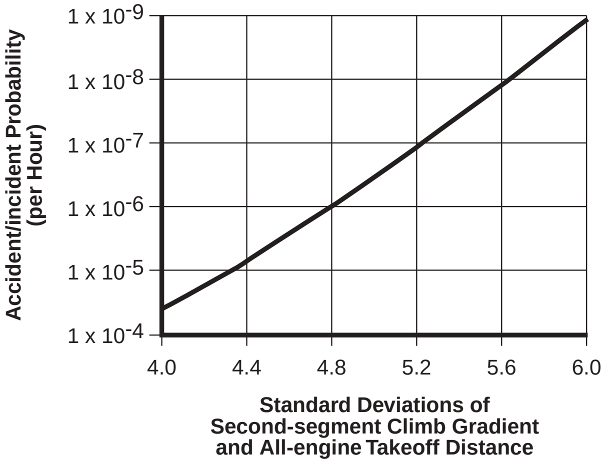


TOW = Takeoff weight RTOW = Reference takeoff weight

Source: Joop H. Wagenmakers

Figure 4

Effect of Variations in Second-segment Climb Gradient and All-engine Takeoff Distance on Accident/incident Probability



Source: Joop H. Wagenmakers

Figure 5

In Figure 5, the standard deviations of two significant performance criteria — all-engine takeoff distance (3 percent) and second-segment climb gradient (0.5 percent)— were derived from various sources. The current all-engine takeoff distance margin is 15 percent, and the required second-segment climb gradients are 2.4 percent for twin-engine airplanes and 3 percent for four-engine airplanes.

Figure 5 shows that in the area of interest on the normal (Gaussian) frequency-distribution curve (probability of occurrence, $1x10^{-5}$ to $1x10^{-9}$), there is an almost linear relationship between accident/incident probability and standard deviations, and that one order of magnitude corresponds with approximately 0.4 standard deviation.

By combining these standard deviations with the data in Figure 3, Figure 4 and Figure 5, and assuming that normal frequency distributions are applicable, mutual relationships are established between variations in safety level in terms of orders of magnitude and various aircraft performance parameters. For the two selected performance criteria — all-engine takeoff distance and second-segment climb gradient — the following are equivalent to a change of one order of magnitude (approximately 0.4 standard deviation):

- All-engine takeoff distance: 1.2 percent of required takeoff distance, 0.6 percent of takeoff weight, 1.8 percent of maximum payload and 100 nautical miles of range; and,
- Second-segment climb gradient: 0.2 percent of required second-segment climb gradient, 1.6 percent of takeoff

weight, 4.8 percent of maximum payload, and 250 nautical miles of range.

Statistical tools such as this enable organizations reviewing the performance requirements to recognize readily the effects of proposed changes. Adjustments of takeoff performance requirements that theoretically increase or decrease the incident/accident probability by one order of magnitude, for example, might have significant economic effects because of the altered payload/range capability of flights. Adjustment of performance requirements in other phases of flight also may affect the capabilities of the airplane.

The experience and the data that have been gained in the 40 years since the current performance requirements for transport airplanes were introduced would enable FAA and JAA study groups — assisted by universities and research institutes, and using new tools such as flight operational quality assurance[20] to capture much more accurate data — to conduct an in-depth review of the performance requirements.

Among the first tasks to be accomplished in the review are the following:[21]

- Validation of an adequate safety level and a justifiable safety level;
- Determination of the extent to which the target safety level has increased;
- Determination of the extent that engine-failure rates have improved;
- Determination — from analysis of accidents and incidents — of any need for failure cases other than engine failure (e.g., tire failure) to be incorporated into the performance requirements; and,
- Identification of any performance requirements that are deficient or that unnecessarily penalize manufacturers or operators, or divert resources from safety improvements.

A review of transport airplane performance requirements would be a major task that would involve a significant amount of statistical work. Nevertheless, the SCP work in the 1950s and the ETOPS developments in the 1980s demonstrate the benefits in safety and operating economy that such work can provide.♦

References and Notes

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3. U.S. Civil Aviation Authority. U.S. Civil Air Regulations (CARs) Part 4b, *Airplane Airworthiness: Transport Categories*.
4. International Civil Aviation Organization (ICAO). *Final Report of the Standing Committee on Performance*, Doc. 7401–AIR/OPS/612, Montreal, Canada, August 1953.
5. CARs Part 4a defined V_{SO} as "the true indicated stalling speed in miles per hour [mph] with engines idling, throttles closed, propellers in low pitch, landing gear extended, flaps in the 'landing position,'… cowl flaps closed, center-of-gravity [c.g.] in the most unfavorable position within the allowable landing range, and the weight of the airplane equal to the weight in connection with which V_{SO} is being used as a factor to determine a required performance." Part 4a said, "V_{SO} at maximum landing weight shall not exceed 80 [mph]." Part 4a defined V_{S1} as "the true indicated stalling speed in [mph] with engines idling, throttles closed, propellers in low pitch, and with the airplane in all other respects (flaps, landing gear, etc.) in the condition existing for the particular test in connection with which V_{S1} is being used." Part 4a said, "V_{S1} at maximum landing weight, flaps in the approach position, landing gear extended, and [c.g.] in the most unfavorable position permitted for landing, shall not exceed 85 [mph]."
6. Climb gradients are expressed as percentages. A climb gradient of 2.4 percent, for example, means that a 2.4-foot increase in altitude is achieved for every 100 feet (31 meters) traveled horizontally over the ground.
7. ICAO. *International Standards and Recommended Practices; Operation of Aircraft; Annex 6 to the Convention on International Civil Aviation.*
8. ICAO. *International Standards and Recommended Practices; Airworthiness of Aircraft; Annex 8 to the Convention on International Civil Aviation.*
9. ICAO. *Airworthiness Technical Manual (ATM)*, Second Edition, Doc. 9051–AN/896.
10. Standard deviation in statistics is a measure of the spread or scatter of the values in a data set.
11. A flight-incident probability of $2x10^{-6}$ (0.000002) means that there is a 0.0002 percent chance that an incident will occur during a particular flight, or that there is a chance that an incident will occur during one flight in every 500,000 flights.
12. FAA. Advisory Circular (AC) 25.1309-1A, *System Design and Analysis.* June 21, 1988.
13. JAA. Advisory Material–Joint (AMJ) 25.1309 *System Design and Analysis.*

14. In a normal frequency distribution (a Gaussian distribution), 68 percent of all values in the data set are distributed evenly between –1 and +1 of the median value.

15. A catastrophic accident involves destruction of the airplane and/or fatalities.

16. FAA. AC 120-42A, *Extended Range Operation with Two-engine Airplanes (ETOPS)*, defines ETOPS as an operation "over a route that contains a point farther than one hour flying time at the normal one-engine inoperative cruise speed (in still air) from an adequate airport." An *adequate airport* is defined as an airport certified to FARs Part 139 standards or to equivalent standards. AC 120-42A provides acceptable means for obtaining approval of ETOPS with deviations of 75 minutes, 120 minutes and 180 minutes from an adequate airport. ICAO Annex 6 defines *extended-range operation* as "any flight by an aeroplane with two turbine power units where the flight time at the one-power-unit-inoperative cruise speed (in ISA [international standard atmosphere] and still-air conditions) from a point on the route to an adequate alternate aerodrome is greater than the threshold time approved by the state of the operator." *Adequate alternate aerodrome* is defined as "one at which the landing performance requirements can be met and which is expected to be available, if required, and which has the necessary facilities and services, such as air traffic control, lighting, communications, meteorological services, navigation aids, rescue and fire fighting services, and one suitable instrument approach procedure."

17. JAA. *Information Leaflet No. 20 — ETOPS, Appendix 1, Risk Management and Risk Model*. July 1, 1995. The leaflet said, "A review of information for modern fixed-wing jet-powered aircraft over a recent six-year period shows that the rate of fatal accidents for all causes is in the order of $0.3x10^{-6}$."

18. Current performance requirements do not include obstacle-clearance requirements with all engines operating. Such a requirement may be needed for four-engine airplanes with high-aspect-ratio wings and/or winglets. Increasing the wing aspect ratio from seven to 10 typically reduces a four-engine airplane's all-engine climb gradient at the second-segment-limited weight from 7.7 percent to 6.8 percent. The effect of increased aspect ratio is not as significant for two-engine airplanes and for three-engine airplanes because their all-engine climb gradients are relatively steep.

19. The second segment of climb begins at 35 feet, with landing gear retracted, flaps in the takeoff position, full power on the operating engines and airspeed at V_2 (takeoff safety speed). The second segment of climb ends at 400 feet, where flaps are retracted and climb angle is reduced to allow the airplane to accelerate to V_{FS} (final-segment speed).

20. U.S. General Accounting Office, "Aviation Safety: U.S. Efforts to Implement Flight Operational Quality Assurance Programs"; Enders, John H., "FSF Study Report Urges Application of Flight Operational Quality Assurance Methods in U.S. Air Carrier Operations"; FSF Editorial Staff with Pinet, John and Enders, John H., "Flight Safety Foundation Icarus Committee Cites Advantages of FOQA for Trend Analysis, Knowledge Building and Decision Making." *Flight Safety Digest* Volume17 (July–September 1998); 1–54.

21. Wagenmakers, Joop. *Aircraft Performance Engineering*. Hertfordshire, England: Prentice Hall International, 1991.

About the Author

Joop H. Wagenmakers joined KLM Royal Dutch Airlines in 1946 after completing studies of aeronautical engineering at Haarlem Institute of Technology. He served in various positions before his promotion in 1956 as manager of the KLM aircraft performance department, a position he held until he retired from KLM in 1987. Wagenmakers has participated in international studies of topics such as aircraft-performance requirements, obstacle-clearance criteria, noise abatement and fuel conservation. He chaired the International Air Transport Association Performance Subcommittee for five years. He authored a book, Aircraft Performance Engineering, *and several papers. He worked for seven years with the Netherlands Directorate General of Civil Aviation on the preparation of JAR–OPS 1 and performed advisory work for Eurocontrol. Wagenmakers coaches aeronautics students for their theses.*

Appendix

Summary of Transport Category Turbine Airplane Performance Standards and Operating Standards

U.S. Federal Aviation Regulations (FARs) Part 25 and European Joint Airworthiness Requirements (JARs) 25 include transport-airplane minimum performance certification standards for takeoff, rejected takeoff, climb and landing. Operating requirements for compliance with the performance standards are contained in FARs Part 91, Part 121 and Part 135, and in JAR–OPS 1. (This discussion will focus on the air-carrier-operating requirements of Part 121 and JAR–OPS 1.)

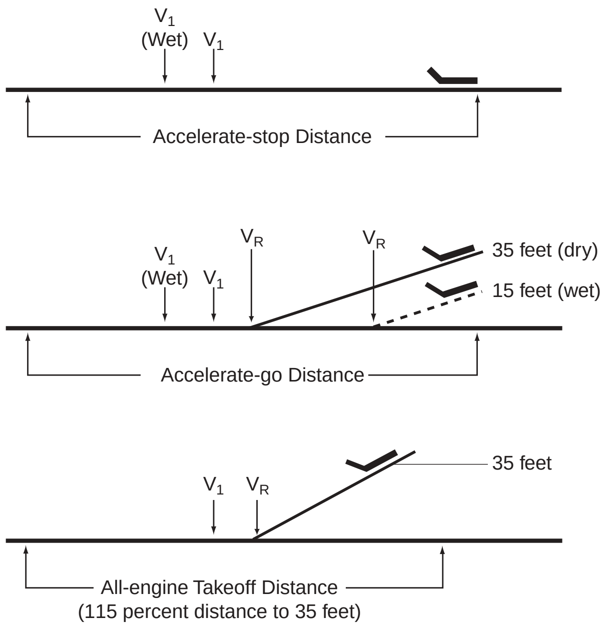
The certification standards require that the airplane manufacturer establish takeoff speeds, accelerate-stop distances, takeoff distances (accelerate-go distances and all-engine takeoff distances) and takeoff flight paths for expected flight conditions, including airplane operating weights, operating altitudes and ambient temperatures.

The manufacturer establishes takeoff performance based on the following calibrated airspeeds:

- V_{EF}, the speed at which the critical engine[1] is assumed to fail during takeoff;
- V_1, the maximum speed at which the pilot must take the first action (e.g., apply brakes, reduce thrust or deploy speed brakes) to stop the airplane within the accelerate-stop distance, and the minimum speed, 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[2];
- V_R, rotation speed, the speed at which the pilot must initiate lift off of the airplane; and,
- V_2, takeoff safety speed, the speed at which the airplane, in takeoff configuration and with the critical engine inoperative, can maintain the required takeoff flight path to 400 feet.

Figure 1a shows the three main takeoff field length criteria that affect airplane performance requirements: accelerate-stop distance, accelerate-go distance and all-engine takeoff distance. One difference between U.S. Federal Aviation Administration (FAA) requirements and Joint Aviation Authorities (JAA) requirements is that JAR-OPS 1 requires that the takeoff field length include the distance used in aligning the airplane on the runway for takeoff; FAA has deferred action on runway-alignment compensation.

Transport Category Turbine Airplane Takeoff Field Length Criteria



V_1 = The maximum speed 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 is the minimum speed, following a failure of the critical engine at V_{EF} [engine-failure speed], at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance.

V_R = Rotation speed

Source: Joop H. Wagenmakers

Figure 1a

The takeoff field length requirements for many years were based on use of a smooth, dry and hard-surfaced runway. Nevertheless, in actual operation, the runway surface often is not dry. FAA and JAA in 1998 published wet-runway takeoff certification requirements and wet-runway takeoff operating requirements. Before the requirements were published, however, the civil aviation authorities in several countries had required wet-runway takeoff performance data to be included in airplane flight manuals (AFMs), and many operators voluntarily applied wet-runway adjustments to takeoff performance calculations.

Accelerate-stop performance applies to a takeoff rejected at V_1 following an engine failure at V_{EF}. Accelerate-stop distance is the distance traveled in accelerating to V_1, decelerating to a stop on the runway or stopway,[3] plus a distance equivalent to two seconds of travel at V_1, to account for pilot reaction time. A lower V_1 is used to establish wet-runway accelerate-stop distance. A 1998 revision of the certification standards requires that the determination of accelerate-stop performance include the use of wheel brakes that are at the fully worn limit of their allowable wear range (i.e., the overhaul limit).

The wet-runway standards allow the decelerative effect of reverse thrust to be used in defining accelerate-stop distance; the standards also apply factors for braking friction, which normally is significantly lower and more variable on a wet runway than on a dry runway. The braking-friction factors include groundspeed, tire pressure, tire tread condition, runway surface texture and the depth of water on the runway.

Accelerate-go performance applies to a takeoff continued after failure of the critical engine at V_{EF}. Dry-runway accelerate-go distance is the horizontal distance traveled from the beginning of the takeoff to the point where the airplane is 35 feet above the runway or clearway.[4] Wet-runway accelerate-go distance is the horizontal distance traveled from the beginning of the takeoff to the point where the airplane is 15 feet above the runway.

A lower V_1 is used to establish wet-runway accelerate-go distance. The FAA and the JAA believed that the use of a lower V_1 and a 15-foot screen height provides a better balance of risks; the risk of a runway overrun is reduced, but the risk of striking an obstacle during initial climb is increased.

All-engine takeoff distance is 115 percent of the horizontal distance traveled from the beginning of the takeoff to a point where the airplane is 35 feet above the runway or clearway.

The options of using stopway distance and clearway distance were especially useful for takeoff planning when turbine airplanes were introduced into commercial service, because many runways at that time were not sufficiently long to accommodate the takeoff field length requirements.

FAA and JAA differ in their applications of the wet-runway takeoff performance requirements. JAR–OPS 1 requires all transport-category airplanes to be operated in compliance with wet–runway takeoff performance requirements. The FARs Part 25 wet-runway takeoff performance certification requirements apply only to airplanes for which certification application was submitted to FAA on or after March 20, 1998. The FAA is not applying the requirements retroactively to other airplanes currently in use or to existing approved designs that will be manufactured in the future. Nevertheless, some manufacturers have complied voluntarily with the requirements.

The certification standards include minimum climb gradients[5] for various phases of flight and specify airplane configurations, airspeeds and power settings for each phase. The operating regulations require flight crews to operate their airplanes at weights that will result in performance characteristics suitable for complying with the minimum climb gradients.

Table 1a shows the minimum climb-gradient requirements for takeoff, en route operations, approach and landing. The requirements might restrict an airplane's takeoff weight, en route weight and/or landing weight. The second-segment climb gradient (takeoff with landing gear retracted) usually is the most limiting takeoff climb requirement related to permissible takeoff weight. The minimum climb gradient required in approach configuration might limit an airplane's landing weight at a high-altitude airport.

Table 1a
Transport Category Turbine Airplane Minimum Climb Gradients

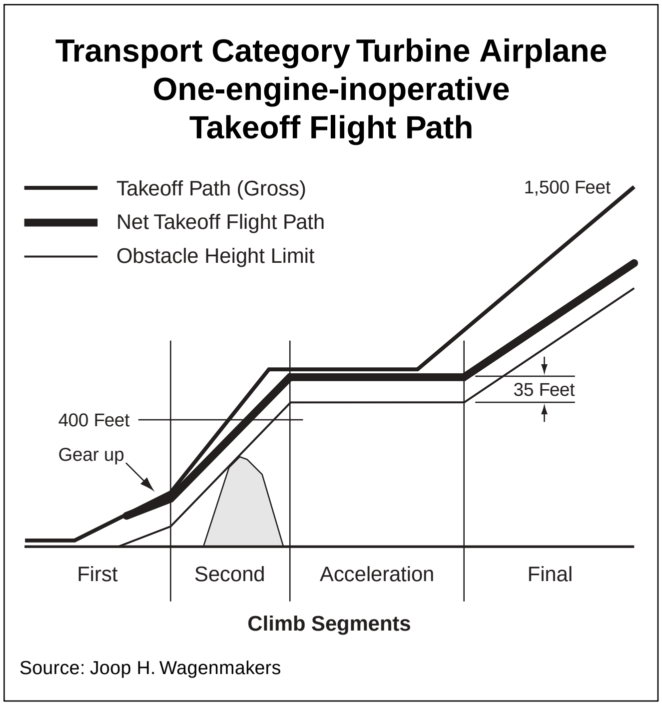
		Climb Gradient		
Airplane Configuration	**Engine Condition**	**Two***	**Three***	**Four***
Takeoff, gear extended	One engine inoperative	positive	0.3%	0.5%
Takeoff, gear retracted	One engine inoperative	2.4%	2.7%	3.0%
Final takeoff	One engine inoperative	1.2%	1.5%	1.7%
En route	One engine inoperative	1.1%	1.4%	1.6%
En route	Two engines inoperative	NA	0.3%	0.5%
Approach**	One engine inoperative	2.1%	2.4%	2.7%
Landing	All engines operating	3.2%	3.2%	3.2%

* Number of airplane engines

** Joint Aviation Requirements (JAR-OPS 1) also require a 2.5% climb gradient or the published instrument-approach-procedure minimum climb gradient, whichever is greater, for Category II/III instrument approaches (decision heights below 200 feet).

NA = Not applicable

Source: Joop H. Wagenmakers


Transport Category Turbine Airplane One-engine-inoperative Takeoff Flight Path

Source: Joop H. Wagenmakers

Figure 2a

The operating regulations require flight crews to operate their airplanes at weights that result in separation from obstacles. The regulations require that the (one-engine-inoperative) net takeoff flight path clears all obstacles by 35 feet (see Figure 2a).

The net flight path corrects the gross takeoff flight path[6] for factors such as average pilot skill and average airplane performance. The net flight path is derived by reducing the gradients of the gross takeoff flight path by 0.8 percent for a two-engine airplane, 0.9 percent for a three-engine airplane and 1 percent for a four-engine airplane.

FARs Part 121 currently requires that the net takeoff flight path clear all obstacles within the airport boundaries by 200 feet (61 meters) horizontally. The net takeoff flight path must clear all obstacles outside the airport boundaries by 300 feet (92 meters) horizontally.

JAR–OPS 1 lateral obstacle-clearance criteria are more demanding than the FARs Part 121 requirements. JAR–OPS 1 requires that the net flight path clear all obstacles horizontally by 90 meters (295 feet) plus 0.125 times "D," the horizontal distance the airplane has traveled from the end of the available takeoff distance, but by not more than either 900 meters (2,951 feet), 600 meters (1,967 feet) or 300 meters (984 feet), depending on turns conducted during takeoff and on navigational accuracy.[7]

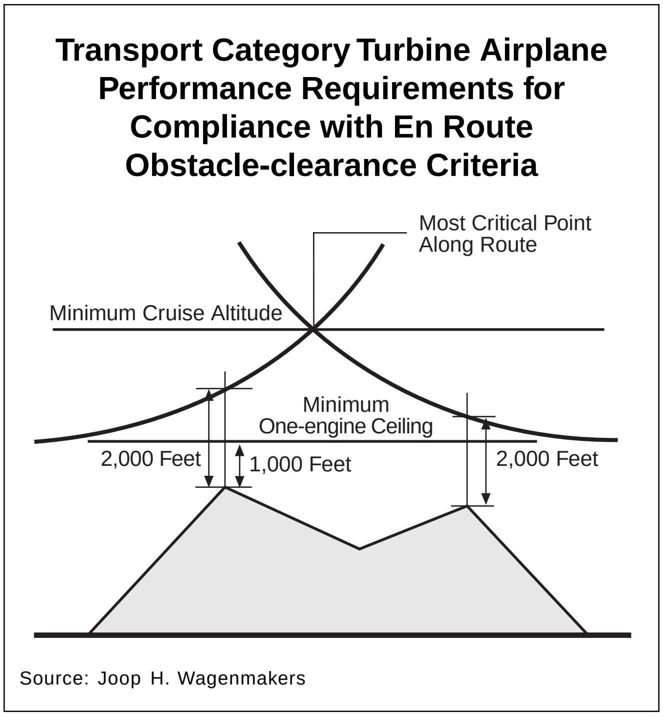
The operating regulations require sufficient airplane engine-out performance to safely operate above any terrain along the route. Figure 3a shows that, to meet this requirement, the operator may demonstrate that, with one engine inoperative, either the gradient of the net flight path is positive at 1,000 feet (305 meters) above the highest point of the terrain or the net flight path during a drift-down procedure following engine failure at the most critical point along the route clears all terrain by 2,000 feet (610 meters).

Furthermore, the operator must demonstrate that the net flight path has a positive gradient at 1,500 feet (456 meters) above the airport at which the aircraft is intended to be landed after an engine failure.

The net flight path is obtained by reducing the demonstrated one-engine-inoperative en route climb performance by 1.1 percent for a twin-engine airplane, 1.4 percent for a three-engine airplane and 1.7 percent for a four-engine airplane.

The operating regulations also require that two-engine airplanes must operate within one hour's flight time at one-engine-inoperative cruise speed (threshold time) from an *adequate airport*[8] unless specific approval for an increased threshold time has been obtained from the appropriate authority (i.e., extended-range twin-engine operations [ETOPS] approval). The basis of ETOPS approval for 120-minutes threshold time or 180-minutes threshold time consists of three elements: a type design approval, an in-service approval and a continuous airworthiness and operations approval.

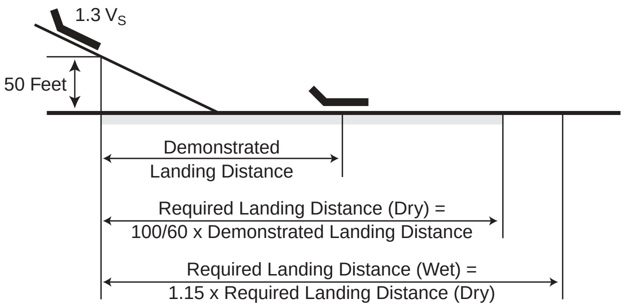
For operation of a three-engine airplane or a four-engine airplane, an en route alternate must be within 90-minutes flight time unless an adequate airport can be reached with two engines


Transport Category Turbine Airplane Performance Requirements for Compliance with En Route Obstacle-clearance Criteria

Source: Joop H. Wagenmakers

Figure 3a

Transport Category Turbine Airplane Landing Criteria



V_S = Stall speed or minimum steady flight speed at which the airplane is controllable.

Source: Joop H. Wagenmakers

Figure 4a

inoperative, taking into account the appropriate climb gradient decrements. This requirement might affect long-distance overwater flights and operations over high terrain. Drift-down procedures and fuel dumping are permitted in complying with the requirement.

Figure 4a summarizes the certification criteria and operating requirements for landing. The certified landing distance is the horizontal distance from where the airplane is 50 feet above the landing surface, in landing configuration and at an airspeed of 1.3 V_S, to where the airplane is brought to a full stop, without use of reverse thrust, on the landing surface.[9]

The operating regulations require that turbine-engine airplane landings be completed within 60 percent of the available landing area at the destination airport and at alternate airports. Thus, the required landing distance is 100/60 times the demonstrated landing distance. Turboprop airplane landings must be completed within 70 percent of the landing area.

The operating regulations also require that, if the runway is wet, the available landing distance must be 115 percent of the required landing distance. Thus, the required landing distance on a wet runway is 1.15 times the required landing distance on a dry runway.

Techniques used by manufacturers to establish landing distances usually are not the same as techniques used by flight crews during normal airline operations. In the past, use of abnormal techniques (steep approaches and high sink rates upon touchdown) during attempts by manufacturers to establish short landing distances resulted in several incidents in which hard landings caused substantial airplane damage. In 1988, FAA published recommended flight-test procedures that preclude such techniques.[10]

The landing distance requirements affect operation of large transport airplanes (with certified maximum takeoff weights that are significantly greater than their certified maximum landing weights) at relatively few airports, because the takeoff standards usually are more limiting — that is, if airplane weight is sufficient to meet takeoff performance requirements, the landing weight usually is sufficient to meet the landing performance requirements. For small transport airplanes (with less difference between maximum takeoff weights and maximum landing weights), however, the required landing distance often is more limiting than the required takeoff distance.

Over the years, there have been many discussions about introducing more realistic landing distance certification standards. One proposal is the International Civil Aviation Organization Airworthiness Committee's Landing Method C, which uses flight-test methods that are similar to normal landing techniques, allows for use of reverse thrust, and uses smaller landing-distance correction factors.♦

— Joop H. Wagenmakers

References and Notes

1. U.S. Federal Aviation Regulations (FARs) Part 1 and Joint Aviation Requirements (JARs) 1 define critical engine as "the engine whose failure would most adversely affect the performance or handling qualities of an aircraft."

2. FSF Editorial Staff. "International Regulations Redefine V_1." *Flight Safety Digest* Volume 17 (October 1998): 1–18.

3. FARs Part 1 and JARs 1 define stopway as "an area beyond the takeoff runway, no less wide than the runway and centered upon the extended centerline of the runway, able to support the airplane during an aborted takeoff, without causing structural damage to the airplane, and designated by the airport authorities for use in decelerating the airplane during an aborted takeoff."

4. FARs Part 1 and JARs 1 define clearway as, "for turbine-engine-powered airplanes certificated after Aug. 29, 1959, an area beyond the runway, not less than 500 feet [152 meters] wide, centrally located about the extended centerline of the runway, and under the control of the airport authorities. The clearway is expressed in terms of a clearway plane, extending from the end of the runway with an upward slope not exceeding 1.25 percent, above which no object nor any terrain protrudes. However, threshold lights may protrude above the plane if their height above the end of the runway is 26 inches [66 centimeters] or less and if they are located to each side of the runway."

5. Climb gradients are expressed as percentages. A climb gradient of 2.4 percent, for example, means that a 2.4-foot increase in altitude is achieved for every 100 feet traveled horizontally over the ground.

6. FARs 25 and JARs 25 define takeoff path as the path extending from where the airplane begins the takeoff from a standing start to where the airplane either is 1,500 feet above the takeoff surface or where the transition from takeoff configuration to en route configuration is complete and airspeed is not less than 1.25 V_S.

7. The lateral obstacle-clearance criteria are reduced for airplanes with wingspans less than 60 meters (197 feet); the regulations require a horizontal obstacle clearance equal to half the wingspan, plus 60 meters, plus 0.125 D.

8. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 120-42A, *Extended Range Operation with Two-engine Airplanes (ETOPS)*, defines an adequate airport as "an airport certified as an FAR[s] Part 139 airport or found to be equivalent to FAR[s] Part 139 safety requirements." Part 139 prescribes certification requirements and operating requirements for airports serving scheduled air carriers operating large airplanes.

9. FARs Part 1 and JARs 1 define V_S as "the stalling speed or the minimum steady flight speed at which the airplane is controllable."

10. FAA AC 25-7, *Flight Test Guide for Certification of Transport Category Airplanes*. April 9, 1986. AC 25-7 was superseded by AC 25-7A on March 31, 1998.

Bird Strikes Found Most Common at Low Altitudes in Daylight

Data show 52,663 bird strikes worldwide from 1988 through 1998.

FSF Editorial Staff

Data compiled by the International Civil Aviation Organization (ICAO) show that bird strikes are most frequent during daylight and at altitudes below 100 feet above ground level (AGL).

The data, based on 52,663 bird strikes worldwide that were reported to the ICAO Bird Strike Information System from 1988 through 1998, showed that in most instances — 42,079 — the flights continued unaffected by the bird strikes. In 6,535 instances, reports did not specify the effect of the bird strike on the flight. Of the 4,049 instances in which the bird strike was reported to have had an effect on the flight, the most frequently reported problems were precautionary landings (1,761) and rejected takeoffs (1,046).

The bird strikes resulted in two fatalities and 10 minor injuries, the data showed. Four aircraft were destroyed, 1,830 received substantial damage and 3,242 received minor damage.

More bird strikes occurred during the approach phase (17,170) and during the takeoff roll (10,817) than at any other time during flight operations or ground operations.

The data also showed that:

- More bird strikes were reported in August (6,819) than in any other month, followed by July (6,656) and September (6,326). Fewer bird strikes were reported in February (2,059) than in any other month;
- Bird strikes were most common during daylight, when 33,983 were reported, and below 100 feet AGL (29,066 reports);
- Most bird strikes involved aircraft classified as “turbo fan over 27,000 kilograms/60,000 pounds”;
- In most situations, only one bird was involved in a bird strike (33,726), although in 28 instances, the reports indicated that more than 100 birds were struck; and,
- The windshield was the part of the aircraft most likely to be struck by the bird (7,238), but damage most often was reported to an engine (2,659).

Sea gulls were identified most often (6,090 reports) as the birds involved in bird strikes, followed by swallows (2,373 reports), sparrows (1,763 reports), pigeons (773 reports), hawks (752 reports) and lapwings (693 reports). Birds of about 400 species were involved in at least one bird strike.♦

Table 1
Reported Bird Strikes, 1988–1998

	Total
Month of Occurrence	
January	2,166
February	2,059
March	2,870
April	3,253
May	4,856
June	5,337
July	6,656
August	6,819
September	6,326
October	5,888
November	3,782
December	2,420
Light Conditions	
Dawn	1,533
Day	33,983
Dusk	2,409
Night	10,038
Aircraft Classification	
Piston over 5,700 kilograms/12,500 pounds	42
Piston under 5,700 kilograms	3,364
Turbo Jet over 27,000 kilograms/60,000 pounds	160
Turbo Jet under 27,000 kilograms	644
Turbo Prop over 27,000 kilograms	132
Turbo Prop under 27,000 kilograms	6,809
Turbo Fan over 27,000 kilograms	37,734
Turbo Fan under 27,000 kilograms	1,371
Turbo Shaft	469
Other, Unknown and glider	1,853
Flight Phase	
Parked	132
Taxi	187
Takeoff run	10,817
Climb	7,934
En route	1,229
Descent	1,001
Approach	17,170
Landing roll	9,088
Height Above Ground Level (feet)	
0–100	29,066
101–200	2,401
201–500	4,126
501–1,000	2,785
1,001–2,500	3,079
Over 2,500	3,620
Indicated Airspeed (knots)	
0–80	8,324
81–100	4,012
101–150	21,456
151–200	5,564
201–250	2,238
Over 250	483
Pilot Warned	
No	33,042
Yes	5,953
Number of Birds Seen	
1	17,313
2–10	10,682
11–100	2,412
Over 100	367
Number of Birds Struck	
1	33,726
2–10	8,290
11–100	605
Over 100	28
Parts Struck	
Radome	5,515
Windshield	7,238
Nose	7,075
Engine 1	3,478
Engine 2	2,566
Engine 3	384
Engine 4	219
Propeller	1,427
Wing or main rotor	5,347
Fuselage	5,978
Landing gear	2,732
Tail	383
Lights	155
Pitot-static head	82
Antenna	13
Tail rotor	2
Helicopter transmission	1
Other	1,782
Parts Damaged	
Radome	631
Windshield	359
Nose	334
Engine 1	1,397
Engine 2	968
Engine 3	183
Engine 4	111
Propeller	123
Wing or main rotor	1,372
Fuselage	249
Landing gear	190
Tail	160
Lights	320
Pitot-static head	25
Antenna	27
Tail rotor	1
Helicopter transmission	1
Other	282
Aircraft Damage	
None	1,7166
Minor	3,242
Substantial	1,830
Destroyed	4
Injury Index	
Fatal	2
Minor	10
Effect on Flight	
None	42,079
Aborted takeoff	1,046
Precautionary landing	1,761
Engine(s) shut down	86
Forced landing	69
Fire	7
Penetrated windshield	21
Penetrated airframe	28
Vision obscured	89
Other effect	942

Source: International Civil Aviation Organization Bird Strike Information System

FAA Publishes Specialty Air Services Guidelines for U.S. Aircraft in Canada and Mexico

The information was developed under terms of the North American Free Trade Agreement.

FSF Library Staff

Advisory Circulars

North American Free Trade Agreement and Specialty Air Services Operations. U.S. Federal Aviation Administration Advisory Circular (AC) 00-60. Nov. 9, 1999. 8 pp. Available through GPO.*

This AC provides information for aircraft operators from the United States who plan to conduct specialty air services (SAS) operations in Canada or Mexico in accordance with the North American Free Trade Agreement (NAFTA). Information also is provided for aircraft operators from Canada or Mexico who plan to conduct SAS operations in the United States. SAS operators include aerial mapping, forest-fire management, sightseeing flights and flight training. This advisory material is directed toward operations in each NAFTA signatory country who wish to conduct a cross-border SAS operation, as defined in Article 1213 of NAFTA. [Adapted from AC]

Reports

GPS User-Interface Design Problems: II. Williams, Kevin W. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine. DOT/FAA/AM-99/26. November 1999. 11 pp. Available through NTIS.**

Keywords
1. Global Positioning System
2. Human-computer Interface
3. Aircraft Displays
4. Applied Psychology

This paper is the second in a series that reviewed human factors problems associated with the user-interfaces of global positioning system (GPS) receivers certified for use in aircraft for nonprecision instrument approaches. Both papers focus on design problems and inconsistencies with the various interfaces that could cause confusion or errors during operation. Problems addressed involve the placement of units in the cockpit, the use and design of moving-map displays, and the co-location of multiple pieces of information on the display. Recommendations are presented to the FAA, the GPS unit manufacturers and pilots for the development and use of these devices. [Adapted from Introduction and Conclusions.]

Books

Aviation History. Millbrooke, Anne. Englewood, Colorado, U.S.: Jeppesen Sanderson, 1999. 622 pp.

This book examines aviation from the first public hot-air balloon flights in France in 1783 to modern accomplishments in space. Containing more than 500 photographs and illustrations, the book is designed as both an aviation history course and a reference. The text is structured to provide a review of the significant events, people, places and technologies involved in aviation as its history has progressed. A summary of events begins each chapter and presents an abbreviated timeline of notable aviation and non-aviation events that took place during the period covered in the chapter. Personal profiles provide biographical information about individuals who achieved outstanding success in aviation. A bibliography concludes each chapter and lists books and other references used by the author. Contains an index. [Adapted from preface and back cover.]

Spitfire. Wilson, Stewart. Fyshwick, Australia: Aerospace Publications, 1999. 152 pp.

This book tells the story of the famous fighter planes in diary form. The book contains a detailed review of Spitfire and Seafire marks and models, a summary of foreign operators, a squadron summary and a comprehensive serial-number table. The author uses this approach to lend some perspective to the somewhat complicated history of the Spitfire/Seafire, and to give the reader an appreciation of how much work was performed in a short time by the people who were involved in that history. The chronology section also introduces technical, personal and operational information. [Adapted from Introduction.]

Helmet-Mounted Displays: Design Issues for Rotary-Wing Aircraft. Rash, Clarence E., editor. Fort Rucker, Alabama, U.S.: U.S. Army Aeromedical Research Laboratory, 1999. 293 pp.

The U.S. Army Aeromedical Research Laboratory (USAARL) helmet-mounted display program combines research and development with testing and evaluation of such topics as optics, acoustics, safety and human factors. In this book, USAARL scientists and engineers summarize 25 years of their work on helmet-mounted displays in Army helicopters. They discuss the visual, acoustic and biodynamic performance of helmet-mounted displays, as well as concerns such as sizing, fitting and emergency egress. Contains a glossary and an index. [Adapted from Forward and Preface.]♦

Sources

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U.S. Government Printing Office (GPO)
Washington, DC 20402 U.S.

**National Technical Information Service (NTIS)
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Updated U.S. Federal Aviation Administration (FAA) Regulations and Reference Materials

Advisory Circulars (ACs)

AC No.	Date	Title
150/5100-13A	Sept. 28, 1999	*Development of State Standards for Nonprimary Airports*. (Cancels AC 150/5100-13, *Development of State Standards for General Aviation Airports*, dated March 1, 1977.)
91-69A	Nov. 19, 1999	*Seaplane Safety for 14 CFR Part 91 Operators*. (Cancels AC 91-69, *Seaplane Safety for FAR Part 91 Operators*, dated March 13, 1992.)
20-126G	Nov. 30, 1999	*Aircraft Certification Service Field Office Listing*. (Cancels AC 20-126F, *Aircraft Certification Service Field Office Listing*, dated Aug. 12, 1997.)
150/5220-16C	Dec. 13, 1999	*Automated Weather Observing Systems (AWOS) for Non-Federal Applications*. (Cancels AC 150/5220-16B, *Automated Weather Observing Systems (AWOS) for Non-Federal Applications*, dated Nov. 13, 1995.)

Federal Aviation Administration Orders

Order No.	Date	Title
7210.3R	Feb. 24, 2000	*Facility Operation and Administration*. (Cancels FAA Order 7210.3P, *Facility Operation and Administration*, dated Feb. 26, 1998.)
7110.65M	Feb. 24, 2000	*Air Traffic Control*. (Cancels FAA Order 7110.65L, *Air Traffic Control*, dated Feb. 26, 1998.)
7110.10N	Feb. 24, 2000	*Flight Services*. (Cancels FAA Order 7110.10M, *Flight Services*, dated Feb. 26, 1998.)

International Reference Updates

Aeronautical Information Publication (A.I.P.) Canada

Amendment No.	Date	
1/00	Jan. 27, 1999	Updates the General, Communications, Meteorology, Rules of the Air and Air Traffic Services, Aeronautical Charts and Publications, Licensing, Registration and Airworthiness, and Airmanship sections of the A.I.P.

Accident/Incident Briefs

Bird Strike Prompts Airplane’s Return to Departure Airport

The incident, which occurred shortly after takeoff, damaged the Boeing 737’s no. 1 engine.

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

Passenger Reports Seeing Flames From Left Engine

Boeing 737. Minor damage. No injuries.

The airplane was climbing through about 100 feet to 200 feet after a morning takeoff from an airport in England and the landing gear was being retracted when a loud “bang” was heard. The report by the U.K. Air Accidents Investigation Branch said that the airplane “shuddered and oscillated in roll momentarily.”

The climb continued, and both pilots checked engine indications, which showed that both engines were operating normally. “Shortly afterwards, however, a pungent smell became apparent on the flight deck and within the passenger cabin, and a passenger reported to the crew that flames had been seen emanating from the left engine for a short time,” the report said.

The pilots transmitted a PAN call (the international radiotelephony urgency signal, repeated three times, indicates uncertainty or alert followed by the nature of the urgency) and flew the airplane back to the departure airport, where they conducted a normal landing.

An inspection revealed evidence of a bird strike on the no. 1 engine intake. A fan blade was damaged and the constant-speed-drive oil-cooler matrix was blocked and damaged, the report said. A microscopic feather analysis determined that the bird involved was a pigeon.

Smoke From Video Control Unit Prompts Unscheduled Landing

McDonnell Douglas MD-11. No damage. No injuries.

Instrument meteorological conditions prevailed about one hour after the airplane’s afternoon departure from an airport in the United States. A “buzz” was heard on the airplane’s public address system, and the flight crew reset the public address system’s circuit breaker. Smoke then was observed in the first-class cabin.

The flight crew declared an emergency and turned the airplane toward the departure airport. A crewmember located the source of the smoke and opened an overhead bin near the rear of the first-class cabin. Halon was discharged from a fire extinguisher onto a video system control unit, and the smoke dissipated. There was no report of fire, and no fire damage was found, said the report by the U.S. National Transportation Safety Board.

Examination of the video system control unit by representatives of the U.S. Federal Aviation Administration revealed that part of a circuit board was charred and that several video distribution units were damaged internally.

“A ‘cannon plug’ power connector that linked the damaged components exhibited evidence of moisture damage and a short circuit between two pins,” the report said. “All video system wiring was intact and undamaged.”

Child Falls Through Gap Between Aircraft, Mobile Airstairs

Boeing 757. No damage. One serious injury.

The ground was wet, and passengers were using mobile airstairs to board the rear of the aircraft when a 2 1/2-year-old child fell through a six-inch (15.24-centimeter) gap between the top of the mobile airstairs and the aircraft door sill. The child landed on the ground and was taken to a hospital, where an examination revealed a fractured wrist and bruises, said the report by the U.K. Air Accidents Investigation Branch.

A subsequent inspection of the mobile airstairs revealed that the stabilizer mount on one side was damaged, that a stabilizer jack was in the retracted position and that the handbrake was in the “off” position. The report said that the mobile airstairs, which had been positioned about one hour earlier and which had been used for passengers disembarking from a previous flight, probably moved from their original location as they were being used, creating the gap between the mobile airstairs and the aircraft. The mobile airstairs were removed from service immediately after the accident, and disciplinary action was taken against the employee who positioned them, the report said.

Tires Burst During Rejected Takeoff on Short Runway

Lockheed L-1011. No damage. No injuries.

Day visual meteorological conditions prevailed when the captain chose to position the airplane for takeoff on a runway that was 2,000 feet shorter than the longer of two parallel runways at an airport in Panama. After the airplane was rotated, the captain rejected the takeoff. After touchdown, all main landing gear tires burst, and the airplane was stopped on the runway. The airplane was not damaged, and the five crewmembers were not injured.

Smoke in Flight Deck, Cabin Prompts Crew to Land Airplane

Boeing 777. No damage. No injuries.

The airplane was being flown through Flight Level (FL) 260 after a late-evening departure from an airport in England, when haze and fumes were observed on the flight deck and in the passenger cabin. The pilots transmitted a PAN call, prepared to return to the departure airport and donned oxygen masks, said the report by the U.K. Air Accidents Investigation Branch.

The flight crew also conducted checklists for smoke removal and jettisoning fuel. A normal autoland was completed, and fire fighting personnel confirmed that there were no further signs of smoke. The aircraft then was taxied for passengers to disembark in the usual manner.

Inspection revealed that the auxiliary power unit (APU) buffer air circuit’s vent tube was blocked.

The report said, “As a result of several previous experiences of oil contamination resulting from the APU buffer air system, which supplies air pressure to the back of the carbon seal at the rear of the APU load compressor, it was decided to replace the APU as a precaution.”

The left air-conditioning pack dual heat exchanger also was replaced because inspectors suspected oil contamination. During subsequent engine runs and APU ground runs, no odors were observed, and the airplane was returned to service. The APU was sent to the manufacturer for further inspection.

Air Taxi Commuter

Crew’s Chartered Airplane Strikes Terrain After Takeoff

Cessna 404 Titan. Airplane destroyed. Eight fatalities; three serious injuries.

The aircraft, which had been chartered to transport a nine-member airline crew from one airport in Scotland to another, was cleared for a midday departure on an instrument flight rules flight plan. The aircraft’s weight was near the maximum permitted takeoff weight, said the report by the U.K. Air Accidents Investigation Branch.

Witnesses said that the takeoff from the 2,658-meter (8,721-foot) runway appeared to proceed normally until just after the airplane became airborne. Then, they said, they heard a thud and saw the airplane enter a left bank, then a right bank and a gentle descent. The witnesses said that they heard an engine sputter and saw at least one propeller rotating slowly.

"There was a brief 'emergency' radio transmission from the [aircraft] commander, and the aircraft was seen in a steep right turn," the report said. "It then entered a dive. A witness saw the wings leveled just before the aircraft struck the ground on a northerly track and caught fire."

A nearby worker helped the three survivors from the wreckage before the airplane was engulfed in flames.

Crew Unable to Pressurize Airplane; Deflated Door Seal Cited

De Havilland DHC-8. No damage. No injuries.

Instrument meteorological conditions prevailed for the airplane's early morning departure from an airport in Canada. Shortly after takeoff, the captain notified air traffic control that a door seal had deflated and that the airplane could not be pressurized, said a report by the Transportation Safety Board of Canada.

The captain flew the airplane back to the departure airport for a normal landing, and maintenance technicians replaced the door seal, deiced blocked pressure lines and removed moisture from the lines. The airplane was returned to service.

Corporate
Business

Confusion About Regulations Cited in Landing in Fog

British Aerospace BAe 125-800A. Minor damage. No injuries.

Fog was forecast for the time of the airplane's planned evening arrival at an airport in England. The airplane was being operated under U.S. Federal Aviation Regulations Part 91, which does not preclude commencement of an instrument approach in instances when the runway visual range (RVR) is below the prescribed minimum RVR for the type of approach being conducted.

The captain could not recall details of the U.K. "Approach Ban," which prohibits aircraft of any nationality, regardless of whether they are operated privately or as public transport, from descending below 1,000 feet during descent to an airport if the RVR is less than the minimum specified for landing.

Before the approach, the crew consulted a Jeppesen approach chart that gave approach minimums, including an RVR of 650 meters (2,133 feet), but did not consult a section of the Jeppesen Airway Manual that discussed the Approach Ban, said the report by the U.K. Air Accidents Investigation Branch (AAIB).

During a conversation with air traffic control (ATC), the captain requested a precision approach radar approach, but he said that he was uncertain whether he could fly the approach under U.K. regulations.

The captain later told a second controller that he would like to "try the approach" if the circumstances were "OK with your ops." The controller read the captain the latest weather observations, which said that the RVR was 200 meters (656 feet). The report said that the controller also told the flight crew that "our ops will have no reason not to accept you" and that "you're making the approach on your minima."

The approach proceeded normally, and the captain needed only minor heading changes to fly the aircraft near the extended runway centerline. At decision altitude, the copilot told the captain that he saw the lights, and the captain continued the approach. The airplane touched down on the tarmac at the intersection of two taxiways to Runway 25, but after the airplane passed the intersections, the main wheels ran onto the grass surface for the rest of the landing run.

The two crewmembers and three passengers were not injured; the right trailing edge flap was damaged during the landing and both engines ingested mud.

The AAIB report said that the RVR was below the minimum of 650 meters for the approach. Although the captain had told ATC that he was uncertain whether he could fly the approach in compliance with U.K. regulations, his "nonstandard" phrasing "was not interpreted by the controllers involved as a request for legal guidance," the report said.

"At that time, ATC had no standard procedures which enabled the controllers to know which minima were applicable to which aircraft type, or any standard phraseology to indicate to an aircraft that the visibility was below acceptable limits," the report said.

Several weeks after the accident, in response to recommendations that followed a 1996 accident, an ATC "absolute minima" procedure was introduced to guide controllers in their communications with pilots who want to conduct approaches when visibility is below an absolute minimum calculated for each runway and each type of approach.

"The controller must advise the pilot of this fact [that the visibility is below the absolute minimum] and then request his/her intentions," the report said. "In the event that the pilot wishes to continue to make the approach, then the controller should advise that there is no known traffic to affect the conduct of the approach or the landing. The decision whether or not to make an approach rests with the aircraft commander, and neither controllers nor [air traffic service] ATS providers may prohibit an approach being made."

Airplane Damaged During Tail-wind Landing

Cessna Citation 550. Substantial damage. No injuries.

Instrument meteorological conditions prevailed as the pilot approached an airport in England for a night landing. Surface winds were 10 knots from 160 degrees, and Runway 13 was in use, but the captain requested an instrument landing system (ILS) approach to Runway 31 because he believed that — even with the tail wind — a coupled ILS approach was a better option than an approach to the reciprocal runway using precision approach radar (PAR).

Air traffic control (ATC) cleared the airplane for landing when it was four nautical miles (7.4 kilometers) from the airport. At the time, ATC said surface winds were "170 degrees, 12 knots, which is a seven-knot tailwind." The captain told the U.K. Air Accidents Investigation Branch that he disconnected the autopilot when he saw the runway from an altitude of 280 feet and declined an offer by ATC to dim the runway lights.

The captain considered the visual portion of the approach normal until the airplane reached about 140 feet, when he was "temporarily blinded by the landing lights reflecting from light mist."

The descent rate increased, the report said, "and the aircraft sank rapidly into the glare of the approach lights."

The captain told investigators, "I was well below the glideslope. I applied full power, pulled back on the control column, felt a light bump and landed on the runway."

Subsequent inspection showed that the airplane had struck and damaged a surveillance radar marker and the PAR reflector.

The morning after the accident, the captain put tape on a section of the flap that had been damaged and prepared to fly the airplane to the airport where it was based, which also was its maintenance base. When he determined that the left fuel gauge was inoperative and that there was a fuel leak from an underwing inspection panel, he decided to fill only the right tank with fuel and to feed both engines from the right tank.

Early portions of the flight appeared to be normal, but as the flight progressed, the captain noticed that the airplane tended to fly with its left wing low, and eventually, he had to apply "a considerable amount" of aileron to keep the wings level, the report said. As he flew the downwind leg of the traffic pattern, he observed "a significant amount of fuel venting from the left wing." He landed the airplane without difficulty.

Subsequent inspection showed that damage to the left wing was more extensive than originally believed, with damage to the flap, dents on the wing's leading edge, buckled wing ribs and a bowed left forward stringer. The flap assembly was damaged beyond repair.

The airplane was registered in the Cayman Islands, and the Civil Aviation Authority of the Cayman Islands was notified of the accident. The agency said that authority for single-pilot operation of the airplane had not been granted. The agency also said that the accident invalidated the certificate of airworthiness and the Air Navigation (Overseas Territories) Order 1989 because the captain had not had the damage assessed by a qualified person before flying the airplane to another airport.

Tires Burst During Takeoff Roll

Learjet 36A. Substantial damage. No injuries.

The pilot of the medical-transport flight said that the airplane was traveling at 120 knots on a takeoff roll for a night departure in visual meteorological conditions from an airport in Bahrain when both left main landing gear tires burst. The airplane swerved to the left, and the pilot applied right rudder and braked to align the airplane with the runway, the accident report said. Then both right main landing gear tires burst. The pilot deployed the drag chute, and the airplane went off the right side of the runway.

The right main landing gear separated from the aircraft, and the right wing tip and right wing struck the ground.

Other General Aviation

Airplane Strikes Terrain After Pilot Requests 'Low Go-around'

Pilatus PC-7. Airplane destroyed. One fatality.

The pilot was completing the final day of a five-day flight to ferry the airplane from company headquarters in Stans, Switzerland, to an airport in the United States. Visual meteorological conditions prevailed when the airplane arrived at the destination airport early in the afternoon, and the pilot told air traffic control (ATC) that he wanted to perform a "low go-around." ATC cleared the pilot for an optional approach and told him to continue in a right-hand traffic pattern.

Several witnesses told the U.S. National Transportation Safety Board that they saw the airplane, about 100 feet to 150 feet above the ground, complete two 360-degree rolls to the right, followed by one 360-degree roll to the left.

"The airplane was then seen in a vertical attitude, followed by a right bank of 10 to 20 degrees and a rapid descent," the NTSB report said.

The right wing struck a taxiway before the airplane cartwheeled forward and exploded, the report said.

Airplane Strikes Terrain on Pilot's Flight Home From Safety Seminar

Pitts S1C. Substantial damage. One minor injury.

The pilot was on a late-afternoon flight in visual meteorological conditions, on his way home from an aviation safety seminar, when he became concerned about impending darkness and decided to divert to an airport closer than his home field. The engine lost power and the airplane struck terrain as the airline-transport-rated pilot, who also was a flight instructor, attempted an off-airport landing.

Landing Gear Collapses During Touchdown

Piper PA-30. Substantial damage. No injuries.

The airplane, part of a group of 100 aircraft being flown from France to an airport in England on a mid-morning flight, was the second to arrive in the airport traffic pattern. All the pilots had been briefed to enter the pattern on the downwind leg and to make a radio transmission as they flew over the coastline.

The pilot made his radio transmission to air traffic control (ATC) as instructed, and ATC saw the twin-engine airplane on the downwind leg. The pilot did not make the next expected radio transmission when the airplane was on final approach, said the report by the U.K. Air Accidents Investigation Branch. The pilot conducted a go-around, and witnesses saw the airplane's wings rock during climb-out. There were no radio transmissions from the pilot. The airport fire service was put on standby, and the airplane was seen re-entering the downwind for another approach. Witnesses observed that the nose landing gear was not extended fully.

As the airplane touched down, the landing gear collapsed, and one propeller struck the runway. The airplane lifted off the runway briefly, and the right main gear locked down before the airplane again touched down. The airplane then slid off the runway and came to a stop.

The pilot said that, after he made his first radio transmission and attempted to lower the landing gear, he observed that the flaps did not move and that the cockpit lights had failed. He determined that the airplane had experienced a total electrical failure. When he was unable to confirm that the landing gear had extended, he conducted the go-around and attempted to use the emergency gear-extension system. There were no lights to confirm the landing gear's position, but the pilot believed that the landing gear had extended, and he landed the airplane.

He said that, before leaving the airport in France, the airplane's alternator field switches had been off (even though the "closing down" checklist said that they should be on). He turned the switches on but did not check the operation of the two alternators before takeoff or during flight.

During an inspection that followed the accident, both engines were operated, the electrical system appeared to function normally, and the landing gear was extended fully.

Rotorcraft

Accident Prompts Clarification of Pilot Medical Requirements

Bell 206B JetRanger. Helicopter destroyed. One fatality.

The pilot was flying the helicopter to the home base at a helicopter pad in Australia in weather conditions that were described as "suitable for the flight" in a report by the Australian Bureau of Air Safety Investigation (BASI).

The pilot apparently planned to fly the helicopter along the western side of a mountain, but when the helicopter passed a television transmitting tower, the helicopter entered a descending right turn, struck trees and then struck the ground on the side of the mountain. The helicopter was in a level lateral attitude with no roll rate and a descent angle of about five degrees when it struck the trees, the report said. Speed was estimated to be normal cruise speed. The helicopter was destroyed in the ensuing fire; the pilot was killed.

No evidence was found of any pre-existing defect in the helicopter, the report said.

The pilot had completed a biennial flight review in the week before the accident, and he had received a current medical certificate two months earlier. The pilot's medical certificate had been revoked in 1994, after he experienced a hemorrhage beneath a membrane that covers parts of the central nervous system, but a new medical certificate was issued the following year.

In the weeks before the accident, the pilot had visited a designated aviation medical examiner, a neurologist and an ear, nose and throat specialist, complaining of severe migraine headaches with blurred vision and double vision. The neurologist was the same physician the pilot had consulted after the 1994 hemorrhage, and the neurologist determined that the new symptoms were not related to the 1994 ailment. The pilot eventually was diagnosed as having a severe sinus infection.

After the accident, the Australian Civil Aviation Safety Authority (CASA) aviation medicine staff found that information from the physicians who had treated the pilot indicated that his medical condition had changed and that he "no longer met the required medical standard," the report said.

The report also said that CASA "has advised BASI that: 'Pilot awareness of any aviation risk is an important element in the safety system. Therefore, the authority has decided to take immediate steps to increase the pilot and doctor awareness of the risks associated with medical fitness and aviation activities.'"

Helicopter Rolls After Emergency Landing in Swamp

Robinson R22B. Substantial damage. No injuries.

The pilot had just begun his third flight of the day from an airport in the United States for the purpose of conducting an aerial survey of alligator activity in several swamps. Visual meteorological conditions prevailed for the noon flight, which departed from a farm. Winds were reported at 10 knots. About 15 minutes after departure, as the pilot was repositioning the helicopter at an altitude of 500 feet above ground level, the helicopter suddenly lost engine power. The pilot conducted a straight-in autorotation in an open area covered with grass between four feet and five feet high. The pilot flared the helicopter just above the tall grass, and the helicopter sank into the grass with forward airspeed. The helicopter touched down, nosed over and rolled onto its right side.

The pilot and the sole passenger were rescued, uninjured, about five hours later by the crew of another helicopter. During the accident, the helicopter's tail boom separated from the airframe, and the powertrain system, including the main-rotor blades, were structurally damaged.

Helicopter Fireworks Display Prompts Safety Investigation

Aerospatiale Squirrel. No damage. No injuries.

The helicopter was on a night flight carrying an underslung load of fireworks to be used in an Australia Day fireworks display. The pilot flew along a river and away from spectators. After the fireworks were ignited, projectiles from the fireworks appeared to pass through the left side of the helicopter's main-rotor disk or near the main-rotor disk, but the helicopter was not damaged, said the report by the Bureau of Air Safety Investigation (BASI).

Before the fireworks display, the helicopter operator had requested approval from the Australian Civil Aviation Safety Authority (CASA) to conduct the display. The operator believed that the display would involve nonprojectile fireworks and a cascading display with nothing to be ejected from the helicopter's underslung load. Local CASA officers said that they believed that the display could be conducted safely, even though officers in the national office disagreed. Conditional approval was granted for the flight. The conditions included requirements that the helicopter remain at least 300 meters (984 feet) from the shoreline and that the display not be flown over any person or boat.

The fireworks were ignited from a control box operated by a pyrotechnician in the cabin. The pilot said that he felt movement as the fireworks ignited but that the movement did not affect his ability to control the helicopter. He said that he was unaware that any projectiles had come near the helicopter until he talked to his copilot.

The BASI report said that there had been a misunderstanding among fireworks technicians, event organizers, the helicopter operator and local CASA officers about the types of fireworks being carried by the helicopter and fired from the helicopter. Because of the misunderstanding, approval for the display was based on incorrect information.

"During the investigation, it became apparent that there were differing opinions as to whether an underslung load was considered to be part of the helicopter with respect to dangerous-goods requirements," the report said. "CASA subsequently informed the investigators that anything attached to an aircraft is considered to be part of the aircraft and that dangerous goods carried as an underslung load must be treated no differently from dangerous goods carried inside the aircraft."

As a result of the occurrence, BASI began an investigation of the safety of advice given to helicopter operators about dangerous goods that are carried as underslung loads.♦

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