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ALAR

Approach-and-landing Accident Reduction

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In This Issue

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 830 member organizations in more than 150 countries.

Foreword

This issue of *Flight Safety Digest* presents the Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Briefing Notes. This set of 34 unique documents is one product of the ongoing work of volunteers (see page vi) throughout the world who — with the support of their organizations — have addressed the primary causes of fatalities in commercial aviation. The Foundation-led controlled-flight-into-terrain (CFIT)/ALAR accident-reduction effort was begun in the early 1990s.

The briefing notes are a follow-on to "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents" published in *Flight Safety Digest* in early 1999. They are one product in the extraordinary FSF *ALAR Tool Kit*, which will be released officially by the Foundation in January 2001. The tool kit is published on a compact disc (compatible with Macintosh® and Windows® operating systems) and includes a variety of products, all aimed to help prevent ALAs, including those involving CFIT. Nearly all of the products can be viewed and printed from the CD, which includes the following:

- Several Microsoft® PowerPoint® presentations review a variety of topics in the context of ALAs such as air traffic control (ATC), flight operations and training, aircraft and ground equipment, CFIT, and the economics of safety;
- FSF *Approach-and-landing Risk Assessment Tool* raises flight crew awareness of hazards in that phase of flight;
- FSF *Approach-and-landing Risk Reduction Guide* provides chief pilots, line pilots and dispatchers with a means to determine if training, standard operating procedures and equipment are adequate to cope with risks;
- FSF *CFIT Checklist* is a risk-assessment tool that can be used to evaluate specific flight operations and enhance pilot awareness of CFIT;
- A variety of posters (produced by *Business & Commercial Aviation*) illustrate important messages based on the recommendations of the task force;
- FSF *Standard Operating Procedures Template*;
- Nearly 100 selected FSF publications are linked to the briefing notes and provide additional facts and examples;
- FSF *Controlled Flight Into Terrain: An Encounter Avoided* is a video that reviews a business aviation ALA involving CFIT; and,
- A variety of other products.

The following conclusions and recommendations, adapted from task force findings, provided the framework for the briefing notes:

Conclusion No. 1: Establishing and adhering to adequate standard operating procedures (SOPs) and flight crew decision-making processes improve approach-and-landing safety.

Recommendations

- Nations should mandate, and operators should develop and implement, SOPs for approach-and-landing operations. The data showed that the absence of SOPs resulted in higher exposure to approach-and-landing incidents and accidents.
- Operators should develop practical SOPs for a normal operating environment. The involvement of pilots is essential in the development and evaluation of SOPs; they will identify and will help eliminate inadequate procedures; and they will support adherence to SOPs that they helped to create.
- Operators should conduct regular evaluations of SOPs to remove procedures that are obsolete or ineffective, and to include new ones as required. Pilot input should be a primary resource for such evaluations.
- Operators should provide education and training that enhance flight crew decision making and risk management. Whether the training comprises a version of crew resource management (CRM) or other aids, the goal is to develop satisfactory flight crew decision making. Sufficient resources must be allocated to achieve this goal.
- Operators should develop SOPs for the use of automation in approach-and-landing operations, and train flight crews accordingly.
- All operators should have a written policy in their flight operations manuals (FOMs) for defining the role of the pilot-in-command in operationally demanding situations. The data show that task saturation and overload of the pilot flying are factors in ALAs. Company policy on the sharing of flight deck duties must recognize that the effective distribution of tasks and decision making among crewmembers is essential to avoid overloading the pilot flying. Training should provide SOPs for the practice of transferring pilot-flying duties during operationally demanding situations.

Conclusion No. 2: Failure to recognize the need for a missed approach and to execute a missed approach is a major cause of ALAs.

Recommendations

- Company policy should specify a well-defined approach gate for approach-and-landing. Criteria for reaching the decision to conduct a go around should include:
  - Visibility minimums required before proceeding past the final approach fix (FAF) or the outer marker (OM);
  - Assessment at FAF or OM of crew and aircraft readiness for the approach; and,
  - Minimum altitude at which the aircraft must be stabilized.
- Companies should implement and should support no-fault go-around policies. Training systems and company management should reinforce those policies.

Conclusion No. 3: Unstabilized approaches cause ALAs.

Recommendations

- Operators should define the required elements of a stabilized approach in their FOMs, including at least the following:
  - Flight path;

- Airspeed;
- Power setting;
- Attitude;
- Sink rate;
- Configuration; and,
- Crew readiness.

- Company policy should state that a go-around is required if the aircraft becomes unstabilized during the approach. Training should reinforce this policy.
- Pilots should "take time to make time" when the flight deck environment becomes task saturated or confusing. This means climbing, holding, requesting vectors for delaying purposes, or conducting a missed approach. "Rushing" approaches and "press-on-itis" (continuing toward the destination despite a lack of readiness of the airplane or flight crew) are factors in ALAs.
- Nonprecision approaches are five-times more hazardous than precision approaches. The implementation of constant-angle nonprecision approach (CANPA) procedures should be expedited globally, and pilots should be trained to use them.
- Pilots also should be educated on approach-design criteria and obstacle-clearance requirements.

Conclusion No. 4: Improving communication and mutual understanding between controllers and pilots of each other's operational environment will improve approach-and-landing safety.

Recommendations

ATC should:

- Introduce joint training programs that involve controllers and pilots to:
  - Promote mutual understanding of each other's procedures, instructions, operational requirements and limitations;
  - Improve controllers' knowledge of the capabilities and limitations of advanced-technology flight decks; and,
  - Foster improved communication and task management by pilots and controllers during emergency situations.
- Ensure that controllers are aware of the hazards of ambiguous communication, particularly during in-flight emergencies. The use of standard ICAO phraseology should be emphasized.
- Implement procedures that require immediate clarification/verification by a controller if communication from a pilot indicates a possible emergency.
- Implement procedures for ATC handling of aircraft in emergency situations to minimize pilot distractions.
- In cooperation with airport authorities and rescue services, implement procedures for emergencies and implement standard phraseology.
- Develop, jointly with airport authorities and local rescue services, training programs that are conducted on a regular basis.

Pilots should:

- Confirm each communication with the controller and request clarification/verification when necessary.
- Report accurately abnormal/emergency situations, and use ICAO standard phraseology.

Conclusion No. 5: The risk of ALAs increases in operations conducted in low light and poor visibility, on wet runways, or runways contaminated by standing water, snow, slush or ice, and with the presence of visual/physiological illusions.

Recommendations

- Pilots should be trained to recognize these conditions before they are assigned line duties.
- Pilots should use a risk assessment tool or a checklist to identify approach-and-landing hazards; appropriate SOPs should be implemented to reduce risk.
- Operators should develop and should implement CANPA procedures to enable pilots to conduct stabilized approaches.
- Operators should develop and should implement a policy for the use of appropriate levels of automation for the approach being flown.

Conclusion No. 6: Using the radio altimeter effectively will help prevent ALAs.

Recommendations

Education is needed to improve pilot awareness of radio-altimeter operation and its benefits.

- Operators should install radio altimeters in their aircraft and activate "smart call-outs" at 2,500 feet, 1,000 feet, 500 feet, the altitude set in the DH (decision height) window, 50 feet, 40 feet, 30 feet, 20 feet and 10 feet for terrain awareness. The smart-call-outs system recognizes when an ILS approach is being conducted, and some call-outs can be eliminated to prevent confusion.
- Operators should and specify SOPs for radio altimeter and require that the radio altimeter be used during the approach.
- Development and installation of advanced terrain awareness and warning systems (TAWS) should be continued; "enhanced ground-proximity warning system" and "ground collision avoidance system" are other terms used to describe TAWS equipment. TAWS is effective in reducing CFIT accidents. This recommendation, however, recognizes that time will be required to implement TAWS worldwide and to ensure that terrain-awareness tools are used correctly.

Conclusion No. 7: Collection and analysis of in-flight data (e.g., flight operational quality assurance [FOQA] programs) can be used to identify trends that can be used to improve approach-and-landing safety.

Recommendations

- FOQA should be implemented worldwide in conjunction with information-sharing partnerships such as the Global Aviation Information Network (GAIN), British Airways Safety Information System (BASIS) and FAA Aviation Safety Action Program (ASAP).
- Examples of FOQA benefits (safety improvements and cost reductions) should be publicized widely.
- A process should be fostered to develop FOQA and information-sharing partnerships among regional airlines and business aviation operators.

Conclusion No. 8: Global sharing of aviation information decreases the risk of ALAs.

Recommendations

- De-identification of data is essential in FOQA/information-sharing programs.
- Pilots who are aware of an accident and its causes are likely to avoid repeating the events that would lead to a similar accident. Distribution of accident reports in the pilots' native languages will enhance their understanding of safety information.

- Public awareness of the importance of FOQA/information sharing must be increased through a coordinated and responsible process.

Optimum Use of Current Technology/Equipment

- Operators should consider the immediate benefit of optimizing the use of current technology such as:
  - TAWS;
  - Quick access recorder (QARs) to support FOQA programs;
  - Radio altimeter with smart call-outs;
  - Precision approach guidance, whenever available, and visual approach slope indicator (VASI) or precision approach path indicator (PAPI) during the visual segment of the approach;
  - Global positioning system (GPS)-based lateral navigation and barometric vertical navigation (pending enhancements that will enable precision approaches with GPS);
  - Communication/navigation/surveillance (CNS) equipment, such as controller-pilot data-link communication;
  - Mechanical checklists or electronic checklists to improve checklist compliance (particularly amid interruptions/distractions); and,
  - Airport/approach familiarization programs based on:
    - Charts printed at high-resolution;
    - Video display; and/or,
    - Simulator visual presentations.

Together, we continue to make a safe transportation system safer.

Stuart Matthews
President and CEO
Flight Safety Foundation

November 2000

CFIT/ALAR Action Group (CAAG)

In April 1998, the CFIT/ALAR Action Group (CAAG) was created to supersede the FSF ALAR Task Force. The CAAG is involved currently in implementing the task force's recommendations.

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ALAR

Approach-and-landing Accident Reduction

Tool Kit

ALAR Briefing Notes

The Go-around

Approach Techniques

Landing Techniques

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Approach-and-landing Accident Reduction

Tool Kit

Introduction to ALAR Briefing Notes

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Briefing Notes were produced to help prevent ALAs, including those involving controlled flight into terrain. The briefing notes are based on the data-driven conclusions and recommendations of the FSF ALAR Task Force, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

Generally, each briefing note includes the following:

- Statistical data related to the topic;
- Recommended standard operating procedures;
- Discussion of factors that contribute to excessive deviations that cause ALAs;
- Suggested accident-prevention strategies for companies and personal lines of defense for individuals;
- Summary of facts;
- Cross-references to other briefing notes;
- Cross-references to selected FSF publications; and,
- References to relevant International Civil Aviation Organization standards and recommended practices, U.S. Federal Aviation Regulations and European Joint Aviation Requirements.

Developed as an aid to education and training, the briefing notes can be used by a variety of aviation professionals in company management, flight operations and air traffic control for:

- Assessment of risk exposure;
- Development/enhancement of accident-prevention strategies for companies and personal lines of defense for individuals;
- Development/enhancement of standard operating procedures/best practices;
- Development/enhancement of simulator training;
- Development/enhancement of crew resource management;
- Information in company bulletins;
- Safety features in publications;
- Classroom discussions/lectures; and.
- Self-study.

The briefing notes have been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for those who operate fuselage-mounted turbine engines, turboprop-powered airplanes and piston-powered airplanes) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturer's/operator's standard operating procedures; and,
- Two-person flight crew.

The information in the briefing notes is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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Approach-and-landing Accident Reduction

Tool Kit

FSF ALAR Briefing Note 1.1 — Operating Philosophy

Adherence to standard operating procedures (SOPs) is an effective method of preventing approach-and-landing accidents (ALAs), including those involving controlled flight into terrain (CFIT).

Crew resource management (CRM) is not effective without adherence to SOPs.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that "omission of action/ inappropriate action" (i.e., *inadvertent* deviation from SOPs) was a causal factor[1] in 72 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[2]

The task force also found that "deliberate nonadherence to procedures" was a causal factor in 40 percent of the accidents and serious incidents.

Manufacturer's SOPs

SOPs published by an airframe manufacturer are designed to:

- Reflect the manufacturer's flight deck design philosophy and operating philosophy;
- Promote optimum use of aircraft design features; and,
- Apply to a broad range of company operations and environments.

The initial SOPs for a new aircraft model are based on the manufacturer's objectives and on the experience acquired during flight-testing programs and route-proving programs.

After they are introduced into service, SOPs are reviewed periodically and are improved based on feedback received from users (in training and in line operations).

Customized SOPs

An airframe manufacturer's SOPs can be adopted "as is" by a company or can be used to develop customized SOPs.

Changes to the airframe manufacturer's SOPs should be coordinated with the manufacturer and should be approved by the appropriate authority.

SOPs must be clear and concise; expanded information should reflect the company's operating philosophy and training philosophy.

U.S. Federal Aviation Administration (FAA) Advisory Circular 120-71, *Standard Operating Procedures for Flight Deck Crewmembers*, published Aug. 10, 2000, includes a list of generic topics that can be used for the development of company SOPs (see *Standard Operating Procedures Template*, page 6).

Company SOPs usually are developed to ensure standardization among different aircraft fleets operated by the company.

Company SOPs should be reassessed periodically, based on revisions of the airframe manufacturer's SOPs and on internal company feedback, to identify any need for change.

Flight crews and cabin crews should participate with flight standards personnel in the development and revision of company SOPs to:

- Promote constructive feedback; and,
- Ensure that the SOPs, as well as the reasons for their adoption, are understood fully by users.

Scope of SOPs

The primary purpose of SOPs is to identify and describe the standard tasks and duties of the flight crew for each flight phase.

SOPs generally are performed by recall, but tasks related to the selection of systems and to the aircraft configuration should be cross-checked with normal checklists.

SOPs are supplemented usually by information about specific operating techniques or by recommendations for specific types of operations (e.g., operation on wet runways or contaminated runways, extended-range twin-engine operations [ETOPS] and/or operation in reduced vertical separation minimums [RVSM] airspace).

SOPs assume that all aircraft systems are operating normally and that all automatic functions are used normally. (A system may be partially inoperative or totally inoperative without affecting the SOPs.)

SOPs should emphasize the following items:

- Operating philosophy;
- Task-sharing;
- Optimum use of automation;
- "Golden rules" (see FSF ALAR Briefing Note *1.3 — Golden Rules*);
- Standard calls;
- Normal checklists;
- Approach briefings;
- Altimeter-setting and cross-checking procedures;
- Descent profile management;
- Energy management;
- Terrain awareness;
- Approach hazards awareness;
- Radio altimeter;
- Elements of a stabilized approach (see Table 1) and approach gate[3];
- Approach procedures and techniques;
- Landing and braking techniques; and,
- Preparation and commitment to go around.

Table 1
Recommended Elements Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

General Principles

SOPs should contain safeguards to minimize the potential for inadvertent deviations from SOPs, particularly when operating under abnormal conditions or emergency conditions, or when interruptions/distractions occur.

Safeguards include:

- Action blocks — groups of actions being accomplished in sequence;
- Triggers — events that initiate action blocks;
- Action patterns — instrument panel scanning sequences or patterns supporting the flow and sequence of action blocks; and,

- Standard calls — standard phraseology and terms used for effective crew communication.

Standardization

SOPs are the reference for crew standardization and establish the working environment required for CRM.

Task-sharing

The following guidelines apply to any flight phase but are particularly important to the high-workload approach-and-landing phases.

The pilot flying (PF) is responsible for controlling the horizontal flight path and the vertical flight path, and for energy management, by:

- Supervising autopilot operation and autothrottle operation (maintaining awareness of the modes armed or selected, and of mode changes); or,
- Hand-flying the aircraft, with or without flight director (FD) guidance, and with an appropriate navigation display (e.g., horizontal situation indicator [HSI]).

The pilot not flying (PNF) is responsible for monitoring tasks and for performing the actions requested by the PF; this includes:

- Performing the standard PNF tasks:
  - SOP actions; and,
  - FD and flight management system (FMS) mode selections and target entries (e.g., altitude, airspeed, heading, vertical speed, etc.), when the PF is hand-flying the aircraft;
- Monitoring systems and aircraft configuration; and,
- Cross-checking the PF to provide backup as required (this includes both flight operations and ground operations).

Automation

With higher levels of automation, flight crews have more options and strategies from which to select for the task to be accomplished.

Company SOPs should define accurately the options and strategies available for the various phases of flight and for the various types of approaches.

Training

Disciplined use of SOPs and normal checklists should begin during transition training, because habits and routines acquired during transition training have a lasting effect.

Transition training and recurrent training provide a unique opportunity to discuss the reasons for SOPs and to discuss the consequences of failing to adhere to them.

Conversely, allowing deviations from SOPs and/or normal checklists during initial training or recurrent training may encourage deviations during line operations.

Deviations From SOPs

To ensure adherence to published SOPs, it is important to understand why pilots intentionally or inadvertently deviate from SOPs.

In some intentional deviations from SOPs, the procedure that was followed in place of the SOP seemed to be appropriate for the prevailing situation.

The following factors and conditions are cited often in discussing deviations from SOPs:

- Inadequate knowledge or failure to understand the procedure (e.g., wording or phrasing was not clear, or the procedure was perceived as inappropriate);
- Insufficient emphasis during transition training and recurrent training on adherence to SOPs;
- Inadequate vigilance (e.g., fatigue);
- Interruptions (e.g., communication with air traffic control);
- Distractions (e.g., flight deck activity);
- Task saturation;
- Incorrect management of priorities (e.g., lack of a decision-making model for time-critical situations);
- Reduced attention (tunnel vision) in abnormal conditions or high-workload conditions;
- Inadequate CRM (e.g., inadequate crew coordination, cross-check and backup);
- Company policies (e.g., schedules, costs, go-arounds and diversions);
- Other policies (e.g., crew duty time);
- Personal desires or constraints (e.g., schedule, mission completion);
- Complacency; and,
- Overconfidence.

These factors may be used to assess company exposure to deviations and/or personal exposure to deviations, and to develop corresponding methods to help prevent deviations from SOPs.

Summary

Deviations from SOPs occur for a variety of reasons; intentional deviations and inadvertent deviations from SOPs have been identified as causal factors in many ALAs.

CRM is not effective without adherence to SOPs, because SOPs provide a standard reference for the crew's tasks on the flight deck. SOPs are effective only if they are clear and concise.

Transition training provides the opportunity to establish the disciplined use of SOPs, and recurrent training offers the opportunity to reinforce that behavior.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.2 — Automation*;
- *1.3 — Golden Rules*;
- *1.4 — Standard Calls*;
- *1.5 — Normal Checklists*;
- *1.6 — Approach Briefing*;
- *2.1 — Human Factors*; and,
- *2.2 — Crew Resource Management*.♦

References

1. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]." Each accident and incident in the study sample involved several causal factors.

2. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

3. The FSF ALAR Task Force defines *approach gate* as "a point in space (1,000 feet above airport elevation in instrument meteorological conditions or 500 feet above airport elevation in visual meteorological conditions) at which a go-around is required if the aircraft does not meet defined stabilized approach criteria."

Related Reading From FSF Publications

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Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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Standard Operating Procedures Template

[The following template is adapted from U.S. Federal Aviation Administration (FAA) Advisory Circular 120-71, *Standard Operating Procedures for Flight Deck Crewmembers*.]

A manual or a section in a manual serving as the flight crew's guide to standard operating procedures (SOPs) may serve also as a training guide. The content should be clear and comprehensive, without necessarily being lengthy. No template could include every topic that might apply unless it were constantly revised. Many topics involving special operating authority or new technology are absent from this template, among them extended-range twin-engine operations (ETOPS), precision runway monitor (PRM), surface movement guidance system (SMGS), required navigation performance (RNP) and many others.

The following are nevertheless viewed by industry and FAA alike as examples of topics that constitute a useful template for developing comprehensive, effective SOPs:

- Captain's authority;
- Use of automation, including:
  - The company's automation philosophy;
  - Specific guidance in selection of appropriate levels of automation;
  - Autopilot/flight director mode selections; and,
  - Flight management system (FMS) target entries (e.g., airspeed, heading, altitude);
- Checklist philosophy, including:
  - Policies and procedures (who calls for; who reads; who does);
  - Format and terminology; and,
  - Type of checklist (challenge-do-verify, or do-verify);
- Walk-arounds;
- Checklists, including:
  - Safety check prior to power on;
  - Originating/receiving;
  - Before start;
  - After start;
  - Before taxi;
  - Before takeoff;
  - After takeoff;
  - Climb check;
  - Cruise check;
  - Approach;
  - Landing;
  - After landing;
  - Parking and securing;
  - Emergency procedures; and,
  - Abnormal procedures;
- Communication, including:
  - Who handles radios;
  - Primary language used with air traffic control (ATC) and on the flight deck;
  - Keeping both pilots "in the loop";
  - Company radio procedures;
  - Flight deck signals to cabin; and,
  - Cabin signals to flight deck;

- Briefings, including:
  - Controlled-flight-into-terrain (CFIT) risk considered;
  - Special airport qualifications considered;
  - Temperature corrections considered;
  - Before takeoff; and,
  - Descent/approach/missed approach;
- Flight deck access, including:
  - On ground/in flight;
  - Jump seat; and,
  - Access signals, keys;
- Flight deck discipline, including:
  - "Sterile cockpit"[1];
  - Maintaining outside vigilance;
  - Transfer of control;
  - Additional duties;
  - Flight kits;
  - Headsets/speakers;
  - Boom mikes/handsets;
  - Maps/approach charts; and,
  - Meals;
- Altitude awareness, including:
  - Altimeter settings;
  - Transition altitude/flight level;
  - Standard calls (verification of);
  - Minimum safe altitudes (MSAs); and,
  - Temperature corrections;
- Report times; including:
  - Check in/show up;
  - On flight deck; and,
  - Checklist accomplishment;
- Maintenance procedures, including:
  - Logbooks/previous write-ups;
  - Open write-ups;
  - Notification to maintenance of write-ups;
  - Minimum equipment list (MEL)/dispatch deviation guide (DDG);
  - Where MEL/DDG is accessible;
  - Configuration deviation list (CDL); and,
  - Crew coordination in ground deicing;
- Flight plans/dispatch procedures, including:
  - Visual flight rules/instrument flight rules (VFR/IFR);
  - Icing considerations;
  - Fuel loads;
  - Weather-information package;
  - Where weather-information package is available; and,
  - Departure procedure climb gradient analysis;
- Boarding passengers/cargo, including:
  - Carry-on baggage;
  - Exit-row seating;
  - Hazardous materials;
  - Prisoners/escorted persons;
  - Firearms onboard; and,
  - Count/load;
- Pushback/powerback;
- Taxiing, including:
  - Single-engine;
  - All-engines;
  - On ice or snow; and,
  - Prevention of runway incursion;
- Crew resource management (CRM), including crew briefings (cabin crew and flight crew);
- Weight and balance/cargo loading, including:
  - Who is responsible for loading cargo and securing cargo; and,
  - Who prepares the weight-and-balance data form; who checks the form; and how a copy of the form is provided to the crew;
- Flight deck/cabin crew interchange, including:
  - Boarding;
  - Ready to taxi;
  - Cabin emergency; and,
  - Prior to takeoff/landing;
- Takeoff, including:

- Who conducts the takeoff;
- Briefing, VFR/IFR;
- Reduced-power procedures;
- Tail wind, runway clutter;
- Intersections/land and hold short operations (LAHSO) procedures;
- Noise-abatement procedures;
- Special departure procedures;
- Use/nonuse of flight directors;
- Standard calls;
- Cleanup;
- Loss of engine, including rejected takeoff after V_1 (actions/standard calls);
- Flap settings, including:
  - Normal;
  - Nonstandard and reason for; and,
  - Crosswind; and,
- Close-in turns;

- Climb, including:
  - Speeds;
  - Configuration;
  - Confirm compliance with climb gradient required in departure procedure; and,
  - Confirm appropriate cold-temperature corrections made;
- Cruise altitude selection (speeds/weights);
- Position reports to ATC and to company;
- Emergency descents;
- Holding procedures;
- Procedures for diversion to alternate airport;
- Normal descents, including:
  - Planning top-of-descent point;
  - Risk assessment and briefing;
  - Use/nonuse of speedbrakes;
  - Use of flaps/gear;
  - Icing considerations; and,
  - Convective activity;
- Ground-proximity warning system (GPWS) or terrain awareness and warning system (TAWS)[2] recovery ("pull-up") maneuver;
- Traffic-alert and collision avoidance system (TCAS)/ airborne collision avoidance system (ACAS);
- Wind shear, including:
  - Avoidance of likely encounters;
  - Recognition; and,
  - Recovery/escape maneuver;
- Approach philosophy, including:
  - Precision approaches preferred;
  - Stabilized approaches standard;
  - Use of navigation aids;
  - FMS/autopilot use and when to discontinue use;
  - Approach gate[3] and limits for stabilized approaches, (Table 1);
  - Use of radio altimeter; and,
  - Go-arounds (plan to go around; change plan to land when visual, if stabilized);
- Individual approach type (all types, including engine-out approaches);
- For each type of approach:
  - Profile;
  - Flap/gear extension;
  - Standard calls; and,
  - Procedures;
- Go-around/missed approach, including:
  - Initiation when an approach gate is missed;
  - Procedure;
  - Standard calls; and,
  - Cleanup profile; and,
- Landing, including:
  - Actions and standard calls;
  - Configuration for conditions, including:
    - Visual approach;
    - Low visibility; and,
    - Wet or contaminated runway;
  - Close-in turns;
  - Crosswind landing;
  - Rejected landing; and,
  - Transfer of control after first officer's landing.

Table 1
Recommended Elements of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1, November 2000)

References

1. The *sterile cockpit rule* refers to U.S. Federal Aviation Regulations Part 121.542, which states: "No flight crewmember may engage in, nor may any pilot-in-command permit, any activity during a critical phase of flight which could distract any flight crewmember from the performance of his or her duties or which could interfere in any way with the proper conduct of those duties. Activities such as eating meals, engaging in nonessential conversations within the cockpit and nonessential communications between the cabin and cockpit crews, and reading publications not related to the proper conduct of the flight are not required for the safe operation of the aircraft. For the purposes of this section, critical phases of flight include all ground operations involving taxi, takeoff and landing, and all other flight operations below 10,000 feet, except cruise flight." [The FSF ALAR Task Force says that "10,000 feet" should be height above ground level during flight operations over high terrain.]
2. Terrain awareness and warning system (TAWS) is the term used by the European Joint Aviation Authorities and the U.S. Federal Aviation Administration to describe equipment meeting International Civil Aviation Organization standards and recommendations for ground-proximity warning system (GPWS) equipment that provides predictive terrain-hazard warnings. "Enhanced GPWS" and "ground collision avoidance system" are other terms used to describe TAWS equipment.
3. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *approach gate* as "a point in space (1,000 feet above airport elevation in instrument meteorological conditions or 500 feet above airport elevation in visual meteorological conditions) at which a go-around is required if the aircraft does not meet defined stabilized approach criteria."

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FSF ALAR Briefing Note 1.2 — Automation

Three generations of system automation for airplane flight guidance — autopilot/flight director (AP/FD), autothrottles (A/THR) and flight management system (FMS) — are currently in service:

- The first generation features a partial integration of the AP/FD and A/THR modes, offering *selected AP/FD modes and lateral navigation only*;
- The second generation features complete integration (pairing) of AP/FD and A/THR modes and offers *selected modes as well as lateral navigation and vertical navigation (FMS)*; and,
- The third generation features *full-regime lateral navigation (LNAV) and vertical navigation (VNAV)*.

High levels of automation provide flight crews with more options from which to select for the task to be accomplished.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that inadequate flight crew interaction with automatic flight systems was a causal factor[1] in 20 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[2]

The task force said that these accidents and incidents involved crew unawareness of automated system modes or crew unfamiliarity with automated systems.

AP-A/THR Integration

Integrated AP-A/THR automatic flight systems (AFSs) feature pairing of the AP pitch modes (elevator control) and the A/THR modes (throttles/thrust control).

An integrated AP-A/THR flies the aircraft the same way as a human pilot:

- The elevator is used to control pitch attitude, airspeed, vertical speed, altitude, flight path angle or VNAV profile, or to track a glideslope; and,
- The throttle levers are used to maintain a given thrust setting or a given airspeed.

Depending on the task to be accomplished, maintaining a given airspeed is assigned either to the AP or to the A/THR, as shown in Table 1.

Table 1
Autothrottle/Autopilot Integration

Autothrottles	Autopilot
Throttles/thrust	Elevators
Thrust or idle	Airspeed
Airspeed	Vertical speed Vertical navigation Altitude Glideslope

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force.

Design Objective

The design objective of the AFS is to provide assistance to the crew throughout the flight, by:

- Relieving the pilot flying (PF) from routine tasks, thus allowing time and resources to enhance his/her situational awareness or for problem-solving tasks; and,
- Providing the PF with adequate attitude guidance and flight-path guidance through the FD for hand-flying the aircraft.

The AFS provides guidance along the defined flight path and at the intended airspeed, in accordance with the modes selected by the crew and the targets (e.g., altitude, airspeed, heading, vertical speed, waypoints, etc.) entered by the crew.

The AFS control panel is the main interface between the pilot and the AFS for *short-term guidance* (i.e., for the current flight phase).

The FMS control display unit (CDU) is the main interface between the pilot and the AFS for *long-term guidance* (i.e., for the current flight phase and subsequent flight phases).

On aircraft equipped with an FMS featuring LNAV and VNAV, two types of guidance (modes and associated targets) are available:

- *Selected guidance*:
  - The aircraft is guided along a flight path defined by the modes selected and the targets entered by the crew on the AFS control panel; and,
- *FMS guidance*:
  - The aircraft is guided along the FMS lateral flight path and vertical flight path; the airspeed and altitude targets are optimized by the FMS (adjusted for restrictions of altitude and/or airspeed).

Automated Systems

Understanding any automated system, but particularly the AFS and FMS, requires answering the following questions:

- How is the system designed?
- Why is the system designed this way?
- How does the system interface and communicate with the pilot?
- How is the system operated in normal conditions and abnormal conditions?

Pilot-Automation Interface

To use the full potential of automation and to maintain situational awareness, a thorough understanding of the interface between the pilot and the automation is required to allow the pilot to answer the following questions at any time:

- What did I tell the aircraft to do?
- Is the aircraft doing what I told it to do?
- What did I plan for the aircraft to do next?

(The terms “tell” and “plan” in the above paragraph refer to arming or selecting modes and/or entering targets.)

The functions of the following controls and displays must be understood:

- AFS mode-selection keys, target-entry knobs and display windows;
- FMS CDU keyboard, line-select keys, display pages and messages;
- Flight-mode annunciator (FMA) annunciations; and,
- Primary flight display (PFD) and navigation display (ND) data.

Effective monitoring of these controls and displays promotes and increases pilot awareness of:

- The status of the system (modes armed and selected); and,
- The available guidance (for flight-path control and airspeed control).

Effective monitoring of controls and displays also enables the pilot to predict and to anticipate the entire sequence of flight-mode annunciations throughout successive flight phases (i.e., throughout mode changes).

Operating Philosophy

FMS or selected guidance can be used in succession or in combination (e.g., FMS lateral guidance together with selected vertical guidance) as best suited for the flight phase and prevailing conditions.

Operation of the AFS must be monitored at all times by:

- Cross-checking the status of AP/FD and A/THR modes (armed and selected) on the FMA;
- Observing the result of any target entry (on the AFS control panel) on the related data as displayed on the PFD or ND; and,

- Supervising the resulting AP/FD guidance and A/THR operation on the PFD and ND (e.g., attitude, airspeed and airspeed trend, altitude, vertical speed, heading, etc.).

The PF always retains the authority and the capability to use the most appropriate guidance and level of automation for the task. This includes:

- Reverting from FMS guidance to selected guidance (more direct level of automation);

- Selecting a more appropriate lateral mode or vertical mode; or,

- Reverting to hand-flying (with or without FD, with or without A/THR) for direct control of the aircraft trajectory and thrust.

If doubt exists about the aircraft's flight path or airspeed control, no attempt should be made to reprogram the automated systems. Selected guidance or hand-flying with raw data[3] should be used until time and conditions permit reprogramming the AP/FD or FMS.

If the aircraft does not follow the intended flight path, check the AP engagement status. If engaged, the AP must be disconnected using the AP-disconnect switch to revert to hand-flying with FD guidance or with reference to raw data.

When hand-flying, the FD commands should be followed; otherwise, the FD command bars should be cleared from the PFD.

If the A/THR does not function as desired, the A/THR must be disconnected using the A/THR-disconnect switch to revert to manual thrust control.

AP systems and A/THR systems must not be overridden manually (except under conditions set forth in the aircraft operating manual [AOM] or quick reference handbook [QRH]).

Factors and Errors

The following factors and errors can cause an incorrect flight path, which — if not recognized — can lead to an approach-and-landing accident, including one involving controlled flight into terrain:

- Inadvertent arming of a mode or selection of an incorrect mode;

- Failure to verify the armed mode or selected mode by reference to the FMA;

- Entering an incorrect target (e.g., altitude, airspeed, heading) on the AFS control panel and failure to confirm the entered target on the PFD and/or ND;

- Changing the AFS control panel altitude target to any altitude below the final approach intercept altitude during approach;

- Inserting an incorrect waypoint;

- Arming the LNAV mode with an incorrect active waypoint (i.e., with an incorrect "TO" waypoint);

- Preoccupation with FMS programming during a critical flight phase, with consequent loss of situational awareness;

- Inadequate understanding of mode changes (e.g., mode confusion, automation surprises);

- Inadequate task-sharing and/or inadequate crew resource management (CRM), preventing the PF from monitoring the flight path and airspeed (e.g., both pilots being engaged in the management of automation or in the troubleshooting of an unanticipated or abnormal condition); and,

- Engaging the AP or disengaging the AP when the aircraft is in an out-of-trim condition.

Recommendations

Proper use of automated systems reduces workload and increases the time and resources available to the flight crew for responding to any unanticipated change or abnormal/emergency condition.

During normal line operations, the AP and A/THR should be engaged throughout the flight, including the descent and the approach, especially in marginal weather or when operating into an unfamiliar airport.

Using the AFS also enables the flight crew to give more attention to air traffic control (ATC) communications and to other aircraft, particularly in congested terminal areas.

The AFS/FMS also is a valuable aid during a go-around or missed approach.

When the applicable missed approach procedure is included in the FMS flight plan and the FMS navigation accuracy has been confirmed, the LNAV mode reduces workload during this critical flight phase.

Safe-and-efficient use of the AFS and FMS is based on the following three-step method:

- Anticipate:

  – Understand system operation and the result(s) of any action, be aware of modes being armed or selected, and seek concurrence of other flight crewmember(s);

- Execute:
  - Perform the action on the AFS control panel or on the FMS CDU; and,
- Confirm:
  - Cross-check armed modes, selected modes and target entries on the FMA, PFD/ND and FMS CDU.

The following recommendations support the implementation of the three-step method:

- Before engaging the AP, ensure that:
  - The modes selected for FD guidance (as shown by the FMA) are the correct modes for the intended flight phase; and,
  - The FD command bars do not show large flight-path-correction commands (if large corrections are commanded, hand-fly the aircraft to center the FD command bars [engaging the AP while large flight-path corrections are required may result in overshooting the intended target]);
- Before taking any action on the AFS control panel, check that the knob or push-button is the correct one for the desired function;
- After each action on the AFS control panel, verify the result of the action by reference to the FMA (for mode arming or mode selection) and to other PFD/ND data (for entered targets) or by reference to the flight path and airspeed;
- Monitor the FMA and call all mode changes in accordance with standard operating procedures (SOPs);
- When changing the altitude entered on the AFS control panel, cross-check the selected-altitude readout on the PFD:
  - During descent, check whether the entered altitude is below the minimum en route altitude (MEA) or minimum safe altitude (MSA) — if the entered altitude is below the MEA or MSA, obtain altitude confirmation from ATC; and,
  - During final approach, set the go-around altitude on the AFS control panel altitude window (the minimum descent altitude/height [MDA(H)] or decision altitude/height [DA(H)] should *not* be set in the window);
- Prepare the FMS for arrival before beginning the descent;
- An expected alternative arrival routing and/or runway can be prepared on the second flight plan;
- If a routing change occurs (e.g., "DIR TO" [direct to a waypoint]), cross-check the new "TO" waypoint before selecting the "DIR TO" mode (making sure that the intended "DIR TO" waypoint is not already behind the aircraft):
  - Caution is essential during descent in mountainous areas; and,
  - If necessary, the selected heading mode and raw data can be used while verifying the new route;
- Before arming the LNAV mode, ensure that the correct active waypoint (i.e., the "TO" waypoint) is displayed on the FMS CDU and ND (as applicable);
- If the displayed "TO" waypoint is not correct, the desired "TO" waypoint can be restored by either:
  - Deleting an intermediate waypoint; or,
  - Performing a "DIR TO" the desired waypoint; and then,
  - Monitoring the interception of the lateral flight path;
- If a late routing change or runway change occurs, reversion to selected modes and raw data is recommended;
- Reprogramming the FMS during a critical flight phase (e.g., in terminal area, on approach or go-around) is not recommended, except to activate the second flight plan, if needed. Primary tasks are, in order of priority:
  - Lateral flight path control and vertical flight path control;
  - Altitude awareness and traffic awareness; and,
  - ATC communications;
- No attempt should be made to analyze or to correct an anomaly by reprogramming the AFS or the FMS until the desired flight path and airspeed are restored;
- If cleared to leave a holding pattern on a radar vector, the holding exit prompt should be pressed (or the holding pattern otherwise deleted) to allow the correct sequencing of the FMS flight plan;
- On a radar vector, when intercepting the final approach course in a selected mode (e.g., heading, localizer capture, etc. [not LNAV]), the flight crew should ensure that the FMS flight plan is sequencing normally by checking that the "TO" waypoint (on the FMS CDU and the ND, as applicable) is correct, so that the LNAV mode can be re-selected for a go-around;
- If the FMS flight plan does not sequence correctly, the correct sequencing can be restored by either:
  - Deleting an intermediate waypoint; or,

– Performing a "DIR TO" a waypoint ahead in the approach;

– Otherwise, the LNAV mode should not be used for the remainder of the approach or for a go-around; and,

- Any time the aircraft does not follow the desired flight path and/or airspeed, do not hesitate to revert to a lower (more direct) level of automation. For example:

  – Revert from FMS to selected modes;

  – Disengage the AP and follow FD guidance;

  – Disengage the FD, select the flight path vector (FPV [as available]) and fly raw data or fly visually (if in visual meteorological conditions); and/or,

  – Disengage the A/THR and control the thrust manually.

Summary

For optimum use of automation, the following should be emphasized:

- Understanding of AP/FD and A/THR modes integration (pairing);
- Understanding of all mode-change sequences;
- Understanding of the pilot-system interface:
  – Pilot-to-system communication (mode selection and target entries); and,
  – System-to-pilot feedback (modes and target cross-check);
- Awareness of available guidance (AP/FD and A/THR status, modes armed or engaged, active targets); and,
- Alertness and willingness to revert to a lower level of automation or to hand-flying/manual thrust control, if required.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.3 — Golden Rules*; and,
- *1.4 — Standard Calls*.♦

References

1. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]." Each accident and incident in the study sample involved several causal factors.

2. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

3. The FSF ALAR Task Force defines *raw data* as "data received directly (not via the flight director or flight management computer) from basic navigation aids (e.g., ADF, VOR, DME, barometric altimeter)."

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ICAO. Circular 234, *Human Factors Digest No. 5*, "Operational Implications of Automation in Advanced Technology Flight Decks." 1992.

Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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ALAR

Approach-and-landing Accident Reduction

Tool Kit

FSF ALAR Briefing Note 1.3 — Golden Rules

"Golden rules" guide human activities in many areas.

In early aviation, golden rules defined the basic principles of airmanship.

With the development of technology in modern aircraft and with research on human-machine interface and crew coordination, the golden rules have been broadened to include the principles of interaction with automation and crew resource management (CRM).

The following golden rules are designed to assist trainees (but are useful for experienced pilots) in maintaining basic airmanship even as they progress to highly automated aircraft. These rules apply with little modification to all modern aircraft.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force, in a study of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997,[1] found that:

- Inadequate professional judgment/airmanship was a causal factor[2] in 74 percent of the accidents and serious incidents;
- Failure in CRM (crew coordination, cross-check and backup) was a causal factor in 63 percent of the events; and,
- Incorrect interaction with automation was a causal factor in 20 percent of the events.

Golden Rules

Automated Aircraft Can Be Flown Like Any Other Aircraft

To promote this rule, each trainee should be given the opportunity to hand-fly the aircraft — that is, to fly "stick, rudder and throttles."

The flight director (FD), autopilot (AP), autothrottles (A/THR) and flight management system (FMS) should be introduced progressively in the training syllabus.

The progressive training will emphasize that the pilot flying (PF) always retains the authority and capability to revert:

- To a lower (more direct) level of automation; or,
- To hand-flying — directly controlling the aircraft trajectory and energy condition.

Aviate (Fly), Navigate, Communicate and Manage — In That Order

During an abnormal condition or an emergency condition, PF-PNF (pilot not flying) task-sharing should be adapted to the situation (in accordance with the aircraft operating manual [AOM] or quick reference handbook [QRH]), and tasks should be accomplished with this four-step strategy:

Aviate. The PF must fly the aircraft (pitch attitude, thrust, sideslip, heading) to stabilize the aircraft's pitch attitude, bank angle, vertical flight path and horizontal flight path.

The PNF must back up the PF (by monitoring and by making call-outs) until the aircraft is stabilized.

Navigate. Upon the PF's command, the PNF should select or should restore the desired mode for lateral navigation and/or vertical navigation (selected mode or FMS lateral navigation [LNAV]/vertical navigation [VNAV]), being aware of terrain and minimum safe altitude.

Navigate can be summarized by the following:

- Know where you are;
- Know where you should be; and,
- Know where the terrain and obstacles are.

Communicate. After the aircraft is stabilized and the abnormal condition or emergency condition has been identified, the PF should inform air traffic control (ATC) of the situation and of his/her intentions.

If the flight is in a condition of *distress* or *urgency*, the PF should use standard phraseology:

- *"Pan Pan, Pan Pan, Pan Pan,"*[3] *or,*
- *"Mayday, Mayday, Mayday."*[4]

Manage. The next priority is management of the aircraft systems and performance of the applicable abnormal procedures or emergency procedures.

Table 1 shows that the design of highly automated aircraft fully supports the four-step strategy.

Implement Task-sharing and Backup

After the four-step strategy has been completed, the actions associated with the abnormal condition or emergency condition should be called by the PF.

Table 1
Display Use in Abnormal or Emergency Situations

Golden Rule	Display Unit
Aviate (Fly)	PFD
Navigate	ND
Communicate	Audio Control Unit
Manage	ECAM or EICAS

PFD = Primary flight display
ND = Navigation display
ECAM = Electronic centralized aircraft monitor
EICAS = Engine indication and crew alerting system

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Procedures should be performed as set forth in the AOM/QRH or in the following sequence:

- Emergency checklists;
- Normal checklists; and,
- Abnormal checklists.

These should be performed in accordance with the published task-sharing, CRM and standard phraseology.

Critical actions or irreversible actions (e.g., selecting a fuel lever or a fuel-isolation valve to "OFF") should be accomplished by the PNF after confirmation by the PF.

Know Your Available Guidance at All Times

The AP/FD-A/THR control panel(s) and the FMS control display unit (CDU) are the primary interfaces for the crew to communicate with the aircraft systems (to arm modes or select modes and to enter targets [e.g., airspeed, heading, altitude]).

The primary flight display (PFD), the navigation display (ND) and particularly the flight-mode annunciator (FMA) are the primary interfaces for the aircraft to communicate with the crew to confirm that the aircraft system has accepted correctly the crew's mode selections and target entries.

Any action on the AP/FD-A/THR control panel(s) or on the FMS CDU should be confirmed by cross-checking the corresponding FMA annunciation or data on the FMS display unit and on the PFD/ND.

At all times, the PF and the PNF should be aware of the guidance modes that are armed or selected and of any mode changes.

Cross-check the Accuracy of the FMS With Raw Data

When within navaid-coverage areas, the FMS navigation accuracy should be cross-checked with raw data.[5]

FMS navigation accuracy can be checked usually by:

- Entering a tuned very-high-frequency omnidirectional radio/distance-measuring equipment (VOR/DME) station in the bearing/distance ("BRG/DIST TO" or "DIST FR") field of the appropriate FMS page;
- Comparing the resulting FMS "BRG/DIST TO" (or "DIST FR") reading with the bearing/distance raw data on the radio magnetic indicator (RMI) or ND; and,
- Checking the difference between FMS and raw data against the criteria applicable for the flight phase (as required by standard operating procedures [SOPs]).

If the required accuracy criteria are not met, revert from LNAV to selected heading and raw data, with associated ND display.

One Head Up

Significant changes to the FMS flight plan should be performed by the PNF. The changes then should be cross-checked by the other pilot after transfer of aircraft control *to maintain one head up at all times*.

When Things Do Not Go as Expected, Take Control

If the aircraft does not follow the desired horizontal flight path or vertical flight path and time does not permit analyzing and solving the anomaly, *revert without delay from FMS guidance to selected guidance or to hand-flying.*

Use the Optimum Level of Automation for the Task

On highly automated and integrated aircraft, several levels of automation are available to perform a given task:

- FMS modes and guidance;
- Selected modes and guidance; or,
- Hand-flying.

The optimum level of automation depends on:

- Task to be performed:
  - Short-term (tactical) task; or,
  - Long-term (strategic) task;
- Flight phase:
  - En route;
  - Terminal area; or,
  - Approach; and,
- Time available:
  - Normal selection or entry; or,
  - Last-minute change.

The optimum level of automation often is the one that the flight crew feels the most comfortable with, depending on their knowledge of and experience with the aircraft and systems.

Reversion to hand-flying and manual thrust control may be the optimum level of automation for a specific condition.

Golden Rules for Abnormal Conditions And Emergency Conditions

The following golden rules may assist flight crews in their decision making in any abnormal condition or emergency condition, but particularly if encountering a condition not covered by the published procedures.

Understand the Prevailing Condition Before Acting

Incorrect decisions often are the result of incorrect recognition of the prevailing condition and/or incorrect identification of the prevailing condition.

Assess Risks and Time Pressures

Take time to make time when possible (e.g., request a holding pattern or radar vectors).

Evaluate the Available Options

Weather conditions, crew preparedness, type of operation, airport proximity and self-confidence should be considered in selecting the preferred option.

Include all flight crewmembers, cabin crewmembers, ATC and company maintenance technicians, as required, in this evaluation.

Match the Response to the Condition

An emergency condition requires immediate action (this does not mean rushed action), whereas an abnormal condition may tolerate a delayed action.

Consider All Implications, Plan for Contingencies

Consider all the aspects of continuing the flight through the landing.

Manage Workload

Adhere to the defined task-sharing for abnormal/emergency conditions to reduce workload and to optimize crew resources.

Use the AP and A/THR to alleviate PF workload.

Use the proper level of automation for the prevailing condition.

Communicate

Communicate to all aircraft crewmembers the prevailing condition and planned actions so they all have a common reference as they work toward a common and well-understood objective.

Apply Procedures and Other Agreed Actions

Understand the reasons for any action and the implications of any action before acting and check the result(s) of each action before proceeding with the next action.

Beware of irreversible actions (cross-check before acting).

Summary

If only one golden rule were to be adopted, the following is suggested:

Ensure always that at least one pilot is controlling and is monitoring the flight path of the aircraft.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy;*
- *1.2 — Automation;*
- *1.5 — Normal Checklists;* and,
- *2.2 — Crew Resource Management.*♦

References

1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

2. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]."

3. The International Civil Aviation Organization (ICAO) says that the words "Pan Pan" (pronounced "Pahn, Pahn") at the beginning of a communication identifies *urgency* — i.e., "a condition concerning the safety of an aircraft … or of some person on board or within sight, but which does not require immediate assistance." ICAO says that "Pan Pan" should be spoken three times at the beginning of an urgency call.

4. ICAO says that the word "Mayday" at the beginning of a communication identifies *distress* — i.e., "a condition of being threatened by serious and/or imminent danger and of requiring immediate assistance." ICAO says that "Mayday" should be spoken three times at the beginning of a distress call.

5. The FSF ALAR Task Force defines *raw data* as "data received directly (not via the flight director or flight management computer) from basic navigation aids (e.g., ADF, VOR, DME, barometric altimeter)."

Related Reading from FSF Publications

Wiener, Earl L.; Chute, Rebecca D.; Moses, John H. "Transition to Glass: Pilot Training for High-technology Transport Aircraft." *Flight Safety Digest* Volume 18 (June–August 1999).

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FSF ALAR Briefing Note 1.4 — Standard Calls

Standard phraseology is essential to ensure effective crew communication, particularly in today's operating environment, which increasingly features:

- Two-person crew operation; and,
- Crewmembers from different cultures and with different native languages.

Standard calls — commands and responses — are designed to enhance overall situational awareness (including awareness of the status and the operation of aircraft systems).

Standard calls may vary among aircraft models, based upon flight deck design and system designs, and among company standard operating procedures (SOPs).

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that an absence of standard calls was a factor in approach-and-landing accidents and serious incidents worldwide in 1984 through 1997 that were attributed, in part, to failure in crew resource management (CRM).[1] Sixty-three percent of the 76 accidents and serious incidents during the period involved failure in CRM as a causal factor.[2]

Use of Standard Calls — General Rules

Standard calls should be *alerting*, so that they are clearly identified by the pilot flying (PF) or pilot not flying (PNF), and should be distinguished from communication within the flight deck or between pilots and controllers.

Standard calls reduce the risk of tactical (short-term) decision-making errors (in selecting modes or entering targets [e.g., airspeed, heading, altitude] or in setting configurations).

The importance of using standard calls increases with increased workload.

Standard calls should be practical, concise, clear and consistent with the aircraft design and operating philosophy.

Standard calls should be included in the flow sequence of the manufacturer's SOPs or the company's SOPs and with the flight-pattern illustrations in the aircraft operating manual (AOM).

Standard calls should be performed in accordance with the defined PF/PNF task-sharing (i.e., task-sharing for hand-flying vs. autopilot operation, or task-sharing for normal condition vs. abnormal/emergency condition).

Nevertheless, if a standard call is omitted by one pilot, the other pilot should suggest the call, per CRM.

The absence of a standard call at the appropriate time or the absence of an acknowledgment may be the result of a system malfunction or equipment malfunction, or possible incapacitation of the other crewmember.

Standard calls should be used to:

- Give a command (delegate a task) or transfer information;
- Acknowledge a command or confirm receipt of information;

- Give a response or ask a question (feedback);
- Call a change of indication (e.g., a flight-mode annunciator [FMA] mode change); or,
- Identify a specific event (e.g., crossing an altitude or flight level).

General Standard Calls

The following are standard calls:

- "Check" (or "verify"): A command for the other pilot to check an item or to verify an item;
- "Checked": A confirmation that an item has been checked;
- "Cross-check(ed)": A confirmation that information has been checked at both pilot stations;
- "Set": A command for the other pilot to enter a target value or a configuration;
- "Arm": A command for the other pilot to arm a system (or a mode);
- "Engage": A command for the other pilot to engage a system or select a mode; and,
- "On" (or "off") following the name of a system: A command for the other pilot to select (or deselect) the system; or a response confirming the status of the system.

Specific Standard Calls

Specific standard calls should be defined for the following events:

- Flight crew/ground personnel communication;
- Engine-start sequence;
- Landing gear and slats/flaps selection (retraction or extension);
- Initiation, interruption, resumption and completion of normal checklists;
- Initiation, sequencing, interruption, resumption and completion of abnormal checklists and emergency checklists;
- FMA mode changes;
- Changing the altimeter setting;
- Approaching the cleared altitude or flight level;
- Traffic-alert and collision avoidance system (TCAS) traffic advisory (TA) or resolution advisory (RA);
- PF/PNF transfer of controls;
- Excessive deviation from a flight parameter;
- Specific points along the instrument approach procedure;
- Approaching minimums and reaching minimums;
- Acquisition of visual references; and,
- Decision to land or to go around.

The use of standard calls is of paramount importance for the optimum use of automation (autopilot, flight director and autothrottle mode arming or mode selection, target entries, FMA annunciations, flight management system [FMS] mode selections):

- Standard calls should trigger immediately the question "What do I want to fly now?" and thus clearly indicate which:
  - Mode the pilot intends to arm or select; or,
  - Target the pilot intends to enter; and,
- When the intention of the PF is clearly transmitted to the PNF, the standard calls also will:
  - Facilitate cross-check of the FMA (and primary flight display or navigation display, as applicable); and,
  - Facilitate crew coordination, cross-check and backup.

Standard calls also should be defined for flight crew/cabin crew communication in both:

- Normal conditions; and,
- Abnormal conditions or emergency conditions (e.g., cabin depressurization, on-ground emergency/evacuation, forced landing or ditching, crewmember incapacitation).

Harmonization of Standard Calls

The harmonization of standard calls across various aircraft fleets (from the same aircraft manufacturer or from different aircraft manufacturers) is desirable but should not be an overriding demand.

Standard calls across fleets are essential only for crewmembers operating different fleets (i.e., communication between flight deck and cabin or flight deck and ground).

Within the flight deck, pilots must use standard calls appropriate for the flight deck and systems.

With the exception of aircraft models with flight deck commonality, flight deck layouts and systems are not the same; thus, similarities as well as differences should be recognized.

When defining standard calls, standardization and operational efficiency should be balanced carefully.

Summary

Standard calls are a powerful tool for effective crew interaction and communication.

The command and the response are of equal importance to ensure timely action or correction.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.2 — Automation*;
- *1.5 — Normal Checklists*;
- *2.3 — Pilot-Controller Communication*; and,
- *2.4 — Interruptions/Distractions*.♦

Reference

1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.
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Flight Safety Foundation Editorial Staff. "Cockpit Coordination, Training Issues Pivotal in Fatal Approach-to-Landing Accident." *Accident Prevention* Volume 54 (January 1994).

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Notice

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Approach-and-landing Accident Reduction

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FSF ALAR Briefing Note 1.5 — Normal Checklists

Adherence to standard operating procedures (SOPs) and use of normal checklists are essential in preventing approach-and-landing accidents (ALAs), including those involving controlled flight into terrain (CFIT).

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that omission of action or inappropriate action (i.e., inadvertent deviation from SOPs) was a causal factor[1] in 72 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[2]

Scope and Use of Normal Checklists

SOPs are performed by recall using a defined flow pattern for each flight deck panel; *safety-critical points* (primarily related to the aircraft configuration) should be cross-checked with *normal checklists*.

Normal checklists enhance flight safety by providing an opportunity to confirm the aircraft configuration or to correct the aircraft configuration.

Normal checklists usually are *not* read-and-do lists and should be conducted after performing the flow of SOPs.

Completion of normal checklists is essential for safe operation, particularly during approach and landing.

Initiating Normal Checklists

Normal checklists should be initiated (called) by the pilot flying (PF) and read by the pilot not flying (PNF).

This should not prevent the PNF from applying an important crew resource management (CRM) principle by suggesting the initiation of a normal checklist if the PF fails to do so.

Normal checklists should be conducted during low-workload periods — conditions permitting — to help prevent any rush that could defeat the safety purpose of the normal checklists.

Time management and availability of other crewmember(s) are key factors in the initiation of normal checklists and the effective use of normal checklists.

Conducting Normal Checklists

Normal checklists are conducted usually by challenge and response (exceptions, such as the “AFTER-LANDING” checklist, are conducted as defined by SOPs).

Most checklist items require responses by the PF; some items may be challenged and responded to by the PNF.

To enhance crew communication, the following procedures and phraseology should be used:

- The responding pilot should respond to the challenge only after having checked or achieved the required configuration;
- If achieving the required configuration is not possible, the responding pilot should call the actual configuration;
- The challenging pilot should wait for a positive response (and should cross-check the validity of the response) before proceeding to the next item; and,

- The PNF should call the completion of the checklist (e.g., "checklist complete").

Some aircraft have electronic normal checklists or mechanical normal checklists that allow positive identification of:

- Items completed;
- Items being completed; and,
- Items to be completed.

Interrupting and Resuming Normal Checklists

If the flow of the normal checklist is interrupted for any reason, the PF should call "hold (stop) checklist at [item]."

"Resume (continue) checklist at [item]" should be called before resuming the normal checklist after an interruption. When the checklist resumes, the last completed item should be repeated.

Information introducing the SOPs in the aircraft operating manual (AOM), the normal checklists or the quick reference handbook (QRH) should be referred to for aircraft-model-specific information.

Training

Adherence to SOPs and disciplined use of normal checklists should begin during transition training, because *habits and routines acquired during transition training have a lasting effect*.

Transition training and recurrent training provide a unique opportunity to discuss the reasons for SOPs, and to discuss the consequences of failing to adhere to them.

Conversely, allowing deviations from SOPs and/or normal checklists during initial training or recurrent training may encourage deviations during line operations.

Line checks and line audits should reinforce adherence to SOPs and use of normal checklists.

Factors That May Affect Normal Checklists

To ensure effective use of normal checklists, it is important to understand why pilots inadvertently may omit some checklist items or omit completely a normal checklist.

Such omissions often are the result of operational circumstances that disrupt the normal flow of flight-deck duties.

The following factors often are cited in discussing the partial omission or complete omission of a normal checklist:

- Out-of-phase timing, whenever a factor (such as a tail wind or a system malfunction) modifies the time scale of the approach or the occurrence of the trigger event for the initiation of the normal checklist;
- Interruptions (e.g., because of pilot-controller communication);
- Distractions (e.g., because of flight deck activities);
- Task saturation;
- Incorrect management of priorities (e.g., lack of a decision-making model for time-critical situations);
- Reduced attention (tunnel vision) in abnormal conditions or high-workload conditions;
- Inadequate CRM (e.g., inadequate coordination, cross-check and backup);
- Overreliance on memory (overconfidence);
- Less-than-optimum checklist content, task-sharing and/or format; and,
- Possible inadequate emphasis on use of normal checklists during transition training and recurrent training.

Summary

Timely initiation and completion of normal checklists is the most effective method of preventing omission of actions or preventing inappropriate actions.

Calls should be defined in the SOPs for the interruption (hold) and resumption (continuation) of a normal checklist (in case of interruption or distraction).

Disciplined use of normal checklists should be:

- Emphasized at all stages of initial training, transition training and line training; and,
- Enforced during all checks and audits performed during line operation.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.3 — Golden Rules*;
- *1.4 — Standard Calls*; and,
- *2.4 — Interruptions/Distractions*.♦

References

1. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the

accident [or incident].” Each accident and incident in the study sample involved several causal factors.

2. Flight Safety Foundation. “Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents.” *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

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Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force’s data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers’/operators’ standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators’ or manufacturers’ policies, practices or requirements, and is not intended to supersede government regulations.

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FSF ALAR Briefing Note 1.6 — Approach Briefing

To ensure mutual understanding and effective cooperation among flight crewmembers and air traffic control (ATC), a thorough approach briefing should be conducted on each flight.

Care should be taken to conduct a thorough briefing regardless of:

- How familiar the destination airport and the approach may be; or,
- How often the crewmembers have flown together.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that omission of an approach briefing or the conduct of an inadequate approach briefing were factors in the particular approach-and-landing accidents and serious incidents worldwide in 1984 through 1997 that were attributed, in part, to omission of action/inappropriate action. Seventy-two percent of the 76 accidents and serious incidents during the period involved omission of action/inappropriate action.[1]

Briefing Techniques

The importance of briefing techniques often is underestimated, although effective briefings enhance crew standardization and crew communication.

An interactive briefing style — e.g., confirming the agreement and understanding of the pilot not flying (PNF) after each phase of the briefing — will provide a more effective briefing than an uninterrupted recitation terminated by the final query, "Any questions?"

An interactive briefing fulfills two important purposes:

- To provide the pilot flying (PF) and the PNF with an opportunity to correct each other (e.g., confirm the correct approach chart and confirm the correct setup of navaids for the assigned landing runway); and,
- To share a common mental image of the approach.

The briefing should be structured (i.e., follow the logical sequence of the approach and landing) and concise.

Routine and formal repetition of the same information on each flight may become counterproductive; adapting and expanding the briefing by highlighting the special aspects of the approach or the actual weather conditions will result in more effective briefings.

In short, the briefing should attract the PNF's attention.

Thus, the briefing should be conducted when the workload and availability of the PNF permit an effective briefing.

Anything that may affect normal operation (e.g., system failures, weather conditions or other particular conditions) should be carefully evaluated and discussed.

The briefing should help the PF (giving the briefing) and the PNF (acknowledging the briefing) to know the sequence of events and actions, as well as the special hazards and circumstances of the approach.

Whether anticipated or not, changes in ATC clearance, weather conditions or landing runway require a partial review of the initial briefing.

Timeliness of Briefings

To prevent any rush (and increased workload) in initiating and conducting the descent and the approach, descent preparation and the approach briefing typically should be conducted 10 minutes before reaching the top-of-descent point.

Scope of Briefing

The approach briefing should include the following aspects of the approach and landing, including a possible missed approach and a second approach or diversion:

- Minimum safe altitude (MSA);
- Terrain, man-made obstructions and other hazards;
- Approach conditions (weather conditions, runway conditions);
- Instrument approach procedure details, including the initial steps of the missed approach procedure;
- Stabilization height (Table 1);
- Final approach descent gradient (and vertical speed);
- Use of automation (e.g., lateral navigation [LNAV] and vertical navigation [VNAV]);
- Communications;
- Abnormal procedures, as applicable; and,
- *Flight Safety Foundation Approach-and-landing Risk Awareness Tool* (review and discuss [see FSF ALAR Briefing Note *5.1 — Approach Hazards Overview*]).

Approach Briefing

The flight management system (FMS) pages and the navigation display (ND) should be used to guide and illustrate the briefing, and to confirm the various data entries.

An expanded review of the items to be covered in the approach briefing — *as practical and appropriate for the conditions of the flight* — is provided below.

Aircraft Status

Review the status of the aircraft (i.e., any failure or malfunction experienced during the flight) and discuss the possible consequences in terms of operation and performance (i.e., final approach speed and landing distance).

Table 1
Recommended Elements
Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

Fuel Status

Review the following items:

- Fuel on board;
- Minimum diversion fuel; and,
- Available holding fuel and time.

Automatic Terminal Information Service (ATIS)

Review and discuss the following items:

- Runway in use (type of approach);

- Expected arrival route (standard terminal arrival [STAR] or radar vectors);
- Altimeter setting (QNH [altimeter setting that causes the altimeter to indicate height above sea level (i.e., field elevation after landing)] or QFE [altimeter setting that causes the altimeter to indicate height above the QFE datum (i.e., zero feet after landing)], as required);
  - For international operations, be aware of the applicable altimeter-setting unit (hectopascals or inches of mercury);
- Transition altitude/flight level (unless standard for the country or for the airport);
- Terminal weather (e.g., runway condition, likely turbulence, icing or wind shear conditions); and,
- Advisory messages (as applicable).

Notices to Airmen (NOTAMS)

Review and discuss en route and terminal NOTAMS (as applicable).

Top-of-descent Point

Confirm or adjust the top-of-descent point, computed by the FMS, as a function of the expected arrival (i.e., following the published STAR or radar vectors).

Approach Charts

Review and discuss the following items using the approach chart and the FMS/ND (as applicable):

- Designated runway and approach type;
- Chart index number and date;
- Minimum safe altitude (MSA) — reference point, sectors and altitudes;
- Let-down navaids — frequencies and identifications (confirm the correct navaids setup);
- Airport elevation;
- Approach transitions (fixes, holding pattern, altitude and airspeed restrictions, required navaids setup);
- Final approach course (and lead-in radial);
- Terrain features (location and elevation of hazardous terrain or man-made obstacles);
- Approach profile view:
  - Final approach fix (FAF);
  - Final descent point (if different from FAF);
  - Visual descent point (VDP);
  - Missed approach point (MAP);
  - Typical vertical speed at expected final approach groundspeed; and,
  - Touchdown zone elevation (TDZE);
- Missed approach:
  - Lateral navigation and vertical navigation;
  - Airspeed restrictions;
  - Minimum diversion fuel; and,
  - Second approach (discuss the type of approach if a different runway and/or type of approach is expected) or diversion to the alternate airport;
- Ceiling and visibility minimums:
  - Decision altitude/height (DA[H]) setting (Category [CAT] I with or without radio altitude, CAT II and CAT III with radio altitude); or,
  - Minimum descent altitude/height (MDA[H]) setting and radio altimeter setting in DH window (nonprecision approaches); and,
- Local airport requirements (e.g., noise restrictions on the use of thrust reversers, etc.).

CAT II/CAT III Instrument Landing System (ILS)

Review and discuss as applicable, depending on the type of approach.

Airport Charts

Review and discuss the following items using the airport charts:

- Runway length, width and slope;
- Approach lighting and runway lighting, and other expected visual references;
- Specific hazards (as applicable); and,
- Intended exit taxiway.

If another airport is located in the close vicinity of the destination airport, relevant details or procedures should be discussed for awareness purposes.

Use of Automation

Discuss the use of automation for vertical navigation and lateral navigation:

- Use of FMS or selected modes; and,
- Step-down approach (if a constant-angle nonprecision approach [CANPA] is not available).

Landing and Stopping

Discuss the intended landing flaps configuration (if different from full flaps).

Review and discuss the following features of the intended landing runway:

- Surface condition;
- Intended use of autobrakes and thrust reversers; and,
- Expected runway turn-off.

Taxi to Gate

Review and discuss the taxiways expected to be used to reach the assigned gate (with special emphasis on the possible crossing of active runways). As required, this review and discussion can be delayed until after landing.

Deviations from Standard Operating Procedures (SOPs)

Any intended deviation from SOPs or from standard calls should be discussed during the briefing.

Go-around

To enhance preparation for a go-around, primary elements of the missed approach procedure and task-sharing under normal conditions or abnormal conditions should be discussed during the approach briefing.

The briefing should include the following:

- Go-around call (a loud and clear "go-around/flaps");
- PF/PNF task-sharing (flow of respective actions, including desired guidance — mode selection — airspeed target, go-around altitude, excessive-parameter-deviation calls);
- Intended use of automation (automatic or manual go-around, use of FMS LNAV or use of selected modes for the missed approach);
- Missed-approach lateral navigation and vertical navigation (highlight obstacles and terrain features, as applicable); and,
- Intentions (second approach or diversion).

Crews should briefly recall the main points of the go-around and missed approach when established on the final approach course or after completing the landing checklist.

Summary

The approach briefing should be adapted to the conditions of the flight and focus on the items that are relevant for the approach and landing (such as specific approach hazards).

The approach briefing should include the following items:

- MSA;
- Terrain and man-made obstacles;
- Weather conditions and runway conditions;
- Other approach hazards, as applicable;
- Minimums (ceiling and visibility or runway visual range);
- Stabilization height;
- Final approach descent gradient (and vertical speed); and,
- Go-around altitude and missed-approach initial steps.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *2.1 — Human Factors*;
- *2.3 — Pilot-Controller Communication*;
- *5.1 — Approach Hazards Overview*;
- *6.1 — Being Prepared to Go Around*; and,
- *7.1 — Stabilized Approach*.♦

Reference

1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

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FSF ALAR Briefing Note 2.1 — Human Factors

Human factors identified in approach-and-landing accidents (ALAs) should be used to assess a company's risk exposure and develop corresponding company accident-prevention strategies, or to assess an individual's risk exposure and develop corresponding personal lines of defense.

Whether involving crew, air traffic control (ATC), maintenance, organizational factors or aircraft design, each link of the error chain involves human beings and, therefore, human decisions and behaviors.

Statistical Data

There is general agreement that human error is involved in more than 70 percent of aviation accidents.

Human Factors Issues

Standard Operating Procedures (SOPs)

To ensure adherence to published standard operating procedures (SOPs) and associated normal checklists and standard calls, it is important to understand why pilots may deviate from SOPs.

Pilots sometimes deviate intentionally from SOPs; some deviations occur because the procedure that was followed in place of the SOP seemed to be appropriate for the prevailing situation. Other deviations are usually unintentional.

The following factors often are cited in discussing deviations from SOPs:

- Task saturation;
- Inadequate knowledge or failure to understand the rule, procedure or action because of:
  - Inadequate training;
  - Printed information not easily understood; and/or,
  - Perception that a procedure is inappropriate;
- Insufficient emphasis on adherence to SOPs during transition training and recurrent training;
- Inadequate vigilance (fatigue);
- Interruptions (e.g., because of pilot-controller communication);
- Distractions (e.g., because of flight deck activities);
- Incorrect management of priorities (lack of decision-making model for time-critical situations);
- Reduced attention (tunnel vision) in abnormal conditions or high-workload conditions;
- Incorrect crew resource management (CRM) techniques (for crew coordination, cross-check and backup);
- Company policies (e.g., schedules, costs, go-arounds and diversions);
- Other policies (e.g., crew duty time);
- Personal desires or constraints (schedule, mission completion);
- Complacency; and/or,
- Overconfidence.

Automation

Errors in using automatic flight systems (AFSs) and insufficient knowledge of AFS operation have been contributing factors in approach-and-landing accidents and incidents, including those involving controlled flight into terrain.

The following are some of the more common errors in using AFSs:

- Inadvertent selection of an incorrect mode;
- Failure to verify the selected mode by reference to the flight-mode annunciator (FMA);
- Failure to arm a mode (e.g., failure to arm the approach mode) at the correct time;
- Inadvertent change of a target entry (e.g., changing the target airspeed instead of entering a new heading);
- Failure to enter a required target (e.g., failure to enter the correct final approach course);
- Incorrect altitude entry and failure to confirm the entry on the primary flight display (PFD);
- Entering a target altitude that is lower than the final approach intercept altitude during approach;
- Preoccupation with FMS programming during a critical flight phase, with consequent loss of situational awareness; and/or,
- Failure to monitor automation and cross-check parameters with raw data.[1]

Other frequent causal factors[2] in ALAs include:

- Inadequate situational awareness;
- Incorrect interaction with automation;
- Overreliance on automation; and/or,
- Inadequate effective crew coordination, cross-check and backup.[3]

Briefing Techniques

The importance of briefing techniques often is underestimated, although effective briefings enhance crew standardization and communication.

Routine and formal repetition of the same information on each flight may become counterproductive; adapting and expanding the briefing by highlighting the special aspects of the approach or the actual weather conditions will result in more effective briefings.

In short, the briefing should attract the attention of the pilot not flying (PNF).

The briefing should help the pilot flying (PF) and the PNF to know the sequence of events and actions, as well as the special hazards and circumstances of the approach.

An interactive briefing style provides the PF and the PNF with an opportunity to fulfill two important goals of the briefing:

- Correct each other; and,
- Share a common mental image of the approach.

Crew-ATC Communication

Effective communication is achieved when our intellectual process for interpreting the information contained in a message accommodates the message being received.

This process can be summarized as follows:

- How do we perceive the message?
- How do we reconstruct the information contained in the message?
- How do we link the information to an objective or to an expectation?
- What amount of bias or error is introduced in this process?

CRM highlights the relevance of the *context* and the *expectations* in communication.

The following factors may affect adversely the understanding of communications:

- High workload;
- Fatigue;
- Nonadherence to the "sterile cockpit rule"[4];
- Interruptions;
- Distractions; and/or,
- Conflicts and pressures.

The results may include:

- Incomplete communication;
- Omission of the aircraft call sign or use of an incorrect call sign;
- Use of nonstandard phraseology; and,
- Failure to listen or to respond.

Crew Communication

Interruptions and distractions on the flight deck break the flow pattern of ongoing activities, such as:

- SOPs;
- Normal checklists;
- Communication (listening, processing, responding);
- Monitoring tasks; and,
- Problem-solving activities.

The diverted attention resulting from the interruption or distraction usually causes the flight crew to feel rushed and to be confronted by competing tasks.

Moreover, when confronted with concurrent task demands, the natural human tendency is to perform one task to the detriment of another.

Unless mitigated by adequate techniques to set priorities, interruptions and distractions may result in the flight crew:

- Not monitoring the flight path (possibly resulting in an altitude deviation, course deviation or controlled flight into terrain);
- Missing or misinterpreting an ATC instruction (possibly resulting in a traffic conflict or runway incursion);
- Omitting an action and failing to detect and correct the resulting abnormal condition or configuration, if interrupted during a normal checklist; and,
- Leaving uncertainties unresolved (e.g., an ATC instruction or an abnormal condition).

Altimeter-setting Error

An incorrect altimeter setting often is the result of one or more of the following factors:

- High workload;
- Incorrect pilot-system interface;
- Incorrect pilot-controller communication;
- Deviation from normal task-sharing;
- Interruptions and distractions; and/or,
- Insufficient backup between crewmembers.

Adherence to the defined task-sharing (for normal conditions or abnormal conditions) and use of normal checklists are the most effective lines of defense against altimeter-setting errors.

Unstabilized Approaches

The following often are cited when discussing unstabilized approaches:

- Fatigue in short-haul, medium-haul or long-haul operations (which highlights the need for developing countermeasures to restore vigilance and alertness for the descent, approach and landing);
- Pressure of flight schedule (making up for delays);
- Any crew-induced circumstance or ATC-induced circumstance resulting in insufficient time to plan, prepare and conduct a safe approach (including accepting requests from ATC to fly higher, to fly faster or to fly shorter routings than desired);
- Inadequate ATC awareness of crew capability or aircraft capability to accommodate a last-minute change;
- Late takeover from automation (e.g., after the autopilot fails to capture the localizer or glideslope, usually because the crew failed to arm the approach mode);
- Inadequate awareness of adverse wind conditions;
- Incorrect anticipation of aircraft deceleration characteristics in level flight or on a three-degree glide path;
- Failure to recognize deviations or to remember the excessive-parameter-deviation limits;
- Belief that the aircraft will be stabilized at the minimum stabilization height (i.e., 1,000 feet above airport elevation in instrument meteorological conditions or 500 feet above airport elevation in visual meteorological conditions) or shortly thereafter;
- PNF overconfidence in the PF to achieve timely stabilization;
- PF/PNF overreliance on each other to call excessive deviations or to call for a go-around; and/or,
- Visual illusions during the acquisition of visual references or during the visual segment.

Runway Excursions and Runway Overruns

The following are human factors (involving ATC, flight crew and/or maintenance personnel) in runway excursions and runway overruns:

- No go-around decision when warranted;
- Inaccurate information on surface wind, runway condition or wind shear;
- Incorrect assessment of crosswind limit for prevailing runway conditions;
- Incorrect assessment of landing distance for prevailing wind conditions and runway conditions, or for a malfunction affecting aircraft configuration or braking capability;
- Captain taking over the controls and landing the aircraft despite the announcement or initiation of a go-around by the first officer (the PF);
- Late takeover from automation, when required (e.g., late takeover from autobrakes because of system malfunction);
- Inoperative equipment not noted per the minimum equipment list (e.g., one or more brakes being inoperative); and/or,
- Undetected thrust asymmetry (forward/reverse asymmetric thrust condition).

Adverse Wind Conditions

The following human factors often are cited in discussing events involving adverse winds (e.g., crosswinds, tail winds):

- Reluctance to recognize changes in landing data over time (e.g., change in wind direction/velocity, increase in gusts);
- Failure to seek evidence to confirm landing data and established options (i.e., reluctance to change plans);
- Reluctance to divert to an airport with more favorable wind conditions; and/or,
- Insufficient time to observe, evaluate and control the aircraft attitude and flight path in a dynamic situation.

Summary

Addressing human factors in ALAs must include:

- Defined company safety culture;
- Defined company safety policies;
- Company accident-prevention strategies;
- SOPs;
- CRM practices; and,
- Personal lines of defense.

The following FSF ALAR Briefing Notes provide information to supplement this discussion

- *1.1 — Operating Philosophy*;
- *1.3 — Golden Rules*;
- *1.4 — Standard Calls*;
- *1.5 — Normal Checklists*;
- *1.6 — Approach Briefing*;
- *2.2 — Crew Resource Management*;
- *2.3 — Pilot-Controller Communication*;
- *2.4 — Interruptions/Distractions*;
- *3.1 — Barometric Altimeter and Radio Altimeter*;
- *3.2 — Altitude Deviations*;
- *7.1 — Stabilized Approach*; and,
- *8.1 — Runway Excursions and Runway Overruns*.♦

References

1. The FSF ALAR Task Force defines *raw data* as "data received directly (not via the flight director or flight management computer) from basic navigation aids (e.g., ADF, VOR, DME, barometric altimeter)."
2. The FSF ALAR Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]."
3. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.
4. The *sterile cockpit rule* refers to U.S. Federal Aviation Regulations Part 121.542, which states: "No flight crewmember may engage in, nor may any pilot-in-command permit, any activity during a critical phase of flight which could distract any flight crewmember from the performance of his or her duties or which could interfere in any way with the proper conduct of those duties. Activities such as eating meals, engaging in nonessential conversations within the cockpit and nonessential communications between the cabin and cockpit crews, and reading publications not related to the proper conduct of the flight are not required for the safe operation of the aircraft. For the purposes of this section, critical phases of flight include all ground operations involving taxi, takeoff and landing, and all other flight operations below 10,000 feet, except cruise flight." [The FSF ALAR Task Force says that "10,000 feet" should be height above ground level during flight operations over high terrain.]

Related Reading from FSF Publications

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The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers’/operators’ standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators’ or manufacturers’ policies, practices or requirements, and is not intended to supersede government regulations.

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Approach-and-landing Accident Reduction

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FSF ALAR Briefing Note 2.2 — Crew Resource Management

Minimum required crew resource management (CRM) training is defined by regulations, and companies should consider customized CRM training for company-specific operations, such as multi-cultural flight crews.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that failure in CRM (i.e., flight crew coordination, cross-check and backup) was a causal factor[1] in 63 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[2]

Because CRM is a key factor in flight crew performance and in their interaction with automated systems, *CRM has a role to some degree in most aircraft incidents and accidents*.

Company Safety Culture and Policies

Although the flight crew is the last line of defense — and usually the last link in an error chain — many factors associated with accidents are early links in the accident chain and can be forged far from the flight deck. The early links could be inadequate training, a design flaw in equipment or incorrect maintenance.

Thus, company safety culture should support CRM throughout the organization, as well as among aircraft crewmembers.

International Cultural Factors

As more companies have international operations and multi-cultural flight crews, cultural factors become an important part of customized CRM training.

Understanding differences among cultures and recognizing the importance of national sensitivities should be emphasized in CRM training.

The importance of using standard phraseology as a common working language also should be emphasized.

Leadership

The role of the pilot-in-command (PIC) in complex and demanding situations (e.g., an approach with marginal weather conditions, abnormal conditions or emergency conditions) is an integral part of CRM training.

Teamwork

The captain's attitude in establishing communication with the first officer and flight attendants is essential to maintain open communication, thus ensuring effective:

- Human relations (e.g., effective crew communication);
- Teamwork (e.g., encouraging the first officer to voice any concern about the safety and the progress of the flight); and,
- Crew coordination, cross-check and backup.

Conducting a preflight briefing that includes the flight crew and the cabin crew is one method of establishing the basis for effective teamwork.

Assertiveness

Incidents and accidents have revealed that when an option (such as conducting a go-around) has not been briefed, the flight crew may lack the information to make the go-around decision or to conduct the missed approach correctly.

Fatigue, overconfidence or reluctance to change a plan often result in inadequate assertiveness and decision making.

Inquiry and Advocacy

Flight crews often receive air traffic control (ATC) requests that are either:

- Not understood (e.g., instructions to fly below the minimum safe altitude when the minimum vectoring altitude is not known); or,
- Challenging (e.g., a request to fly higher and/or faster than desired, or to fly a shorter route than desired).

Flight crews should not accept instructions without asking for clarification or being sure that they can comply safely with the instructions.

Procedures

Deviations from standard operating procedures (SOPs) and from other procedures usually are not deliberate; understanding the human factors involved in such deviations is essential for the development of company accident-prevention strategies.

Briefings

Conducting effective and interactive briefings requires adherence to SOPs to ensure crew coordination and preparation for planned or unexpected occurrences.

Time Management

Taking time to make time, task-sharing and ensuring task prioritization are essential factors in *staying ahead of the aircraft*.

Interruptions/Distractions

Coping with interruptions/distractions on the flight deck requires the flight crew "to expect the unexpected," which lessens the effects of any disruption in the flow pattern of ongoing flight deck activities.

Error Management

Error management should be practiced at the company level and at the personal level.

To foster this practice, identifying and understanding the relevant factors that cause errors are necessary for the development of associated:

- Company accident-prevention strategies; and,
- Personal lines of defense.

The most critical aspect in discussing error management is not the error (deviation), but the failure to detect the error by cross-checking.

Risk Management

Risk management is the process of assessing potential safety hazards and finding ways to avoid the hazards or to minimize their effects on safety.

Risk management should be seen as *a balanced management of priorities*.

Decision Making

SOPs sometimes are perceived as limiting the flight crew's judgment and decisions.

Without denying the captain's emergency authority, SOPs are safeguards against biased decision making.

Effective flight crew decision making often requires a joint evaluation of options prior to proceeding with an agreed-upon decision and action.

The effect of pressures (such as delays or company policies) that may affect how the flight crew conducts the flight and makes decisions should be recognized by the aviation industry.

Nevertheless, eliminating all pressures is not a realistic objective. Thus, CRM — incorporated with company accident-prevention strategies and personal lines of defense — should be used to cope effectively with such pressures.

For example, using a tactical-decision-making model for time-critical situations is an effective technique.

Several tactical-decision-making models (usually based on memory aids or on sequential models) are available for discussion during CRM training.

All tactical-decision-making models include the following steps:

- Recognizing the prevailing condition;
- Assessing short-term consequences and long-term consequences for the flight;
- Evaluating available options and procedures;

- Deciding on a course of action;
- Taking action in accordance with the defined procedures, as available, and task-sharing;
- Evaluating and monitoring results; and,
- Resuming standard flying duties.

Postponing a decision until a safe option is no longer available is a recurring pattern in ALAs.

CRM Factors

The following CRM factors have been identified as contributing to approach-and-landing incidents and accidents, including controlled flight into terrain:

- Risks associated with complacency (e.g., when operating at a familiar airport) or with overconfidence (e.g., resulting from a high level of experience with the aircraft);
- Inadequate proactive flight management (i.e., "staying ahead of the aircraft");
- Inadequate preparedness to respond to changing situations or to an emergency (i.e., expecting the unexpected) by precise planning and by using all the available flight deck technical and human resources;
- Crewmembers' personal factors (e.g., fatigue, spatial disorientation); and/or,
- Absence of specific training of instructors and check airmen to evaluate the CRM performance of trainees and line pilots.

Factors Affecting CRM

The following factors may adversely affect implementation of effective CRM:

- Company culture and policies;
- Belief that actions or decisions are the correct ones at the time, although they deviate from SOPs;
- Effects of fatigue and inadequate countermeasures for restoring vigilance and alertness; and/or,
- Reluctance to accept the influence of human factors and CRM in ALAs.

Summary

CRM alone is not the answer or universal remedy for preventing ALAs. Nevertheless, CRM is a powerful tool to optimize flight crew performance.

Good CRM skills:

- Relieve the effects of pressures, interruptions and distractions;
- Provide benchmarks for timely decision making; and,
- Provide safeguards for effective error management.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.3 — Golden Rules*;
- *1.4 — Standard Calls*;
- *1.5 — Normal Checklists*;
- *1.6 — Approach Briefing*;
- *2.1 — Human Factors;*
- *2.3 — Pilot-Controller Communication*; and,
- *2.4 — Interruptions/Distractions*.♦

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FSF ALAR Briefing Note 2.3 — Pilot-Controller Communication

Until data-link communication comes into widespread use, air traffic control (ATC) will depend primarily upon voice communication that is affected by various factors.

Communication between pilot and controller can be improved by the mutual understanding of each other's operating environment.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that incorrect or inadequate ATC instruction/advice/service was a causal factor[1] in 33 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[2]

These accidents and incidents involved incorrect or inadequate:

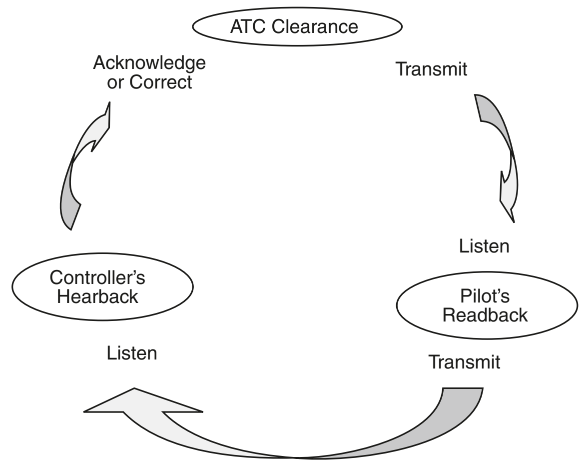
- ATC instructions (e.g., radar vectors);
- Weather or traffic information; and/or,
- Advice/service in an emergency.

Pilot-Controller Communication Loop

The responsibilities of the pilot and controller overlap in many areas and provide backup.

The pilot-controller confirmation/correction process is a "loop" that ensures effective communication (Figure 1).

Pilot-Controller Communication Loop: The Confirmation/Correction Process



ATC = Air traffic control

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 1

Whenever adverse factors are likely to affect communication, adherence to the confirmation/correction process is a line of defense against communication errors.

Effective Communication

Pilots and controllers are involved equally in the ATC system.

Achieving effective radio communication involves many factors that should not be considered in isolation; more than one factor usually is involved in a breakdown of the communication loop.

Human Factors

Effective communication is achieved when the intellectual process for interpreting the information contained in a message accommodates the message received.

This process can be summarized as follows:

- How do we *perceive* the message?
- How do we *reconstruct* the information contained in the message?
- How do we link the information to an *objective* or to an *expectation* (e.g., route, altitude or time)?
- What *bias* or *error* is introduced in this process?

Crew resource management (CRM) highlights the relevance of the *context* and the *expectation* in communication. Nevertheless, expectation may introduce either a positive bias or a negative bias in the effectiveness of the communication.

High workload, fatigue, noncompliance with the "sterile cockpit rule,"[3] distractions, interruptions and conflicts are among the factors that may affect pilot-controller communication and result in:

- Incomplete communication;
- Omission of the aircraft call sign or use of an incorrect call sign;
- Use of nonstandard phraseology;
- Failure to hear or to respond; and,
- Failure to effectively implement a confirmation or correction.

Language and Communication

Native speakers may not speak their own language correctly and consistently.

The language of pilot-controller communication is intended to overcome this basic shortcoming.

The first priority of any communication is to establish an *operational context* that defines the following elements:

- Purpose — clearance, instruction, conditional statement or proposal, question or request, confirmation;
- When — immediately, anticipate, expect;
- What and how — altitude (climb, descend, maintain), heading (left, right), airspeed; and,
- Where — (at […] waypoint).

The construction of the initial message and subsequent message(s) should support this operational context by:

- Following the chronological order of the actions;
- Grouping instructions and numbers related to each action; and,
- Limiting the number of instructions in the transmission.

The intonation, the speed of speaking and the placement and duration of pauses may affect the understanding of a communication.

Mastering the Language

CRM studies show that language differences on the flight deck are a greater obstacle to safety than cultural differences on the flight deck.

Because English has become a shared language in aviation, an effort has been initiated to improve the English-language skills of pilots and controllers worldwide.

Nevertheless, even pilots and controllers for whom English is the native language may not understand all words spoken in English because of regional accents or dialects.

In many regions of the world, language differences generate other communication difficulties.

For example, controllers using both English (for communication with international flights) and the country's official language (for communication with domestic flights) hinder some flight crews from achieving the desired level of situational awareness (loss of "party-line" communication).

Nonstandard Phraseology

Nonstandard phraseology is a major obstacle to effective communication.

Standard phraseology in pilot-controller communication is intended to be understood universally.

Standard phraseology helps lessen the ambiguities of spoken language and, thus, facilitates a common understanding among speakers:

- Of different native languages; or,
- Of the same native language but who use, pronounce or understand words differently.

Nonstandard phraseology or the omission of key words may change completely the meaning of the intended message, resulting in potential traffic conflicts.

For example, any message containing a number should indicate what the number refers to (e.g., an altitude, a heading or an airspeed). Including key words prevents erroneous interpretation and allows an effective readback/hearback.

Pilots and controllers might use nonstandard phraseology, with good intentions, for simplicity; however, standard phraseology minimizes the potential for misunderstanding.

Building Situational Awareness

Radio communication should contribute to the pilot's and the controller's situational awareness, which may be enhanced if they provide each other with advance information.

Frequency Congestion

Frequency congestion affects significantly the flow of communication during approach-and-landing phases at high-density airports, and demands enhanced vigilance by pilots and by controllers.

Omission of Call Sign

Omitting the call sign or using an incorrect call sign jeopardizes an effective readback/hearback.

Omission of Readback or Inadequate Readback

The term "roger" often is misused, as in the following situations:

- A pilot says "roger" (instead of providing a readback) to acknowledge a message containing numbers, thus preventing any effective hearback and correction of errors by the controller; or,
- A controller says "roger" to acknowledge a message requiring a definite answer (e.g., a positive confirmation or correction, such as acknowledging a pilot's statement that an altitude or airspeed restriction cannot be met), thus decreasing both the pilot's and the controller's situational awareness.

Failure to Correct Readback

The absence of an acknowledgment or a correction following a clearance readback is perceived by most flight crews as an implicit confirmation of the readback.

The absence of acknowledgment by the controller usually is the result of frequency congestion and the need for the controller to issue clearances and instructions to several aircraft in succession.

An uncorrected erroneous readback (known as a *hearback error*) may lead to a deviation from the assigned altitude or noncompliance with an altitude restriction or with a radar vector.

A deviation from an intended clearance may not be detected until the controller observes the deviation on his/her radar display.

Less-than-required vertical separation or horizontal separation (and near midair collisions) and runway incursions usually are the result of hearback errors.

Expectations

Bias in understanding a communication can affect pilots and controllers.

The bias of expectation can lead to:

- Transposing the numbers contained in a clearance (e.g., a flight level [FL]) to what was expected, based on experience or routine; and,
- Shifting a clearance or instruction from one parameter to another (e.g., perceiving a clearance to maintain a 280-degree heading as a clearance to climb/descend and maintain FL 280).

Failure to Seek Confirmation

Misunderstandings may involve half-heard words or guessed-at numbers.

The potential for misunderstanding numbers increases when an ATC clearance contains more than two instructions.

Failure to Request Clarification

Reluctance to seek confirmation may cause flight crews to either:

- Accept an inadequate instruction (over-reliance on ATC); or,
- Determine for themselves the most probable interpretation.

Failing to request clarification may cause a flight crew to believe erroneously that they have received an expected clearance (e.g., clearance to cross an active runway).

Failure to Question Instructions

Failing to question an instruction can cause a crew to accept an altitude clearance below the minimum safe altitude (MSA) or a heading that places the aircraft near obstructions.

Taking Another Aircraft's Clearance or Instruction

This usually occurs when two aircraft with similar-sounding call signs are on the same frequency and are likely to receive similar instructions, or when the call sign is blocked by another transmission.

When pilots of different aircraft with similar-sounding call signs omit the call sign on readback, or when simultaneous readbacks are made by both pilots, the error may go unnoticed by the pilots and the controller.

Filtering Communications

Because of other flight deck duties, pilots tend to filter communications, hearing primarily communications that begin with their aircraft call sign and not hearing most other communications.

For workload reasons, controllers also may filter communications (e.g., not hearing and responding to a pilot readback while engaged in issuing clearances/instructions to other aircraft or ensuring internal coordination).

To maintain situational awareness, this filtering process should be adapted, according to the flight phase, for more effective listening.

For example, when occupying an active runway (e.g., back-taxiing or holding in position) or when conducting a final approach to an assigned runway, the flight crew should listen and give attention to communications related to the landing runway.

Timeliness of Communication

Deviating from an ATC clearance may be required for operational reasons (e.g., a heading deviation or altitude deviation for weather avoidance, or an inability to meet a restriction).

Both the pilot and the controller need time to accommodate this deviation; therefore, *ATC should be notified as early as possible* to obtain a timely acknowledgment.

Similarly, when about to enter a known non-radar-controlled flight information region (FIR), the pilot should contact the appropriate ATC facility approximately 10 minutes before reaching the FIR boundary to help prevent misunderstandings or less-than-required separation.

Blocked Transmissions (Simultaneous Communication)

Blocked transmissions often are the result of not immediately releasing the push-to-talk switch after a communication.

An excessive pause in a message (i.e., holding the push-to-talk switch while considering the next item of the transmission) also may result in blocking part of the response or part of another message.

Simultaneous transmission by two stations (two aircraft or one aircraft and ATC) results in one of the two (or both) transmissions being *blocked* and *unheard* by the other stations (or being heard as a buzzing sound or as a squeal).

The absence of a readback (from the pilot) or a hearback acknowledgment (from the controller) should be treated as a blocked transmission and prompt a request to repeat or confirm the message.

Blocked transmissions can result in altitude deviations, missed turnoffs and takeoffs, landings without clearances and other hazards.

Communicating Specific Events

The following events should be reported as soon as practical to ATC, stating the nature of the event, the action(s) taken and the flight crew's intention(s):

- Traffic-alert and collision avoidance system (TCAS) resolution advisory (RA);
- Severe turbulence;
- Volcanic ash;
- Wind shear or microburst; and,
- A terrain-avoidance maneuver prompted by a ground-proximity warning system (GPWS) warning or terrain awareness and warning system (TAWS)[4] warning.

Emergency Communication

In an emergency, the pilot and the controller must communicate clearly and concisely, as suggested below.

Pilot

The standard International Civil Aviation Organization (ICAO) phraseology "Pan Pan"[5] or "Mayday"[6] must be used to alert a controller and trigger an appropriate response.

Controllers

Controllers should recognize that, when faced with an emergency situation, the flight crew's most important needs are:

- Time;
- Airspace; and,
- Silence.

The controller's response to the emergency situation could be patterned after a memory aid such as ASSIST:

- Acknowledge:
  – Ensure that the reported emergency is understood and acknowledged;

- Separate:
  - Establish and maintain separation with other traffic and/or terrain;
- Silence:
  - Impose silence on your control frequency, if necessary; and,
  - Do not delay or disturb urgent flight crew action by unnecessary transmissions;
- Inform:
  - Inform your supervisor and other sectors, units and airports as appropriate;
- Support:
  - Provide maximum support to the flight crew; and,
- Time:
  - Allow the flight crew sufficient time to handle the emergency.

Training Program

A company training program on pilot-controller communication should involve flight crews and ATC personnel in joint meetings, to discuss operational issues and, in joint flight/ATC simulator sessions, to promote a mutual understanding of each other's working environment, including:

- Modern flight decks (e.g., flight management system reprogramming) and ATC equipment (e.g., absence of primary returns, such as weather, on modern radar displays);
- Operational requirements (e.g., aircraft deceleration characteristics, performance, limitations); and,
- Procedures (e.g., standard operating procedures [SOPs]) and instructions (e.g., CRM).

Special emphasis should be placed on pilot-controller communication and task management during emergency situations.

Summary

The following should be emphasized in pilot-controller communication:

- Recognize and understand respective pilot and controller working environments and constraints;
- Use standard phraseology;
- Adhere to the pilot-controller confirmation/correction process in the communication loop;
- Request clarification or confirmation when in doubt;
- Question an incorrect clearance or inadequate instruction;
- Prevent simultaneous transmissions;
- Listen to party-line communications as a function of the flight phase; and,
- Use clear and concise communication in an emergency.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *2.1 — Human Factors*;
- *2.2 — Crew Resource Management*;
- *2.4 — Interruptions/Distractions*; and,
- *7.1 — Stabilized Approach*.♦

References

1. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]." Each accident and incident in the study sample involved several causal factors.

2. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

3. The *sterile cockpit rule* refers to U.S. Federal Aviation Regulations Part 121.542, which states: "No flight crewmember may engage in, nor may any pilot-in-command permit, any activity during a critical phase of flight which could distract any flight crewmember from the performance of his or her duties or which could interfere in any way with the proper conduct of those duties. Activities such as eating meals, engaging in nonessential conversations within the cockpit and nonessential communications between the cabin and cockpit crews, and reading publications not related to the proper conduct of the flight are not required for the safe operation of the aircraft. For the purposes of this section, critical phases of flight include all ground operations involving taxi, takeoff and landing, and all other flight operations below 10,000 feet, except cruise flight." [The FSF ALAR Task Force says

that "10,000 feet" should be height above ground level during flight operations over high terrain.]

4. Terrain awareness and warning system (TAWS) is the term used by the European Joint Aviation Authorities and the U.S. Federal Aviation Administration to describe equipment meeting International Civil Aviation Organization (ICAO) standards and recommendations for ground-proximity warning system (GPWS) equipment that provides predictive terrain-hazard warnings. "Enhanced GPWS" and "ground collision avoidance system" are other terms used to describe TAWS equipment.
5. ICAO says that the words "Pan Pan" at the beginning of a communication identifies *urgency* — i.e., "a condition concerning the safety of an aircraft … or of some person on board or within sight, but which does not require immediate assistance." ICAO says that "Pan Pan" (pronounced "Pahn, Pahn") should be spoken three times at the beginning of an urgency call.
6. ICAO says that the word "Mayday" at the beginning of a communication identifies *distress* — i.e., "a condition of being threatened by serious and/or imminent danger and of requiring immediate assistance." ICAO says that "Mayday" should be spoken three times at the beginning of a distress call.

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Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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ALAR

Approach-and-landing Accident Reduction

Tool Kit

FSF ALAR Briefing Note 2.4 — Interruptions/Distractions

Interruptions and distractions often result in omitting an action and/or deviating from standard operating procedures (SOPs).

Interruptions (e.g., because of an air traffic control [ATC] communication) and distractions (e.g., because of a cabin crewmember entering the flight deck) occur frequently; some cannot be avoided, some can be minimized or eliminated.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that omission of action or inappropriate action (i.e., *inadvertent* deviation from SOPs) was a causal factor[1] in 72 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[2]

Types of Interruptions/Distractions

Interruptions/distractions on the flight deck may be subtle or brief, but they can be disruptive to the flight crew.

Interruptions/distractions can be classified in three categories:

- Communication (e.g., receiving the final weights while taxiing or a flight attendant entering the flight deck);
- Head-down work (e.g., reading the approach chart or programming the flight management system [FMS]); and,
- Responding to an abnormal condition or to an unexpected situation (e.g., system malfunction or traffic-alert and collision avoidance system [TCAS] traffic advisory [TA] or resolution advisory [RA]).

Distractions — even a minor equipment malfunction — can turn a routine flight into a challenging event.

Effect of Interruptions/Distractions

The primary effect of interruptions/distractions is to *break the flow pattern of ongoing flight deck activities* (actions or communications), such as:

- SOPs;
- Normal checklists;
- Communications (listening, processing, responding);
- Monitoring tasks (systems monitoring, pilot flying/pilot not flying [PF/PNF] cross-checking); and,
- Problem-solving activities.

An interruption/distraction can cause the flight crew to feel rushed and to be confronted with competing tasks.

When confronted with competing tasks, the crew must select one task to perform before another task, which can result in poor results in one or more of the completed tasks. Thus, the interruption/distraction can result in the crew:

- Not monitoring the flight path (possibly resulting in an altitude deviation, a course deviation or controlled flight into terrain [CFIT]);
- Not hearing or misinterpreting an ATC instruction (possibly resulting in a traffic conflict or runway incursion);
- Omitting an action and failing to detect and correct the resulting abnormal condition or configuration (if interrupted during a normal checklist); and,
- Leaving uncertainties unresolved (e.g., an ATC instruction or an abnormal condition).

Reducing Interruptions/Distractions

Acknowledging that a flight crew may have control over some interruptions/distractions and not over others is the first step in developing personal lines of defense for the crew.

Actions that are under control (e.g., SOPs, initiation of normal checklists) should be scheduled for usual periods of minimum disruption, to help prevent interference with actions that are not under control (e.g., ATC or cabin crew).

Complying with the U.S. Federal Aviation Administration's "sterile cockpit rule"[3] also can reduce interruptions/distractions.

Complying with the sterile cockpit rule during taxi-out and taxi-in requires discipline because the taxi phases often provide relief between phases of high workload and concentration.

The sterile cockpit rule has been adopted by many non-U.S. operators and is included (although in less explicit terms) in Joint Aviation Requirements–Operations 1.085(d)(8).

The sterile cockpit rule should be implemented with good common sense so that communications remain open among all aircraft crewmembers.

Nevertheless, the application of efficient crew resource management (CRM) by the flight crew or the communication of emergency or safety-related information by cabin crew should not be prevented by a rigid interpretation of this rule.

The U.S. Federal Aviation Administration agrees that *it is better to break the sterile cockpit rule than to fail to communicate*.

Adherence to the sterile cockpit rule by cabin crew creates two challenges:

- How to identify when the rule applies; and,
- How to identify occurrences that warrant breaking the sterile cockpit rule.

Several methods of signaling to the cabin crew that a sterile cockpit is being maintained have been evaluated (e.g., using the all-cabin-crew call or a public-address announcement).

Whatever method is used, it should not create its own distraction to the flight crew.

The following are suggested examples of occurrences that warrant breaking the sterile cockpit rule:

- Fire, burning odor or smoke in the cabin;
- Medical emergency;
- Unusual noise or vibration (e.g., evidence of tail strike);
- Engine fire (torching flame);
- Fuel or fluid leakage;
- Emergency-exit or door-unsafe condition (although this condition is annunciated to the flight crew);
- Localized extreme cabin temperature changes;
- Evidence of a deicing problem;
- Cart-stowage problem;
- Suspicious, unclaimed bag or package; and,
- Any other condition deemed relevant by the senior cabin crewmember (purser).

These examples should be adjusted for local regulations or to suit company policy.

Cabin crewmembers may hesitate (depending on national culture and company policy) to report technical occurrences to the flight crew. To overcome this reluctance, implementation and interpretation of the sterile cockpit rule should be explained during cabin crew CRM training and cited by the captain during the crew preflight briefing.

Analysis of aviation safety reports indicates that the most frequent violations of the sterile cockpit rule are caused by the following:

- Non-flight-related conversations;
- Distractions by cabin crew;
- Non-flight-related radio calls; and/or,
- Nonessential public-address announcements.

Building Lines of Defense

A high level of interaction and communication between flight crewmembers, and between cabin crewmembers and flight crewmembers, constitutes the first line of defense to reduce errors.

Company policies, SOPs, CRM and leadership by the pilot-in-command contribute to effective communication among all aircraft crewmembers, thus enhancing their performance.

The following personal lines of defense can be developed to minimize flight deck interruptions/distractions:

- Communication:
  - Keep flight deck communication clear and concise; and,
  - Interrupt conversations when necessary to correct a flight parameter or to comply with an altitude restriction;
- Head-down work (FMS programming or chart review):
  - Define task-sharing for FMS programming or reprogramming depending on the level of automation being used and on the flight phase (SOPs);
  - Plan long periods of head-down tasks for periods of lower workload; and,

– Announce that you are going "head-down."

- Responding to an abnormal condition or to an unanticipated situation:
  – Keep the autopilot engaged to decrease workload, unless otherwise required;
  – Ensure that one pilot is primarily responsible for flying/monitoring the aircraft;
  – Adhere to PF/PNF task-sharing under abnormal conditions (with particular emphasis for the PNF to maintain situational awareness and back up the PF); and,
  – Give particular attention to normal checklists, because handling an abnormal condition may disrupt the normal flow of SOP actions (SOP actions or normal checklists are initiated based on events — usually referred to as *triggers*; such events may go unnoticed, and the absence of the trigger may be interpreted incorrectly as action complete or checklist complete).

Managing Interruptions/Distractions

Because some interruptions/distractions may be subtle and insidious, the first priority is to recognize and to identify them.

The second priority is to re-establish situational awareness, as follows:

- Identify:
  – What was I doing?
- Ask:
  – Where was I interrupted or distracted?
- Decide/act:
  – What decision or action shall I take to get "back on track"?

In the ensuing decision-making process, the following strategy should be applied:

- Prioritize:
  – Aviate (fly);
  – Navigate;
  – Communicate; and,
  – Manage.
- Plan:

  Some actions may have to be postponed until time and conditions permit. Requesting a delay (e.g., from ATC or from the other crewmember) will prevent being rushed in the accomplishment of competing actions (*take time to make time*); and,
- Verify:

  Various SOP techniques (e.g., event triggers and normal checklists) ensure that the action(s) that had been postponed have been accomplished.

Finally, if the interruption or distraction disrupts a normal checklist or abnormal checklist, an explicit hold should be announced to mark the disruption of the checklist and an explicit command should be used to resume the checklist at the last item checked before the disruption of the checklist.

Summary

Interruptions/distractions usually result from the following factors:

- Flight crew-ATC, flight deck or flight crew-cabin crew communication;
- Head-down work; and,
- Response to an abnormal condition or unexpected situation.

Company accident-prevention strategies and personal lines of defense should be developed to minimize interruptions/distractions.

The most effective company accident-prevention strategies and personal lines of defense are adherence to the following:

- SOPs;
- Golden rules;
- Sterile cockpit rule (as applicable); and,
- Recovery tips, such as:
  – Identify – ask – decide – act; and,
  – Prioritize – plan – verify.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.3 — Golden Rules*;
- *1.4 — Standard Calls*;
- *1.5 — Normal Checklists*;
- *2.1 — Human Factors*;
- *2.2 — Crew Resource Management*; and,
- *2.3 — Pilot-Controller Communication*.♦

References

1. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]." Each accident and incident in the study sample involved several causal factors.

2. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

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U.S. Federal Aviation Administration. *Federal Aviation Regulations*. 121.406 "Reduction of CRM/DRM programmed hours based on credit for previous CRM/DRM training," 121.419 "Pilots and flight engineers: Initial, transition, and upgrade ground training," 121.421 "Flight attendants: Initial and transition ground training," 121.422 "Aircraft dispatchers: Initial and transition ground training," 121.542 "Flight crewmember duties." January 1, 2000.

Joint Aviation Authorities. *Joint Aviation Requirements – Operations 1. Commercial Air Transportation (Aeroplanes)*. 1.085 "Crew responsibilities," 1.945 "Conversion training and checking," 1.955 "Nomination as commander," 1.965 "Recurrent training and checking." March 1, 1998.

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- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

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FSF ALAR Briefing Note 3.1 — Barometric Altimeter and Radio Altimeter

Flight crews on international routes encounter different units of measurement for setting barometric altimeters, thus requiring altimeter cross-check procedures.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that lack of positional awareness was a causal factor[1] in 51 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[2] The task force said that these accidents and incidents generally involved lack of vertical-position awareness and resulted in controlled flight into terrain (CFIT).

QNH or QFE?

QNH (altimeter setting that causes the altimeter to indicate height above mean sea level [i.e., field elevation at touchdown on the runway]) has the advantage of eliminating the need to change the altimeter setting during operations below the transition altitude/flight level (FL).

QNH also eliminates the need to change the altimeter setting during a missed approach, whereas such a change usually would be required when QFE (altimeter setting that causes the altimeter to indicate height above the QFE reference datum [i.e., zero at touchdown on the runway]) is used.

Some operators set the altimeter to QFE in areas where air traffic control (ATC) uses QNH and the majority of operators use QNH. Standard operating procedures (SOPs) can prevent altimeter-setting errors.

Units of Measurement

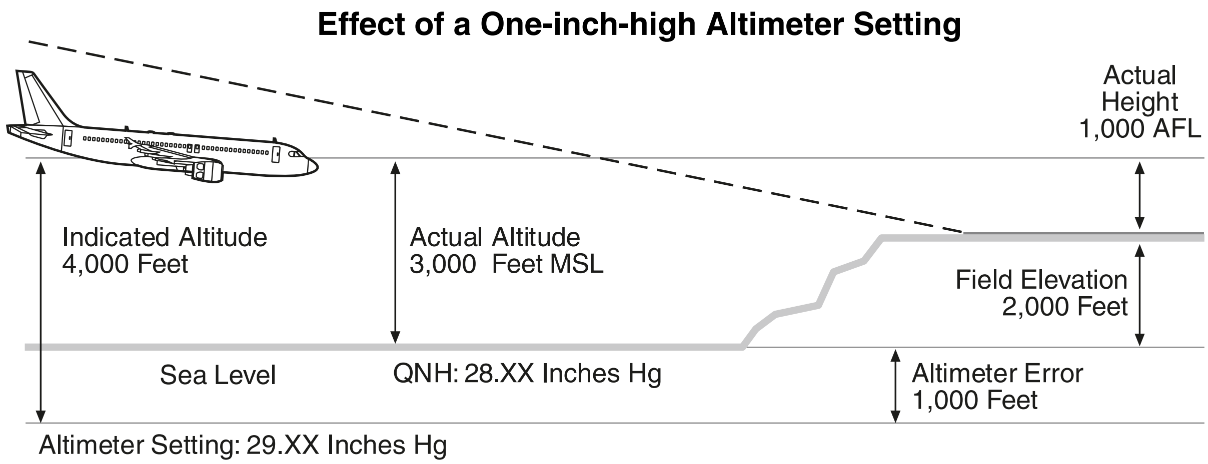
The most common units of measurement for setting altimeters are:

- Hectopascals (hPa) [previously referred to as millibars (mb)]; and,
- Inches of mercury (in. Hg).

When in. Hg is used for the altimeter setting, unusual barometric pressures, such as a 28.XX in. Hg (low pressure) or a 30.XX in. Hg (high pressure), may go undetected when listening to the automatic terminal information service (ATIS) or ATC, resulting in a more usual 29.XX altimeter setting being set.

Figure 1 (page 60) and Figure 2 (page 60) show that a 1.00 in. Hg discrepancy in the altimeter setting results in a *1,000-foot error in the indicated altitude*.

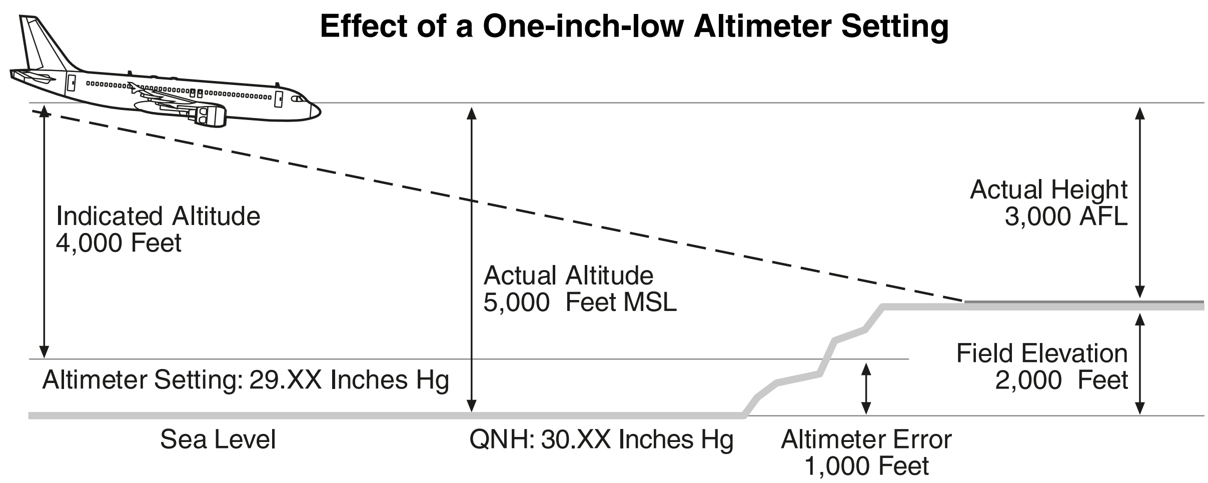
In Figure 1, QNH is an unusually low 28.XX in. Hg, but the altimeter was set mistakenly to a more usual 29.XX in. Hg, resulting in the true altitude (i.e., the aircraft's actual height above mean sea level) being *1,000 feet lower than indicated*.



AFL = Above field level MSL = Mean sea level Hg = Mercury
QNH = Altimeter setting that causes altimeter to indicate height above mean sea level (thus, field elevation at touchdown)

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 1



AFL = Above field level MSL = Mean sea level Hg = Mercury
QNH = Altimeter setting that causes altimeter to indicate height above mean sea level (thus, field elevation at touchdown)

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 2

In Figure 2, QNH is an unusually high 30.XX in. Hg, but the altimeter was set mistakenly to a more usual 29.XX in. Hg, resulting in the true altitude being *1,000 feet higher than indicated.*

Confusion about units of measurement (i.e., hPa vs. in. Hg) leads to similar errors.

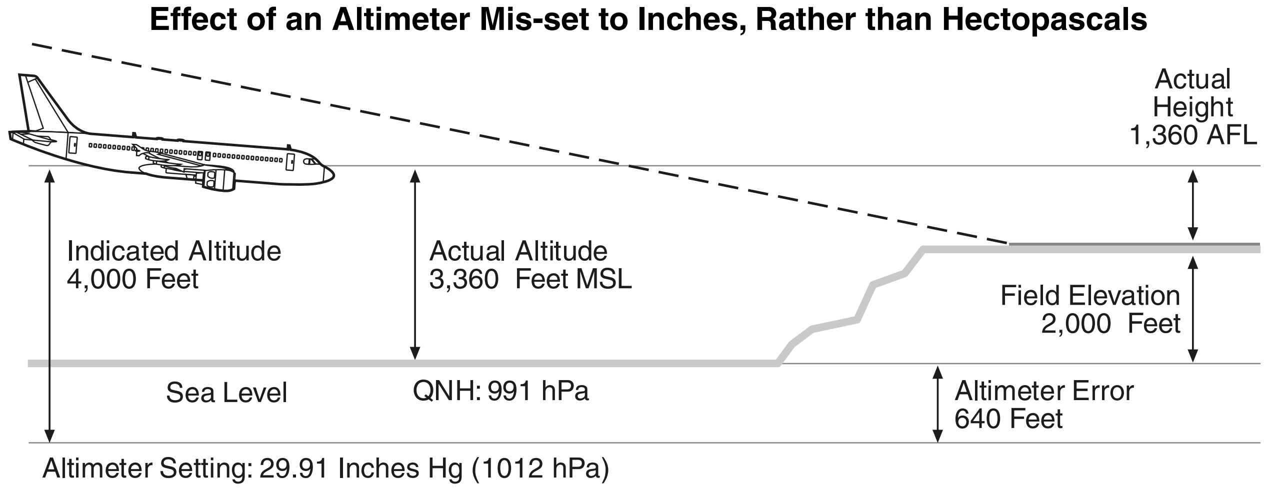
In Figure 3 (page 61), a QNH of 991 hPa was set mistakenly on the altimeter as 29.91 in. Hg (equivalent to 1012 hPa), resulting in the true altitude *being 640 feet lower than indicated.*

Setting the Altimeter

To help prevent errors associated with different units of measurement or with unusual values (low or high), the following SOPs should be used when broadcasting (ATIS or controllers) or reading back (pilots) an altimeter setting:

- All digits, as well as the unit of measurement (e.g., *inches* or *hectopascals*), should be announced.

  A transmission such as "altimeter setting six seven" can be interpreted as 28.67 in. Hg, 29.67 in. Hg, 30.67 in. Hg or 967 hPa.



AFL = Above field level   MSL = Mean sea level   Hg = Mercury hPa = Hectopascals
QNH = Altimeter setting that causes altimeter to indicate height above mean sea level (thus, field elevation at touchdown)

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3

Stating the complete altimeter setting prevents confusion and allows detection and correction of a previous error.

- When using in. Hg, "low" should precede an altimeter setting of 28.XX in. Hg and "high" should precede an altimeter setting of 30.XX in. Hg.

An incorrect altimeter setting often is the result of one or more of the following factors:

- High workload;
- A deviation from defined task-sharing;
- An interruption/distraction;
- Inadequate cross-checking by flight crewmembers; or,
- Confusion about units of measurement.

Adherence to the defined task-sharing (for normal conditions or abnormal conditions) and normal checklists are effective defenses to help prevent altimeter-setting errors.

Metric Altimeter

Metric altitudes in certain countries (e.g., the Commonwealth of Independent States and the People's Republic of China) also require SOPs for the use of metric altimeters (or conversion tables).

Crossing the Transition Altitude/Flight Level

The transition altitude/flight level can be either:

- Fixed for the whole country (e.g., FL 180 in the United States);
- Fixed for a given airport (as indicated on the approach chart); or,
- Variable, depending on QNH (as indicated in the ATIS broadcast).

Depending on the airline's/flight crew's usual area of operation, changing from a fixed transition altitude/flight level to variable transition altitudes/flight levels may result in a premature resetting or a late resetting of the altimeter.

An altitude constraint (expressed in altitude or flight level) also may delay or advance the setting of the standard altimeter setting (1013.2 hPa or 29.92 in. Hg), possibly resulting in crew confusion.

Altimeter References

The barometric-altimeter reference ("bug") and the radio-altimeter decision height (RA DH) bug must be set according to the aircraft manufacturer's SOPs or the company's SOPs. Table 1 (page 62) shows some examples.

For all approaches, except Category (CAT) I instrument landing system (ILS) approaches with RA DH, CAT II ILS approaches and CAT III ILS approaches, the standard call "minimum" will be based on the barometric-altimeter bug set at the minimum descent altitude/height [MDA(H)] or decision altitude/height [DA(H)].

Radio-altimeter standard calls can be either:

- Announced by the PNF (or the flight engineer); or,
- Generated automatically by a synthesized voice.

Table 1
Barometric-altimeter and Radio-altimeter Reference Settings

Approach	Barometric Altimeter	Radio Altimeter
Visual	MDA(H)/DA(H) of instrument approach or 200 feet above airport elevation	200 feet*
Nonprecision	MDA/(H)	200 feet*
ILS CAT I no RA	DA(H)	200 feet*
ILS CAT I with RA	DA(H)	RA DH
ILS CAT II	DA(H)	RA DH
ILS CAT III with DH	DA(H)	RA DH
ILS CAT III with no DH	TDZE	Alert height

MDA(H) = Minimum descent altitude/height
DA(H) = Decision altitude/height
ILS = Instrument landing system
CAT = Category
RA DH = Radio altimeter decision height
TDZE = Touchdown zone elevation

* The RA DH should be set (e.g., at 200 feet) for terrain-awareness purposes. The use of the radio altimeter should be discussed during the approach briefing.

Note: For all approaches, except CAT II and CAT III ILS approaches, the approach "minimum" call will be based on the barometric-altimeter bug set at MDA(H) or DA(H).

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Standard calls are tailored to the company SOPs and to the type of approach.

To enhance the flight crew's awareness of terrain, the standard call "radio altimeter alive" should be announced by the first crewmember observing radio-altimeter activation at 2,500 feet above ground level (AGL).

The radio altimeter then should be included in the instrument scan for the remainder of the approach.

The radio altimeter indicates the aircraft's height above the ground, not the aircraft's height above airport elevation. The radar altimeter does not indicate height above trees or towers.

Nevertheless, unless the airport has high close-in terrain, the radio-altimeter indication should reasonably agree with the height above airport elevation (obtained by direct reading of the altimeter if using QFE or by computation if using QNH).

Radio-altimeter indications below the following obstacle-clearance values, should be cause for alarm:

- Initial approach, 1,000 feet;
- Intermediate approach (or minimum radar vectoring altitude), 500 feet; and,
- Final approach (nonprecision approach), 250 feet.

Low Outside Air Temperature (OAT)

In a standard atmosphere, the indicated QNH altitude is the true altitude.

Whenever the temperature deviates significantly from the standard temperature, the indicated altitude deviates from the true altitude, as follows:

- At extremely *high* temperatures, the true altitude is *higher* than the indicated altitude; and,
- At extremely *low* temperatures, the true altitude is *lower* than the indicated altitude, resulting in reduced terrain clearance.

Flying into an area of *low temperatures* has the same effect as flying into a *low-pressure* area; the aircraft is *lower* than the altimeter indicates.

The International Civil Aviation Organization (ICAO) publishes altitude corrections (based on the airport surface temperature and the height above the elevation of the altimeter-setting source) to be made to the published minimum safe altitudes.[3]

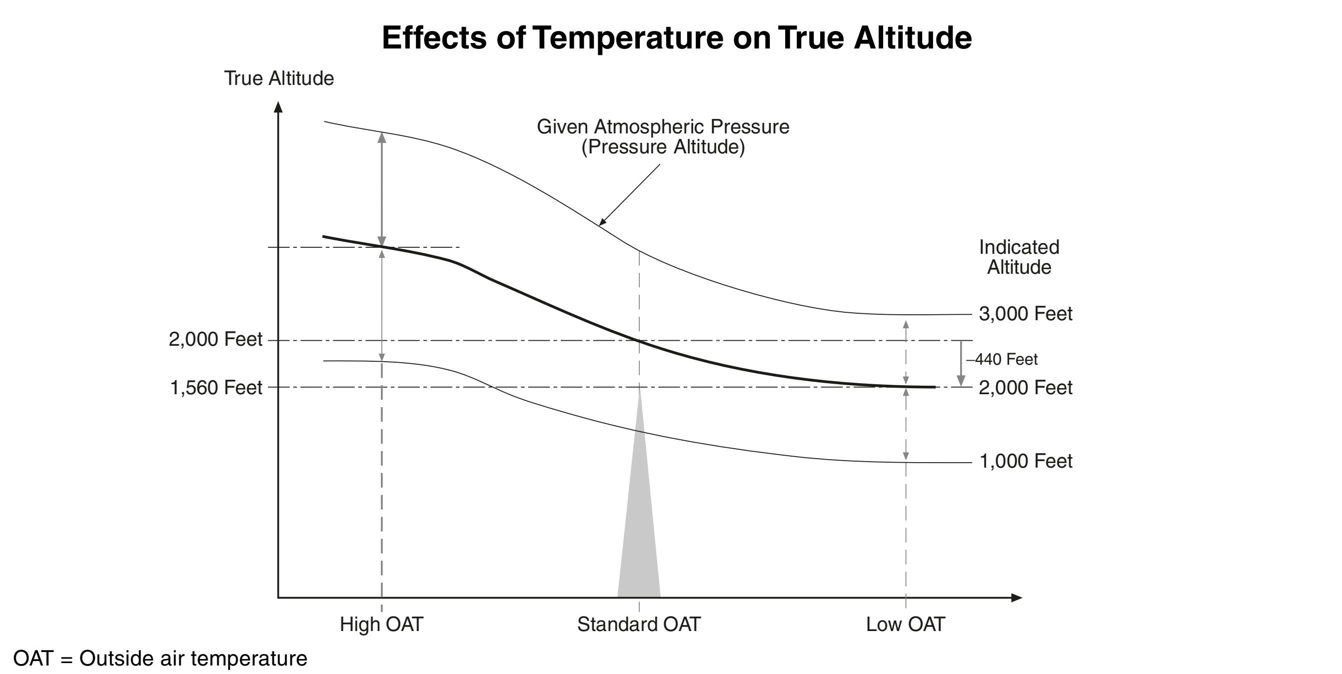
For example, Figure 4 (page 63) shows that when conducting an ILS approach with a published minimum glideslope intercept altitude of 2,000 feet and an OAT of -40 degrees Celsius (-40 degrees Fahrenheit), the minimum glideslope intercept altitude should be *increased* by 440 feet.

The pilot is responsible for conducting this correction, except when under radar control in a radar-vectoring area (because the controller is responsible normally for terrain clearance, including accounting for the cold temperature correction).

Nevertheless, the pilot should confirm this responsibility with the air traffic services of the country of operation.

Flight crews must apply the ICAO corrections for low temperatures to the following published altitudes:

- Minimum en route altitude (MEA) and minimum safe altitude (MSA);
- Transition route altitude;
- Procedure turn altitude (as applicable);
- Final approach fix (FAF) altitude;
- Step-down altitude(s) and MDA(H) during a nonprecision approach;
- Outer marker (OM) crossing altitude during an ILS approach; and,



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4

- Waypoint crossing altitudes during a global positioning system (GPS) approach flown with barometric vertical navigation.

ICAO does not provide altitude corrections for extremely high temperatures; however, the temperature effect on true altitude must not be ignored when planning for a constant-angle nonprecision approach (CANPA) (i.e., to maintain the required flight path/vertical speed).

Summary

Altimeter-setting errors result in insufficient vertical-position awareness. The following minimize the potential for altimeter-setting errors and foster optimum use of the barometric-altimeter bug and RA DH bug:

- Awareness of altimeter-setting changes demanded by prevailing weather conditions (extreme cold fronts, extreme warm fronts, steep frontal surfaces, semi-permanent low pressure areas or seasonal low pressure areas);
- Awareness of the unit of measurement for setting the altimeter at the destination airport;
- Awareness of the anticipated altimeter setting (based on aviation routine weather reports [METARs] and ATIS broadcasts);
- PF-PNF cross-checking; and,
- Adherence to SOPs for:
  - Resetting altimeters at the transition altitude/flight level;
  - Using the standby altimeter to cross-check the primary altimeters;
  - Altitude calls;
  - Radio-altimeter calls; and,
  - Setting the barometric-altimeter bug and RA DH bug.

The following FSF ALAR Briefing Notes provide information to supplement this discussion

- *1.1 — Operating Philosophy*;
- *2.3 — Pilot-Controller Communication*;
- *2.4 — Interruptions/Distractions*; and,
- *3.2 — Altitude Deviations*.♦

References

1. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]." Each accident and incident in the study sample involved several causal factors.
2. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on

analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

3. International Civil Aviation Organization. *Procedures for Air Navigation Services. Aircraft Operations*. Volume I, *Flight Procedures*. Part III, *Approach Procedures*. Fourth edition - 1993. Reprinted May 2000, incorporating Amendments 1–10.

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Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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ALAR

Approach-and-landing Accident Reduction

Tool Kit

FSF ALAR Briefing Note 3.2 — Altitude Deviations

Altitude deviations may result in substantial loss of aircraft vertical separation or horizontal separation, which could cause a midair collision.

Maneuvers to avoid other aircraft often result in injuries to passengers, flight crewmembers and, particularly, to cabin crewmembers.

Statistical Data

An analysis by the U.S. Federal Aviation Administration (FAA) and by USAir (now US Airways) of altitude-deviation events[1] showed that:

- Approximately 70 percent of altitude deviations were the result of a breakdown in pilot-controller communication; and,
- Nearly 40 percent of altitude deviations resulted when air traffic control (ATC) assigned 10,000 feet and the flight crew set 11,000 feet in the selected-altitude window, or when ATC assigned 11,000 feet and the flight crew set 10,000 feet in the selected-altitude window.

Defining Altitude Deviations

An altitude deviation is a deviation from the assigned altitude (or flight level) equal to or greater than 300 feet.

Causes of Altitude Deviations

Altitude deviations are usually the result of a breakdown in either:

- The pilot-system interface:
  - Altimeter setting, use of autopilot, monitoring of instruments and displays; or,
- The pilot-controller interface:
  - Communication loop (i.e., the confirmation/correction process).

Altitude deviations occur usually as the result of one or more of the following conditions:

- The controller assigns an incorrect altitude or reassigns a *flight level* after the pilot was cleared to an *altitude*;
- Pilot-controller communication breakdown — mainly readback/hearback errors such as the following:
  - Controller transmits an incorrect altitude, the pilot does not read back the altitude and the controller does not challenge the absence of a readback;
  - Pilot reads back an incorrect altitude, but the controller does not hear the erroneous readback and does not correct the pilot's readback; or,
  - Pilot accepts an altitude clearance intended for another aircraft (confusion of call signs);
- Pilot receives, understands and reads back the correct altitude or flight level but selects an incorrect altitude or flight level because of:
  - Confusion of numbers with another element of the message (e.g., airspeed, heading or flight number);
  - Expectation of another altitude/flight level;

– Interruption/distraction; or,

– Breakdown in crew cross-checking;

- Autopilot fails to capture the selected altitude;
- The crew does not respond to altitude-alert aural warnings and visual warnings when hand-flying; or,
- The crew conducts an incorrect go-around procedure.

Altitude-awareness Program

The development and implementation of altitude-awareness programs by several airlines have reduced significantly the number of altitude deviations.

To help prevent the primary causes of altitude deviations, an altitude-awareness program should include the following:

General

An altitude-awareness program should enhance the monitoring roles of the pilot flying (PF) and the pilot not flying (PNF) by emphasizing the importance of:

- Announcing intentions and actions, particularly when they are different from expectations (e.g., delayed climb or descent, management of altitude or airspeed restrictions); and,
- Cross-checking.

Communication

The FAA-USAir study showed that approximately 70 percent of altitude deviations are the result of a breakdown in the pilot-controller communication loop caused by:

- Readback/hearback errors (this risk is greater when one pilot does not monitor radio communications because of other duties such as listening to the automatic terminal information service [ATIS], complying with company-communication requirements or making public-address announcements);
- Blocked transmissions; or,
- Confusion of call signs.

The following recommendations improve communication and situational awareness:

- Be aware that readback/hearback errors involve both the pilot and the controller:
  - The pilot may be interrupted or distracted when listening to a clearance, be subject to forgetfulness or be subject to the bias of expectation when listening to or when reading back the instruction (this bias is also termed *wish-hearing*) or may be confused by similar call signs; and,
  - The controller may confuse similar call signs, be distracted by other radio communications or by telephone communications, or be affected by blocked transmissions or by workload;
- Use standard phraseology for clear and unambiguous pilot-controller communication and crew communication.
  - Standard phraseology is a common language for pilots and controllers, and this common language increases the likelihood of detecting and correcting errors;
- Use expanded phraseology, such as:
  - Announcing when leaving an altitude (e.g., “Leaving […] for […],” or, “leaving […] and climbing to […]”), thus increasing the controller’s situational awareness;
  - The announcement “leaving [altitude or flight level]” should be made only when a vertical speed of 500 feet per minute (fpm) has been established and the altimeter confirms departure from the previous altitude;
  - Combining different expressions of specific altitudes (“one one thousand feet — that is, eleven thousand feet”); and,
  - Preceding each number by the corresponding flight parameter (flight level, heading, airspeed [e.g., “descend to flight level two four zero” instead of “descend to two four zero”]); and,
- When in doubt about a clearance, request confirmation from the controller; do not guess about the clearance based on crew discussion.

Task-prioritization and Task-sharing

The following recommendations enable optimum prioritization of tasks and task-sharing:

- Reduce nonessential tasks during climb and descent (in addition to the “critical phases of flight” defined in the “sterile cockpit rule,”[2] some operators consider the final 1,000 feet before reaching the assigned altitude as a sterile-cockpit period);
- Monitor/supervise the operation of the autopilot to confirm correct level-off at the cleared altitude and for compliance with altitude restrictions or time restrictions;
- Plan tasks that preclude listening to ATC communications (e.g., ATIS, company calls, public-address announcements) for periods of infrequent ATC communication; and,
- When one pilot does not monitor the ATC frequency while doing other duties (e.g., company calls) or when leaving the flight deck, the other pilot should:
  - Acknowledge receiving responsibility for ATC radio communication and aircraft control, as applicable;

– Check that the radio volume is adequate to hear an ATC call;

– Give increased attention to listening/confirming/ reading back (because of the absence of cross-checking); and,

– Brief the other pilot when he/she completes other duties or returns to the flight deck, and communicate relevant new information and any change in ATC clearances or instructions.

Altitude-setting Procedures

The following techniques enhance standard operating procedures (SOPs):

- When receiving an altitude clearance, set immediately the assigned/cleared altitude in the altitude window;
- Ensure that the selected altitude is cross-checked by both pilots (e.g., each pilot should announce what he/she heard and then point to the altitude window to confirm that the correct altitude has been set);
- Ensure that the assigned altitude is above the minimum safe altitude (MSA); and,
- Positively confirm the altitude clearance, when receiving radar vectors.

Standard Calls

Use the following calls to increase PF/PNF situational awareness and to ensure effective backup and challenge (and to detect a previous error in the assigned altitude/flight level):

- Mode changes on the flight mode annunciator (FMA) and changes of targets (e.g., airspeed, heading, altitude) on the primary flight display (PFD) and navigation display (ND);
- "Leaving [...] for […]" when a 500 fpm (minimum) vertical speed has been established; and,
- "One to go," "One thousand to go" or "[…] for […]" when within 1,000 feet of the assigned/cleared altitude/ flight level.

When within 1,000 feet of the assigned altitude/flight level or an altitude restriction in visual meteorological conditions (VMC), one pilot should concentrate on scanning instruments (one head down) and one pilot should concentrate on traffic watch (one head up).

Flight Level Confusion

Confusion between 10,000 feet and 11,000 feet (FL 100 and FL 110) is usually the result of the combination of two or more of the following factors:

- Readback/hearback error because of similar-sounding phrases;
- Lack of standard phraseology:
  – International Civil Aviation Organization (ICAO): "flight level one *zero zero*/flight level one one zero";
  – U.K. National Air Traffic Services (NATS): "flight level one *hundred*/flight level one one zero";
- Mindset tending to focus only on "one zero" and thus to more easily understand "10,000 feet";
- Failing to question the unusual (e.g., bias of expectation on a familiar standard terminal arrival [STAR]); and/or,
- Interpreting subconsciously a request to slow to 250 knots as a clearance to descend to FL 100 (or 10,000 feet).

Transition Altitude/Flight Level

The transition altitude/flight level can be either:

- Fixed for the whole country (e.g., FL 180 in the United States);
- Fixed for a given airport (as indicated on the approach chart); or,
- Variable as a function of QNH (an altimeter setting that causes the altimeter to indicate height above mean sea level [i.e., field elevation at touchdown on the runway]) as indicated in the ATIS broadcast.

Depending on the airline's/flight crew's usual area of operation, changing from a fixed transition altitude/flight level to variable transition altitudes/flight levels may result in a premature resetting or a late resetting of the altimeter.

An altitude restriction (expressed in altitude or flight level) also may delay or advance the setting of the standard altimeter setting (1013.2 hPa or 29.92 in. Hg), possibly resulting in crew confusion.

In countries operating with QFE (altimeter setting that causes the altimeter to indicate height above the QFE reference datum [i.e., zero at touchdown on the runway]), the readback should indicate the altimeter reference (i.e., QFE).

Altitude Deviations in Holding Patterns

Controllers assume that the pilot will adhere to a clearance that the pilot has read back correctly.

Two separate holding patterns may be under the control of the same controller, on the same frequency.

With aircraft in holding patterns, controllers particularly rely on pilots because the overlay of aircraft data tags on the controller's radar display may not allow the immediate detection of an impending traffic conflict.

Secondary surveillance radars provide conflict alert but not resolution advisory; thus, accurate pilot-controller communication is essential when descending in a holding pattern.

The following pilot actions are important when in a holding pattern:

- Do not take a communication intended for another aircraft (by confusion of similar call signs);
- Prevent/minimize the risk of blocked transmission (e.g., simultaneous readback by two aircraft with similar call signs or simultaneous transmissions by the pilot and the controller); and,
- Announce "leaving [altitude or flight level]" only when a vertical speed of 500 fpm has been established and the altimeter confirms departure from the previous altitude.

TCAS (ACAS)

The traffic-alert and collision avoidance system (airborne collision avoidance system) is an effective tool to help prevent midair collisions, which can result from altitude deviations.

Summary

Altitude deviations can be prevented by adhering to SOPs to:

- Set the altimeter reference; and,
- Select the assigned altitude/flight level.

To be effective, a company altitude-awareness program should be emphasized during transition training, recurrent training and line checks.

Blame-free reporting of altitude-deviation events should be encouraged to broaden the company's knowledge and the industry's knowledge of the causal factors of altitude deviations.

The following should be promoted:

- Adhere to the pilot-controller confirmation/correction process (communication loop);
- Practice flight crew cross-checking to ensure that the *selected* altitude is the *assigned* altitude;
- Cross-check that the assigned altitude is *above the MSA* (unless the flight crew is aware that the assigned altitude is above the minimum vectoring altitude);
- Monitor instruments and automation when reaching the assigned altitude/flight level; and,
- In VMC, apply the practice of one head down and one head up when reaching the assigned altitude/flight level.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.3 — Golden Rules*;
- *1.4 — Standard Calls*;
- *2.3 — Pilot-Controller Communication*;
- *2.4 — Interruptions/Distractions*; and,
- *3.1 — Barometric Altimeter and Radio Altimeter.*♦

References

1. Pope, John A. "Research Identifies Common Errors Behind Altitude Deviations." *Flight Safety Digest* Volume 12 (June 1993): 1–13.
2. The *sterile cockpit rule* refers to U.S. Federal Aviation Regulations Part 121.542, which states: "No flight crewmember may engage in, nor may any pilot-in-command permit, any activity during a critical phase of flight which could distract any flight crewmember from the performance of his or her duties or which could interfere in any way with the proper conduct of those duties. Activities such as eating meals, engaging in nonessential conversations within the cockpit and nonessential communications between the cabin and cockpit crews, and reading publications not related to the proper conduct of the flight are not required for the safe operation of the aircraft. For the purposes of this section, critical phases of flight include all ground operations involving taxi, takeoff and landing, and all other flight operations below 10,000 feet, except cruise flight." [The FSF ALAR Task Force says that "10,000 feet" should be height above ground level during flight operations over high terrain.]

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Tool Kit

FSF ALAR Briefing Note 4.1 — Descent-and-approach Profile Management

Incorrect management of the descent-and-approach profile and/or aircraft energy condition may result in:

- A loss of situational awareness; and/or,
- An unstabilized approach.

Either situation increases the risk of approach-and-landing accidents, including those involving controlled flight into terrain (CFIT).

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that unstabilized approaches (i.e., approaches conducted either low/slow or high/fast) were a causal factor[1] in 66 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[2]

The task force said that factors associated with being low/slow on approach include:

- "Inadequate awareness of automation/systems status;
- "Lack of vigilance and crew coordination, including omission of standard airspeed-and-altitude calls; and,
- "High workload and confusion during execution of nonprecision approaches."

The task force said that factors associated with being high/fast on approach include:

- "Overconfidence, lack of vigilance and 'press-on-itis'[3];
- "Lack of crew coordination; and,
- "Accepting demanding air traffic control (ATC) clearances, leading to high-workload conditions."

Descent Preparation and Approach Briefing

To help prevent delaying initiation of the descent and to ensure optimum management of the descent-and-approach profile, the following procedures are recommended:

- Descent preparation and the approach briefing should be completed typically 10 minutes before the top-of-descent point (or when within very-high-frequency [VHF] communication range if automatic terminal information system [ATIS] information cannot be obtained 10 minutes before the top-of-descent point);
- If a standard terminal arrival (STAR) is included in the flight management system (FMS) flight plan but is not expected to be flown because of radar vectors, the STAR should be checked (track, distance, altitude and airspeed restrictions) against the expected routing to adjust the top-of-descent point;
- If descent initiation is delayed by ATC, airspeed should be reduced (as appropriate to the aircraft model) to minimize the effect of the delay on the descent profile;
- Wind-forecast data should be programmed on the appropriate FMS page at waypoints near the top-of-descent point and along the descent-profile path;
- If a missed approach procedure is included in the FMS flight plan, the FMS missed approach procedure should be checked against the approach chart; and,

- If FMS navigation accuracy does not meet the applicable criteria for descent, terminal area navigation or approach, no descent should be made below the minimum en route altitude (MEA) or minimum safe altitude (MSA) without prior confirmation of the aircraft position using raw data[4].

Achieving Flight Parameters

The flight crew must "stay ahead of the aircraft" throughout the flight. This includes achieving desired flight parameters (e.g., aircraft configuration, aircraft position, energy condition, track, vertical speed, altitude, airspeed and attitude) during the descent, approach and landing. Any indication that a desired flight parameter will not be achieved should prompt immediate corrective action or the decision to go around.

At the final approach fix (FAF) or the outer marker (OM), the crew should decide whether to proceed with the approach, based on the following factors:

- Ceiling and visibility are better than or equal to applicable minimums;
- Aircraft is ready (position, altitude, configuration, energy condition); and,
- Crew is ready (briefing completed, agreement on the approach).

If the required aircraft configuration and airspeed are not attained, or if the flight path is not stabilized when reaching the minimum stabilization height (1,000 feet above airport elevation in instrument meteorological conditions or 500 feet above airport elevation in visual meteorological conditions), a go-around should be initiated immediately.

The pilot not flying (PNF) should announce any flight parameter that *exceeds the criteria for any of the elements of a stabilized approach* (Table 1).

Descent Profile Monitoring

The descent profile should be monitored, using all available instruments and chart references, including:

- FMS vertical-deviation indication, as applicable;
- Raw data; and,
- Charted descent-and-approach profile.

Wind conditions and wind changes should be monitored closely to anticipate any decrease in head-wind component or increase in tail-wind component, and the flight-path profile should be adjusted appropriately.

The descent also may be monitored and adjusted based on a *typical 3,000 feet per 10 nautical mile (nm) descent gradient* (corrected for the prevailing head-wind component or tail-wind component), while adhering to the required altitude/airspeed restrictions (deceleration management).

Table 1
Recommended Elements
Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

Below 10,000 feet, flying at 250 knots, the following recommendations may be used to confirm the descent profile and to ensure a smooth transition between the various approach phases:

- 9,000 feet above airport elevation at 30 nm from touchdown; and,
- 3,000 feet above airport elevation at 15 nm from touchdown (to allow for deceleration and slats/flaps extension).

Descent Profile Adjustment/Recovery

If the flight path is significantly above the desired descent profile (e.g., because of ATC restrictions or a greater-than-anticipated tail wind), the desired flight path can be recovered by:

- Reverting from FMS vertical navigation (VNAV) to a selected vertical mode, with an appropriate airspeed target (e.g., airspeed, heading, altitude) or vertical-speed target;
- Maintaining a high airspeed (and a steep angle of descent) as long as practical;
- Using speed brakes (as allowed by applicable SOPs, depending on airspeed and configuration, keeping one hand on the speed-brake handle until the speed brakes are retracted);
- Extending the landing gear, as allowed by airspeed and configuration, if speed brakes are not sufficient; or,
- As a last resort, conducting a 360-degree turn (as practical, and with ATC clearance). Maintain instrument references throughout the turn to monitor and control the rate of descent, bank angle and aircraft position; this will help avoid loss of aircraft control or CFIT, and prevent overshooting the localizer or extended runway centerline.

If the desired descent flight path cannot be established, ATC should be notified for timely coordination.

Adverse Factors and Typical Errors

The following factors and errors often are observed during transition training and line training:

- Late descent, which results in rushing the descent, approach preparation and briefing, and increases the likelihood that important items will be omitted;
- Failure to cross-check target entry;
- Failure to allow for a difference between the expected routing and the actual routing (e.g., STAR vs. radar vectors);
- Distraction leading to or resulting from *two heads down*;
- Failure to resolve ambiguities, doubts or disagreements;
- Failure to effectively monitor descent progress using all available instrument references;
- Failure to monitor wind conditions and wind changes; and/or,
- Inappropriate technique to establish the descent profile.

Summary

The following should be emphasized during transition training, line training and line audits:

- Conduct timely descent-and-approach preparation;
- Adhere to SOPs for FMS setup;
- Cross-check all target entries;
- Use the primary flight display (PFD), navigation display (ND) and FMS to support and to illustrate the approach briefing;
- Confirm FMS navigation accuracy before selecting FMS modes for the descent and approach;
- Review terrain-awareness data and other approach hazards; and,
- Monitor the descent profile and adjust the descent profile as required.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.3 — Golden Rules*;
- *4.2 — Energy Management*;
- *5.2 — Terrain*;
- *6.1 — Being Prepared to Go Around*; and,
- *7.1 — Stabilized Approach*.♦

References

1. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]." Each accident and incident in the study sample involved several causal factors.
2. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.
3. The FSF ALAR Task Force defines *press-on-itis* as "continuing toward the destination despite a lack of readiness of the airplane or crew."
4. The FSF ALAR Task Force defines *raw data* as "data received directly (not via the flight director or flight management computer) from basic navigation aids (e.g., ADF, VOR, DME, barometric altimeter)."

Related Reading from FSF Publications

Flight Safety Foundation (FSF) Editorial Staff. "Pilot Loses Control of Twin Turboprop During ILS Approach in Low Visibility." *Accident Prevention* Volume 57 (July 2000).

FSF Editorial Staff. "Learjet Strikes Terrain When Crew Tracks False Glideslope Indication and Continues Descent Below Published Decision Height." *Accident Prevention* Volume 56 (June 1999).

FSF Editorial Staff. "Boeing 767 Descends Below Glide Path, Strikes Tail on Landing." *Accident Prevention* Volume 55 (February 1998).

FSF Editorial Staff. "Preparing for Last-minute Runway Change, Boeing 757 Flight Crew Loses Situational Awareness, Resulting in Collision with Terrain." *Accident Prevention* Volume 54 (July–August 1997).

FSF Editorial Staff. "Learjet MEDEVAC Flight Ends in Controlled-flight-into-terrain (CFIT) Accident." *Accident Prevention* Volume 54 (January 1997).

FSF Editorial Staff. "Commuter Captain Fails to Follow Emergency Procedures After Suspected Engine Failure, Loses Control of the Aircraft During Instrument Approach." *Accident Prevention* Volume 53 (April 1996).

FSF Editorial Staff. "Different Altimeter Displays and Crew Fatigue Likely Contributed to Canadian Controlled-flight-into-terrain Accident." *Accident Prevention* Volume 52 (December 1995).

FSF Editorial Staff. "Captain's Failure to Establish Stabilized Approach Results in Controlled-flight-into-terrain Commuter Accident." *Accident Prevention* Volume 52 (July 1995).

FSF Editorial Staff. "Stall and Improper Recovery During ILS Approach Result in Commuter Airplane's Uncontrolled Collision with Terrain." *Accident Prevention* Volume 52 (January 1995).

Lawton, Russell. "Moving Power Levers Below Flight Idle During Descent Results in Dual Engine Flameout and Power-off Emergency Landing of Commuter Airplane." *Accident Prevention* Volume 51 (December 1994).

Lawton, Russell. "Steep Turn by Captain During Approach Results in Stall and Crash of DC-8 Freighter." *Accident Prevention* Volume 51 (October 1994).

Lawton, Russell. "Breakdown in Coordination by Commuter Crew During Unstabilized Approach Results in Controlled-flight-into-terrain Accident." *Accident Prevention* Volume 51 (September 1994).

Regulatory Resources

International Civil Aviation Organization (ICAO). *International Standards and Recommended Practices, Annex 6 to the Convention of International Civil Aviation, Operation of Aircraft.* Part I, *International Commercial Air Transport – Aeroplanes*. Appendix 2, "Contents of an Operations Manual," 5.18, 5.19. Seventh edition - July 1998, incorporating Amendments 1–25.

ICAO. *Procedures for Air Navigation Services. Aircraft Operations*. Volume I, *Flight Procedures*. Fourth edition, 1993. Reprinted May 2000, incorporating Amendments 1–10.

U.S. Federal Aviation Administration. Advisory Circular 120-71, *Standard Operating Procedures for Flight Deck Crewmembers*. August 10, 2000.

Joint Aviation Authorities. *Joint Aviation Requirements – Operations 1*, *Commercial Air Transportation (Aeroplanes)*. 1.1045 "Operations Manual – structure and contents." March 1, 1998.

Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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Approach-and-landing Accident Reduction

Tool Kit

FSF ALAR Briefing Note 4.2 — Energy Management

The flight crew's inability to assess or to manage the aircraft's energy condition during approach is cited often as a cause of unstabilized approaches.

Either a deficit of energy (low/slow) or an excess of energy (high/fast) may result in an approach-and-landing incident or accident involving:

- Loss of control;
- Landing before reaching the runway;
- Hard landing;
- Tail strike; or,
- Runway overrun.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that unstabilized approaches (i.e., approaches conducted either low/slow or high/fast) were a causal factor[1] in 66 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[2]

These accidents involved incorrect management of aircraft energy condition, resulting in an excess or deficit of energy, as follows:

- Aircraft were low/slow on approach in 36 percent of the accidents/incidents; and,
- Aircraft were high/fast on approach in 30 percent of the accidents/incidents.

Aircraft Energy Condition

Aircraft energy condition is a function of the following primary flight parameters:

- Airspeed and airspeed trend;
- Altitude (or vertical speed or flight path angle);
- Drag (caused by speed brakes, slats/flaps and landing gear); and,
- Thrust.

One of the primary tasks of the flight crew is to control and to monitor aircraft energy condition (using all available references) to:

- Maintain the appropriate energy condition for the flight phase (i.e., configuration, flight path, airspeed and thrust); or,
- Recover the aircraft from a low-energy condition or a high-energy condition.

Controlling aircraft energy involves balancing airspeed, thrust (and drag) and flight path.

Autopilot modes, flight director modes, aircraft instruments, warnings and protections are designed to relieve or assist the flight crew in this task.

Going Down and Slowing Down

A study by the U.S. National Transportation Safety Board[3] said that maintaining a high airspeed to the outer marker (OM) may prevent capture of the glideslope by the autopilot and may prevent aircraft stabilization at the defined stabilization height.

The study concluded that no airspeed restriction should be imposed by air traffic control (ATC) when within three nautical miles (nm) to four nm of the OM, especially in instrument meteorological conditions (IMC).

ATC instructions to maintain a high airspeed to the OM (160 knots to 200 knots, typically) are common at high-density airports, to increase the landing rate.

Minimum Stabilization Height

Table 1 shows that the minimum stabilization height is:

- 1,000 feet above airport elevation in IMC; or,
- 500 feet above airport elevation in visual meteorological conditions (VMC).

Typical company policy is to cross the OM (usually between 1,500 feet and 2,000 feet above airport elevation) with the aircraft in the landing configuration to allow time for stabilizing the final approach speed and completing the landing checklist before reaching the minimum stabilization height.

Aircraft Deceleration Characteristics

Although deceleration characteristics vary among aircraft types and their gross weights, the following typical values can be used:

- Deceleration in level flight:
  - With approach flaps extended: 10 knots to 15 knots per nm; or,
  - During extension of the landing gear and landing flaps: 20 knots to 30 knots per nm; and,
- Deceleration on a three-degree glide path (for a typical 140-knot final approach groundspeed, a rule of thumb is to maintain a descent gradient of 300 feet per nm/700 feet per minute [fpm]):
  - With approach flaps and landing gear down, during extension of landing flaps: 10 knots to 20 knots per nm;
  - Decelerating on a three-degree glide path in a clean configuration is not possible usually; and,
  - When capturing the glideslope with slats extended and no flaps, typically a 1,000-foot descent and three nm are flown while establishing the landing configuration and stabilizing the final approach speed.

Table 1
Recommended Elements Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

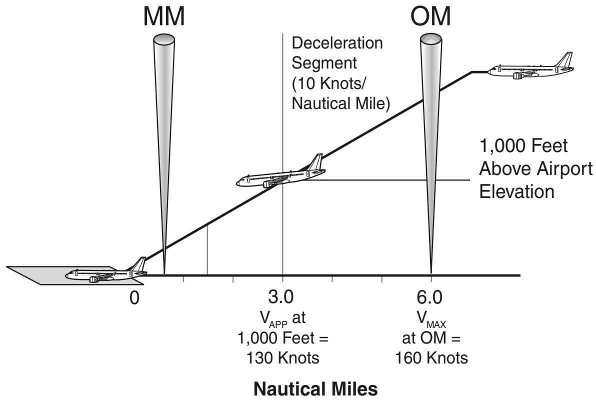
Speed brakes may be used to achieve a faster deceleration of some aircraft (usually, the use of speed brakes is not recommended or not permitted below 1,000 feet above airport elevation or with landing flaps extended).

Typically, slats should be extended not later than three nm from the final approach fix (FAF).

Figure 1 (page 77) shows aircraft deceleration capability and the maximum airspeed at the OM based on a *conservative deceleration rate of 10 knots per nm on a three-degree glide path*.

For example, in IMC (minimum stabilization height, 1,000 feet above airport elevation) and with a typical 130-knot final

Typical Schedule for Deceleration on Three-degree Glide Path From Outer Marker to Stabilization Height (1,000 Feet)



MM = Middle marker OM = Outer marker
V_{APP} = Final approach speed V_{MAX} = Maximum airspeed

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 1

approach speed,[4] the maximum deceleration achievable between the OM (six nm) and the stabilization point (1,000 feet above airport elevation and three nm) is:

10 knots per nm x (6 nm – 3 nm) = 30 knots.

To be stabilized at 130 knots at 1,000 feet above airport elevation, the maximum airspeed that can be accepted and can be maintained down to the OM is, therefore:

130 knots + 30 knots = 160 knots.

Whenever a flight crew is requested to maintain a high airspeed down to the OM, a quick computation such as the one shown above can help assess the ATC request.

Back Side of the Power Curve

During an unstabilized approach, airspeed or the thrust setting often deviates from recommended criteria as follows:

- Airspeed decreases below V_{REF}; and/or,
- Thrust is reduced to idle and is maintained at idle.

Thrust-required-to-fly Curve

Figure 2 shows the *thrust-required-to-fly curve* (also called the *power curve*).

The power curve comprises the following elements:

- A point of minimum thrust required to fly;
- A segment of the curve located right of this point; and,
- A segment of the curve located left of this point, called the *back side of the power curve* (i.e., where induced drag requires more power to fly at a slower steady-state airspeed than the power required to maintain a faster airspeed on the front side of the power curve).

The difference between the available thrust and the thrust required to fly represents the climb or acceleration capability.

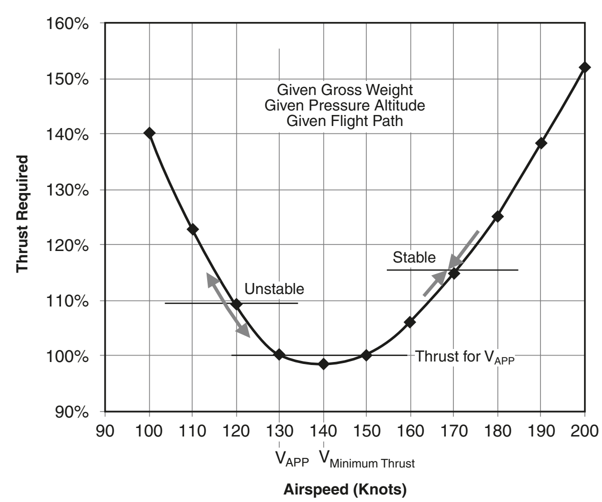
The right segment of the power curve is the normal zone of operation; the thrust balance (i.e., the balance between thrust required to fly and available thrust) is stable.

Thus, at a given thrust level, any tendency to accelerate increases the thrust required to fly and, hence, returns the aircraft to the initial airspeed.

Conversely, the back side of the power curve is unstable: At a given thrust level, any tendency to decelerate increases the thrust required to fly and, hence, increases the tendency to decelerate.

The final approach speed usually is slightly on the back side of the power curve, while the minimum thrust speed is 1.35 times V_{SO} (stall speed in landing configuration) to 1.4 times V_{SO}.

Thrust Required to Fly a Three-degree Glide Path in Landing Configuration



V_{APP} = Final approach speed

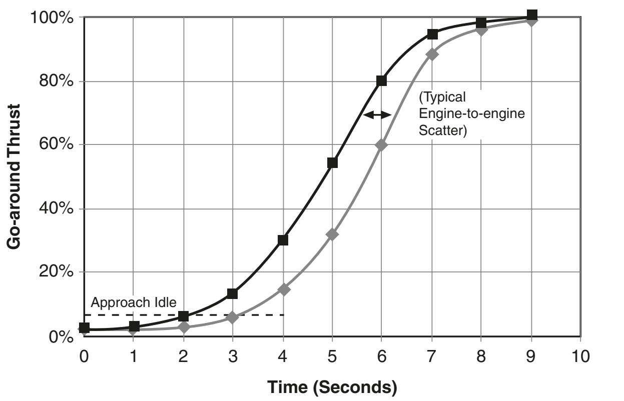
Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 2

If airspeed is allowed to decrease below the final approach speed, more thrust is required to maintain the desired flight path and/or to regain the final approach speed.

If thrust is set to idle and maintained at idle, no energy is available immediately to recover from a low-speed condition or to initiate a go-around (as shown in Figure 3, Figure 4 and Figure 5).

Typical Engine Response From Approach-idle Thrust to Go-around Thrust



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3

Engine Acceleration

When flying the final approach with the thrust set and maintained at idle (approach idle), the pilot should be aware of the acceleration characteristics of jet engines (Figure 3).

By design, the acceleration capability of a jet engine is controlled to protect the engine against a compressor stall or flame-out and to comply with engine and aircraft certification requirements.

For example, Figure 4 shows that U.S. Federal Aviation Regulations (FARs) Part 33 requires a time of five seconds or less to accelerate from 15 percent to 95 percent of the go-around thrust (15 percent of go-around thrust corresponds typically to the thrust level required to maintain the final approach speed on a stable three-degree approach path).

FARs Part 25 requires that a transport airplane achieve a minimum climb gradient of 3.2 percent with engine thrust available eight seconds after the pilot begins moving the throttle levers from the minimum flight-idle thrust setting to the go-around thrust setting.

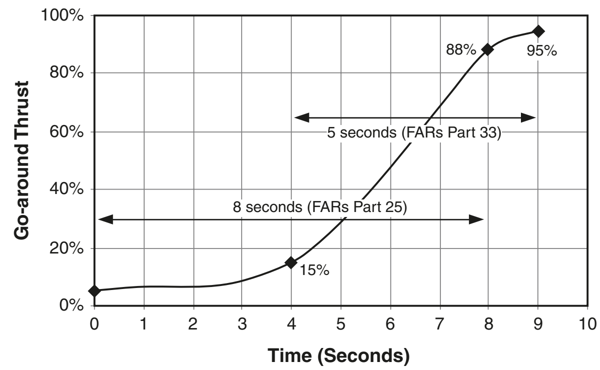
Go-around From Low Airspeed/Low Thrust

Figure 5 shows the hazards of flying at an airspeed below the final approach speed.

The hazards are increased if thrust is set and maintained at idle.

If a go-around is required, the initial altitude loss and the time for recovering the lost altitude are increased if the airspeed is lower than the final approach speed and/or if the thrust is set at idle.

U.S. Federal Aviation Regulations (FARs) Requirements for Engine Response — Flight-idle Thrust to Go-around Thrust

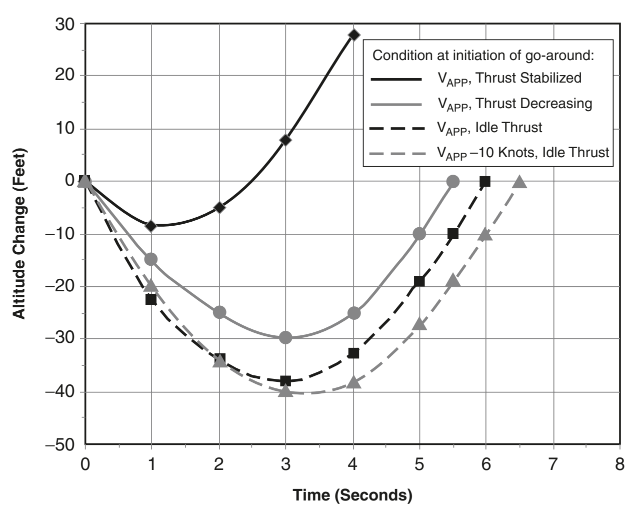


FARs Part 25 = Airworthiness Standards: Transport Category Airplanes
FARs Part 33 = Airworthiness Standards: Aircraft Engines

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4

Typical Altitude Loss After Initiation of a Go-around (Aircraft in Landing Configuration)



V_{APP} = Final approach speed

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 5

Summary

Deceleration below the final approach speed should be allowed only during the following maneuvers:

- Terrain-avoidance maneuver;
- Collision-avoidance maneuver; or,
- Wind shear recovery maneuver.

Nevertheless, during all three maneuvers, the throttle levers must be advanced to maximum thrust (i.e., go-around thrust) while initiating the maneuver.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *6.1 — Being Prepared to Go Around*;
- *7.1 — Stabilized Approach*; and,
- *7.2 — Constant-angle Nonprecision Approach.*♦

References

1. The Flight Safety Foundation Approach-and-landing Accident Reduction Task Force defined causal factor as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]." Each accident and incident in the study sample involved several causal factors.
2. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.
3. U.S. National Transportation Safety Board. *Special Study: Flightcrew Coordination Procedures in Air Carrier Instrument Landing System Approach Accidents*. Report No. NTSB-AAS-76-5. August 18, 1976.
4. Final approach speed is V_{REF} (reference landing speed [typically 1.3 times stall speed in landing configuration]) plus a correction factor for wind conditions, aircraft configuration or other conditions.

Related Reading from FSF Publications

Flight Safety Foundation (FSF) Editorial Staff. "Business Jet Overruns Wet Runway After Landing Past Touchdown Zone." *Accident Prevention* Volume 56 (December 1999).

Sallee, G. P.; Gibbons, D. M. "Propulsion System Malfunction Plus Inappropriate Crew Response (PSM+ICR)." *Flight Safety Digest* Volume 18 (November–December 1999).

FSF Editorial Staff. "Airplane's Low-energy Condition and Degraded Wing Performance Cited in Unsuccessful Go-around Attempt." *Accident Prevention* Volume 56 (July 1999).

FSF Editorial Staff. "Boeing 767 Descends Below Glide Path, Strikes Tail on Landing." *Accident Prevention* Volume 55 (February 1998).

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FSF Editorial Staff. "Captain's Inadequate Use of Flight Controls During Single-engine Approach and Go-around Results in Loss of Control and Crash of Commuter." *Accident Prevention* Volume 52 (November 1995).

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FSF ALAR Briefing Note 5.1 — Approach Hazards Overview

Few air transport accidents occur on calm sunny days; risk increases during flight over hilly terrain, with reduced visibility, adverse winds, contaminated runways and limited approach aids.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction Task Force, in an analysis of 76 approach-and-landing accidents and serious incidents, including controlled-flight-into-terrain (CFIT) accidents, worldwide in 1984 through 1997,[1] found that:

- Fifty-three percent of the accidents and incidents occurred during nonprecision instrument approaches or visual approaches (42 percent of the visual approaches were conducted where an instrument landing system [ILS] approach was available);
- Fifty percent occurred where no radar service was available;
- Sixty-seven percent of the CFIT accidents occurred in hilly terrain or mountainous terrain;
- Fifty-nine percent of the accidents and incidents occurred in instrument meteorological conditions (IMC);
- Fifty percent occurred in precipitation (snow, rain);
- Fifty-three percent occurred in darkness or twilight;
- Thirty-three percent involved adverse wind conditions (i.e., strong crosswinds, tail winds or wind shear);
- Twenty-one percent involved flight crew disorientation or visual illusions;
- Twenty-nine percent involved nonfitment of available safety equipment (e.g., ground-proximity warning system [GPWS] or radio altimeter);
- Eighteen percent involved runway conditions (e.g., wet or contaminated by standing water, slush, snow or ice); and,
- Twenty-one percent involved inadequate ground aids (e.g., navigation aids, approach/runway lights or visual approach-slope guidance).

Awareness Program

A company awareness program on approach-and-landing hazards should emphasize the following elements that lead to good crew decisions:

- Use the FSF *Approach-and-landing Risk Awareness Tool* (page 84) to heighten crew awareness of the specific hazards to the approach;
- Use the FSF *Approach-and-landing Risk Reduction Guide* (page 86);
- Anticipate by asking, “What if?” and prepare;
- Adhere to standard operating procedures (SOPs); and,
- Prepare options, such as:
  - Request a precision approach into the wind;
  - Select an approach gate[2] for a stabilized approach (Table 1, page 82);

– Wait for better conditions; or,

– Divert to an airport with better conditions.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *5.2 — Terrain*;
- *5.3 — Visual Illusions*;
- *5.4 — Wind Shear*;
- *6.1 — Being Prepared to Go Around*; and,
- *6.3 — Terrain-avoidance (Pull-up) Maneuver*.♦

Table 1
Recommended Elements Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

References

1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.
2. The FSF Approach-and-landing Accident Reduction (ALAR) Task Force defines *approach gate* as "a point in space (1,000 feet above airport elevation in instrument meteorological conditions or 500 feet above airport elevation in visual meteorological conditions) at which a go-around is required if the aircraft does not meet defined stabilized approach criteria."

Related Reading from FSF Publications

FSF Editorial Staff. "During Nonprecision Approach at Night, MD-83 Descends Below Minimum Descent Altitude and Contacts Trees, Resulting in Engine Flame-out and Touchdown Short of Runway." *Accident Prevention* Volume 54 (April 1997).

FSF Editorial Staff. "Dubrovnik-bound Flight Crew's Improperly Flown Nonprecision Instrument Approach Results in Controlled-Flight-into-Terrain Accident." *Flight Safety Digest* Volume 15 (July–August 1996).

FSF Editorial Staff. "Captain's Failure to Establish Stabilized Approach Results in Controlled-flight-into-terrain Commuter Accident." *Accident Prevention* Volume 52 (July 1995).

Duke, Thomas A.; FSF Editorial Staff. "Aircraft Descended Below Minimum Sector Altitude and Crew Failed to Respond to GPWS as Chartered Boeing 707 Flew into Mountain in Azores." *Accident Prevention* Volume 52 (February 1995).

Lawton, Russell. "Breakdown in Coordination by Commuter Crew During Unstabilized Approach Results in Controlled-flight-into-terrain Accident." *Accident Prevention* Volume 51 (September 1994).

Lawton, Russell. "Captain Stops First Officer's Go-around, DC-9 Becomes Controlled-flight-into-terrain (CFIT) Accident." *Accident Prevention* Volume 51 (February 1994).

FSF Editorial Staff. "Cockpit Coordination, Training Issues Pivotal in Fatal Approach-to-Landing Accident." *Accident Prevention* Volume 51 (January 1994).

Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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ALAR

Approach-and-landing Accident Reduction

Tool Kit

Approach-and-landing Risk Awareness Tool

Elements of this tool should be integrated, as appropriate, with the standard approach briefing prior to top of descent to improve awareness of factors that can increase the risk of an accident during approach and landing. The number of warning symbols (⚠) that accompany each factor indicates a relative measure of risk. Generally, the greater the number of warning symbols that accompany a factor, the greater the risk presented by that factor. Flight crews should consider carefully the effects of multiple risk factors, exercise appropriate vigilance and be prepared to conduct a go-around or a missed approach.

Failure to recognize the need for a missed approach and to execute a missed approach is a major cause of approach-and-landing accidents.

Flight Crew

- Long duty period — reduced alertness .... ⚠⚠
- Single-pilot operation .... ⚠⚠

Airport Services and Equipment

- No approach radar service or airport tower service .... ⚠⚠⚠
- No current local weather report .... ⚠⚠
- Unfamiliar airport or unfamiliar procedures .... ⚠⚠
- Minimal or no approach lights or runway lights .... ⚠
- No visual approach-slope guidance — e.g., VASI/PAPI .... ⚠
- Foreign destination — possible communication/language problems .... ⚠

Expected Approach

- Nonprecision approach — especially with step-down procedure or circling procedure .... ⚠⚠⚠
- Visual approach in darkness .... ⚠⚠
- Late runway change .... ⚠⚠
- No published STAR .... ⚠

Environment

- Hilly terrain or mountainous terrain .... ⚠⚠
- Visibility restrictions — e.g., darkness, fog, haze, IMC, low light, mist, smoke .... ⚠⚠
- Visual illusions – e.g., sloping terrain, wet runway, whiteout/snow .... ⚠⚠
- Wind conditions — e.g., cross wind, gusts, tail wind, wind shear .... ⚠⚠
- Runway conditions — e.g., ice, slush, snow, water .... ⚠⚠
- Cold-temperature effects — true altitude (actual height above mean sea level) lower than indicated altitude .... ⚠

Aircraft Equipment

- No GPWS/EGPWS/GCAS/TAWS .... ⚠⚠⚠
- No radio altimeter .... ⚠⚠⚠
- No wind shear warning system .... ⚠
- No TCAS .... ⚠

Definitions of acronyms appear on next page.

- Greater risk is associated with conducting a nonprecision approach (rather than a precision approach) and with conducting an approach in darkness and in IMC (rather than in daylight and in VMC). The combined effects of two or more of these risk factors must be considered carefully.
- Crews can reduce risk with planning and vigilance. If necessary, plans should be made to hold for better conditions or to divert to an alternate airport. Plan to abandon the approach if company standards for a stabilized approach are not met.
- After commencement of the approach, *a go-around or a missed approach should be conducted when*:
  - Confusion exists or crew coordination breaks down;
  - There is uncertainty about situational awareness;
  - Checklists are being conducted late or the crew is task overloaded;
  - Any malfunction threatens the successful completion of the approach;
  - The approach becomes unstabilized in altitude, airspeed, glide path, course or configuration;
  - Unexpected wind shear is encountered — proceed per company SOP;
  - GPWS/EGPWS/GCAS/TAWS alert — proceed per company SOP;
  - ATC changes will result in an unstabilized approach; or,
  - Adequate visual references are absent at DH or MDA.

Table 1
Recommended Elements of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1, November 2000)

Notes:

1. All information in the FSF Approach-and-landing Risk Awareness Tool is based on data published in "Killers in Aviation: FSF Task Force Presents Facts about Approach-and-landing and Controlled-flight-into-terrain Accidents," *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999).
2. ATC = Air traffic control
   DH = Decision height
   EGPWS = Enhanced ground-proximity warning system
   GCAS = Ground-collision avoidance system
   GPWS = Ground-proximity warning system
   IMC = Instrument meteorological conditions
   MDA = Minimum descent altitude
   PAPI = Precision approach path indicator
   SOP = Standard operating procedure
   STAR = Standard terminal arrival route
   TAWS = Terrain awareness and warning system
   TCAS = Traffic-alert and collision avoidance system
   VASI = Visual approach slope indicator
   VMC = Visual meteorological conditions

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Approach-and-landing Accident Reduction

Tool Kit

Approach-and-landing Risk Reduction Guide

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force designed this guide as part of the *FSF ALAR Tool Kit*, which is designed to help prevent ALAs, including those involving controlled flight into terrain. This guide should be used to evaluate specific flight operations and to improve crew awareness of associated risks. This guide is intended for use as a strategic tool (i.e., for long-term planning).

Part 1 of this guide should be used by the chief pilot to review flight operations policies and training. Part 2 should be used by dispatchers and schedulers. The chief pilot should provide Part 3 to flight crews for evaluating pilot understanding of company training objectives and policies. Part 4 should be used by the chief pilot and line pilots.

This guide is presented as a "check-the-box" questionnaire; boxes that are not checked may represent shortcomings and should prompt further assessment.

Part 1 — Operations: Policies and Training

Check the boxes below that apply to your specific flight operations.

Approach

Crew Resource Management

- ❑ Is risk management taught in initial training and recurrent training?
- ❑ Are crew resource management (CRM) roles defined for each crewmember?
- ❑ Are CRM roles defined for each crewmember for emergencies and/or system malfunctions?
- ❑ Are standard operating procedures (SOPs) provided for "sterile-cockpit"[1] operations?
- ❑ Are differences between domestic operations and international operations explained in CRM training?
- ❑ Is decision making taught in CRM training?

Approach Procedures

- ❑ Do detailed and mandatory approach-briefing requirements exist? (See Part 4 below.)
- ❑ Are approach risks among the required briefing items?
- ❑ Are standard calls defined for approach deviations?
- ❑ Are limits defined for approach gate[2] at 1,000 feet in instrument meteorological conditions (IMC) or at 500 feet in visual meteorological conditions (VMC).
- ❑ Is a missed approach/go-around recommended when stabilized approach criteria (Table 1) are exceeded?
- ❑ Is a "no fault" go-around policy established? If so, is it emphasized during training?
- ❑ Does the checklist policy require challenge-and-response for specified items?
- ❑ Does the checklist policy provide for interruptions/distractions?
- ❑ Is a go-around recommended when the appropriate checklist is not completed before reaching the approach gate?

Table 1
Recommended Elements of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

- ❑ Are captain/first officer weather limits provided for approach (e.g., visibility, winds and runway conditions)?
- ❑ Are crewmember roles defined for approach (e.g., crewmember assigned pilot flying duties, crewmember monitoring and conducting checklist, crewmember who decides to land or go around, crewmember landing aircraft, exchange of aircraft control)?

Fuel

- ❑ Are fuel minimums defined for proceeding to the alternate airport, contingency fuel, dump-fuel limits?
- ❑ Are crews aware of when to declare "minimum fuel" or an emergency?
- ❑ When declaring an emergency for low fuel, is International Civil Aviation Organization (ICAO) phraseology required (e.g., "Mayday, Mayday, Mayday for low fuel")?

Approach Type

- ❑ Is your risk exposure greatest during precision, nonprecision, circling or visual approaches? Is the training provided appropriate for the risk?
- ❑ Are SOPs provided for constant-angle nonprecision approaches (CANPAs) using rate of descent or angle?

Environment

- ❑ Is training provided for visual illusions on approach (e.g., "black hole effect,"[3] sloping terrain, etc.)?
- ❑ Is training provided for minimum-safe-altitude awareness?
- ❑ Does a policy exist to use the radio altimeter as a terrain-awareness tool?
- ❑ Are crews required to adjust altitudes during approach for lower than international standard atmosphere (ISA) standard temperatures?

- ❑ Are crews aware that most approach-and-landing accidents occur with multiple conditions present (e.g., rain and darkness, rain and crosswind)?

Airport and Air Traffic Control (ATC) Services

- ❑ Are crews aware of the increased risk at airports without radar service, approach control service or tower service?
- ❑ Is training provided for unfamiliar airports using a route check or a video?
- ❑ Is potential complacency at very familiar airports discussed?
- ❑ Are crews provided current weather at destination airfields via automatic terminal information service (ATIS), airborne communications addressing and reporting system (ACARS) and/or routine weather broadcasts for aircraft in flight (VOLMET)?

Aircraft Equipment

- ❑ Are procedures established to evaluate the accuracy and reliability of navigation/terrain databases?
- ❑ Are mechanical checklists or electronic checklists installed?
- ❑ Is a radio altimeter installed in the pilot's normal scan pattern?
- ❑ Does the radio altimeter provide visual/audio alerting?
- ❑ Is a wind shear alert system (either predictive or reactive) installed?
- ❑ Is a ground-proximity warning system (GPWS) or a terrain awareness and warning system (TAWS)[4] installed?
- ❑ Is a traffic-alert and collision avoidance system (TCAS) installed?
- ❑ Are head-up displays (HUDs) installed with a velocity-vector indicators?
- ❑ Are angle-of-attack indicators installed?
- ❑ For aircraft with a flight management system (FMS), are lateral navigation/vertical navigation (LNAV/VNAV) approach procedures database-selected?
- ❑ Are pilots prevented from modifying specified FMS data points on approach?
- ❑ Is the FMS system "sole-means-of-navigation" capable?
- ❑ Is there a policy for appropriate automation use (e.g., "full up for Category III instrument landing system, okay to turn automation off for a daylight visual approach")?
- ❑ Is there a policy requiring standard calls by the pilot not flying for mode changes and annunciations on the mode control panel?
- ❑ Is training provided and are policies established for the use of all the equipment installed on all aircraft?
- ❑ Are current and regulator-approved navigation charts provided for each flight crewmember?

Flight Crew

- ❑ Is there a crew-pairing policy established for new captain/new first officer based on flight time or a minimum number of trip segments?
- ❑ Is the check airmen/training captain program monitored for feedback from pilots? Are additional training needs, failure rates and complaints about pilots from line operations tracked? Is it possible to trace these issues to the check airmen/training captain who trained specific pilots?
- ❑ Is there a hazard reporting system such as a captain's report? Are policies established to identify and to correct problems? Is a system set up to provide feedback to the person who reports a hazard?

Safety Programs

- ❑ Is a nonpunitive safety reporting system established?
- ❑ Is a proactive safety monitoring program such as a flight operational quality assurance (FOQA) program or an aviation safety action program (ASAP) established?

Landing

- ❑ Is training provided and are policies established for the use of visual landing aids?
- ❑ Is it recommended that crews use all available vertical guidance for approaches, especially at night?
- ❑ Is training provided and are policies established for landing on contaminated runways with adverse winds?
- ❑ Are crews knowledgeable of the differences in braking deceleration on contaminated runways and dry runways?
- ❑ Does training include performance considerations for items such as critical touchdown area, braking required, land-and-hold-short operation (LAHSO), engine-out go-around, and full-flaps/gear-extended go-around?
- ❑ Does the aircraft operating manual (AOM)/quick reference handbook (QRH) provide crosswind limitations?
- ❑ Is a policy in effect to ensure speed brake deployment and autobrake awareness?
- ❑ Does policy prohibit a go-around after reverse thrust is selected?

Part 2 — Dispatcher/Scheduler

Check the boxes below that apply to your specific flight operations.

- ❑ Does the company have a dispatch system to provide information to assist flight crews in evaluating approach-and-landing risks?

Approach and Landing

- ❑ Are dispatchers and captains familiar with each other's authority, accountability and responsibility?
- ❑ Are crews monitored for route qualifications and appropriate crew pairing?
- ❑ Are crew rest requirements defined adequately?
- ❑ Does the company monitor and provide suitable crew rest as defined by requirements?
- ❑ Are crews provided with timely and accurate aircraft performance data?
- ❑ Are crews assisted in dealing with minimum equipment list(MEL)/dispatch deviation guide (DDG)/ configuration deviation list (CDL) items?
- ❑ Do dispatch-pilot communications exist for monitoring and advising crews en route about changing conditions?
- ❑ Are updates provided on weather conditions (e.g., icing, turbulence, wind shear, severe weather)?
- ❑ Are updates provided on field conditions (e.g., runway/taxiway conditions, braking-action reports)?
- ❑ Is there coordination with the captain to determine appropriate loads and fuel required for the effects of ATC flow control, weather and alternates?
- ❑ Are all the appropriate charts provided for routing and approaches to destinations and alternates?
- ❑ Is a current notice to airmen (NOTAM) file maintained for all of your operations and is the appropriate information provided to crews?

Part 3 — Flight Crew

Check the boxes below that apply to your specific flight operations.

- ❑ Do you believe that you have appropriate written guidance, training and procedures to evaluate and reduce approach-and-landing risks?

Approach

- ❑ Is the Flight Safety Foundation *Approach-and-landing Risk Awareness Tool* (*RAT*) provided to flight crews, and is its use required before every approach?
- ❑ Does the approach briefing consist of more than the "briefing strip" minimum? (See Part 4 below.)

- ❑ Do briefings include information about visual illusions during approach and methods to counteract them?
- ❑ Are the following briefed: setup of the FMS, autopilot, HUD, navigation radios and missed approach procedures?
- ❑ Is a discussion of missed approach/go-around details required during every approach briefing?
- ❑ Are performance minimums briefed for the approach gate?
- ❑ Are standard calls required for deviations from a stabilized approach?
- ❑ Does the briefing include execution of a missed approach/go-around if criteria for the approach gate are not met?
- ❑ Are stabilized approach criteria defined? Is a go-around recommended in the event that these criteria are not met?
- ❑ Does your company practice a no-fault go-around policy?
- ❑ Are you required to write a report to the chief pilot if you conduct a missed approach/go-around?
- ❑ Do you back up the flight plan top-of-descent point with your own calculation to monitor descent profile?
- ❑ Are approach charts current and readily available for reference during approach?
- ❑ Are policies established to determine which crewmember is assigned pilot flying duties, which crewmember is assigned checklist duties, which crewmember will land the aircraft and how to exchange aircraft control? Do these policies change based on prevailing weather?
- ❑ Do terrain-awareness procedures exist (e.g., calling "radio altimeter alive," checking radio altimeter altitudes during approach to confirm that the aircraft is above required obstacle clearance heights)?
- ❑ Do altitude-deviation-prevention policies exist (e.g., assigned altitude, minimum descent altitude/height [MDA(H)], decision altitude/height [DA(H)])?
- ❑ Are you familiar with the required obstacle clearance criteria for charting design?
- ❑ Do altimeter-setting procedures and cross-check procedures exist?
- ❑ Do temperature-compensation procedures exist for temperatures lower than ISA at the destination airport?
- ❑ Are you aware of the increased risk during night/low-visibility approaches when approach lighting/visual approach slope indicator/precision approach path indicator aids are not available? How do you compensate for these deficiencies? For example, are runways with vertical guidance requested in those conditions?
- ❑ Are you aware of the increased risk associated with nonprecision approaches compared with precision approaches?
- ❑ Is a CANPA policy established at your company? Are you aware of the increased risk associated with step-down approaches compared with constant-angle approaches?
- ❑ Is a policy established for maintaining visual look-out, and is there a requirement to call "head-down"?
- ❑ Does a look-out policy exist for approach and landing in visual flight rules (VFR) conditions?

Part 4 — Recommended Approach-and-landing Briefing Items

For the approach-risk briefing, refer to top-of-descent use of the FSF *Approach-and-landing RAT*.

In addition to the briefing strip items (e.g., chart date, runway, approach type, glideslope angle, check altitudes), which of following items are briefed, as appropriate?

- ❑ Automation setup and usage
- ❑ Navigation equipment setup and monitoring
- ❑ Rate of descent/angle of descent

- ❑ Intermediate altitudes and standard calls
- ❑ Altitude-alert setting and acknowledgment
- ❑ MDA(H)/DA(H) calls (e.g., "landing, continue, go-around"); runway environment expected to see (offsets); lighting
- ❑ Radio-altimeter setting in the DH window, calls required (e.g., "radio altimeter alive" and "below 1,000 feet" prior to an intermediate approach fix; "below 500 feet" prior to the final approach fix [FAF]; "go around" after the FAF if "minimums" is called [with radio altimeter at 200 feet] and if visual contact with the required references is not acquired or the aircraft is not in position for a normal landing)
- ❑ Aircraft configuration
- ❑ Airspeeds
- ❑ Checklists complete
- ❑ ATC clearance
- ❑ Uncontrolled airport procedures
- ❑ Manual landing or autoland
- ❑ Missed approach procedure/go-around
- ❑ Performance data
- ❑ Contaminated runway/braking action and autobrakes
- ❑ Illusions/hazards or other airport-specific items
- ❑ Abnormals (e.g., aircraft equipment/ground facilities unserviceable, MEL/DDG items, glideslope out)
- ❑ Runway (e.g., length, width, lighting, LAHSO, planned taxiway exit)
- ❑ Procedure for simultaneous approaches (as applicable)

References

1. The *sterile cockpit rule* refers to U.S. Federal Aviation Regulations Part 121.542, which states: "No flight crewmember may engage in, nor may any pilot-in-command permit, any activity during a critical phase of flight which could distract any flight crewmember from the performance of his or her duties or which could interfere in any way with the proper conduct of those duties. Activities such as eating meals, engaging in nonessential conversations within the cockpit and nonessential communications between the cabin and cockpit crews, and reading publications not related to the proper conduct of the flight are not required for the safe operation of the aircraft. For the purposes of this section, critical phases of flight include all ground operations involving taxi, takeoff and landing, and all other flight operations below 10,000 feet, except cruise flight." [The FSF ALAR Task Force says that "10,000 feet" should be height above ground level during flight operations over high terrain.]
2. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *approach gate* as "a point in space (1,000 feet above airport elevation in instrument meteorological conditions or 500 feet above airport elevation in visual meteorological conditions) at which a go-around is required if the aircraft does not meet defined stabilized approach criteria."
3. The *black-hole effect* typically occurs during a visual approach conducted on a moonless or overcast night, over water or over dark, featureless terrain where the only visual stimuli are lights on and/or near the airport. The absence of visual references in the pilot's near vision affect depth perception and cause the illusion that the airport is closer than it actually is and, thus, that the aircraft is too high. The pilot may respond to this illusion by conducting an approach below the correct flight path (i.e., a low approach).
4. Terrain awareness and warning system (TAWS) is the term used by the European Joint Aviation Authorities and the U.S. Federal Aviation Administration to describe equipment meeting International Civil Aviation Organization standards and recommendations for ground-proximity warning system (GPWS) equipment that provides predictive terrain-hazard warnings. "Enhanced GPWS" and "ground collision avoidance system" are other terms used to describe TAWS equipment.

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Approach-and-landing Accident Reduction

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FSF ALAR Briefing Note 5.2 — Terrain

Terrain awareness can be defined as the combined awareness and knowledge of the following:

- Aircraft position;
- Aircraft altitude;
- Applicable minimum safe altitude (MSA);
- Terrain location and features; and,
- Other hazards.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction Task Force found that controlled flight into terrain (CFIT) was involved in 37 percent of 76 approach-and-landing accidents (ALAs) and serious incidents worldwide in 1984 through 1997.[1]

The task force said that among these CFIT accidents/incidents:

- Sixty-seven percent occurred in hilly terrain or mountainous terrain, and 29 percent occurred in areas of flat terrain (the type of terrain in which the remainder of the CFIT accidents/incidents occurred was unknown);
- Fifty-seven percent occurred during nonprecision approaches; and,
- Seventy percent occurred in poor visibility or fog.

The absence or the loss of visual references is the most common primary causal factor[2] in ALAs involving CFIT. These accidents result from:

- Descending below the minimum descent altitude/height (MDA[H]) or decision altitude/height (DA[H]) without adequate visual references or having acquired incorrect visual references (e.g., a lighted area in the airport vicinity, a taxiway or another runway); and,
- Continuing the approach after the loss of visual references (e.g., because of a fast-moving rain shower or fog patch).

Navigation Deviations and Inadequate Terrain Separation

A navigation (course) deviation occurs when an aircraft is operated beyond the course clearance issued by air traffic control (ATC) or beyond the defined airway system.

Inadequate terrain separation occurs when terrain separation of 2,000 feet in designated mountainous areas or 1,000 feet in all other areas is not maintained (unless authorized and properly assigned by ATC in terminal areas).

Navigation deviations and inadequate terrain separation are usually the results of monitoring errors.

Monitoring errors involve the crew's failure to adequately monitor the aircraft trajectory and instruments while programming the autopilot or flight management system (FMS), or while being interrupted or distracted.

Standard Operating Procedures

Standard operating procedures (SOPs) should emphasize the following terrain-awareness items:

- Conduct task-sharing for effective cross-check and backup, particularly mode selections and target entries (e.g., airspeed, heading, altitude); and,
- Adhere to the basic golden rule: aviate (fly), navigate, communicate and manage, in that order.

Navigate can be defined by the following "know where" statements:

- Know where you are;
- Know where you should be; and,
- Know where the terrain and obstacles are.

Terrain-awareness elements of effective cross-check and backup include:

- Assertive challenging;
- Altitude calls;
- Excessive parameter-deviation calls; and,
- Task-sharing and standard calls for the acquisition of visual references.

Terrain awareness can be improved by correct use of the radio altimeter. The barometric-altimeter bug and the radio-altimeter decision height (RA DH) bug must be set according to the aircraft manufacturer's SOPs or the company's SOPs.

Altimeter-setting Errors

The following will minimize the potential for altimeter-setting errors and provide for optimum use of the barometric-altimeter bug and RA DH bug:

- Awareness of altimeter-setting changes because of prevailing weather conditions (temperature-extreme cold front or warm front, steep frontal surfaces, semi-permanent or seasonal low-pressure areas);
- Awareness of the altimeter-setting unit of measurement in use at the destination airport;
- Awareness of the expected altimeter setting (using both routine aviation weather reports [METARs] and automatic terminal information system [ATIS] for cross-checking);
- Effective pilot flying-pilot not flying (PF-PNF) cross-check and backup;
- Adherence to SOPs for:
  – Resetting altimeters at the transition altitude/flight level;
  – Use of the standby altimeter to cross-check the primary altimeters;
  – Altitude calls;
  – Radio-altimeter calls; and,
  – Setting the barometric-altimeter bug and RA DH bug; and,
- Cross-check that the assigned altitude is above the MSA (unless the crew is aware of the applicable minimum vectoring altitude for the sector).

Table 1 shows examples of SOPs for setting the barometric-altimeter bug and the RA DH bug.

Table 1
Barometric-altimeter and Radio-altimeter Reference Settings

Approach	Barometric Altimeter	Radio Altimeter
Visual	MDA(H)/DA(H) of instrument approach or 200 feet above airport elevation	200 feet*
Nonprecision	MDA/(H)	200 feet*
ILS CAT I no RA	DA(H)	200 feet*
ILS CAT I with RA	DA(H)	RA DH
ILS CAT II	DA(H)	RA DH
ILS CAT III with DH	DA(H)	RA DH
ILS CAT III with no DH	TDZE	Alert height

MDA(H) = Minimum descent altitude/height
DA(H) = Decision altitude/height
ILS = Instrument landing system
CAT = Category
RA DH = Radio altimeter decision height
TDZE = Touchdown zone elevation

* The RA DH should be set (e.g., at 200 feet) for terrain-awareness purposes. The use of the radio altimeter should be discussed during the approach briefing.

Note: For all approaches, except CAT II and CAT III ILS approaches, the approach "minimum" call will be based on the barometric-altimeter bug set at MDA(H) or DA(H).

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Use of Radio Altimeter

Radio-altimeter calls can be either:

- Announced by the PNF (or the flight engineer); or,
- Generated automatically by a synthesized voice.

The calls should be tailored to the company operating policy and to the type of approach.

To enhance the flight crew's terrain awareness, the call "radio altimeter alive" should be made by the first crewmember observing the radio-altimeter activation at 2,500 feet.

The radio-altimeter indication then should be included in the instrument scan for the remainder of the approach.

Flight crews should call radio-altimeter indications that are below obstacle-clearance requirements during the approach. The radio altimeter indications should not be below the following minimum heights:

- 1,000 feet during arrival until past the intermediate fix, except when being radar-vectored;
- 500 feet when being radar-vectored by ATC or until past the final approach fix (FAF); and,
- 250 feet from the FAF to a point on final approach to the landing runway where the aircraft is in visual conditions and in position for a normal landing, except during Category (CAT) II instrument landing system (ILS) and CAT III ILS approaches.

The following cross-check procedures should be used to confirm the barometric-altimeter setting:

- When receiving an altitude clearance, immediately set the assigned altitude in the altitude window (even before readback, if appropriate because of workload);
- Ensure that the selected altitude is cross-checked by the captain and the first officer (e.g., each pilot should announce what he or she heard and then point to the altitude window to confirm that the correct altitude has been selected); and,
- Ensure that the assigned altitude is above the applicable MSA.

Training

Altitude Awareness Program

The altitude awareness program should emphasize the following:

- Awareness of altimeter-setting errors:
  - 29.XX inches of mercury (in. Hg) vs. 28.XX in. Hg or 30.XX in. Hg (with typical errors of approximately 1,000 feet); or,
  - 29.XX in. Hg vs. 9XX hectopascals (hPa) (true altitude [actual height above mean sea level] 600 feet lower than indicated); and,
- Awareness of altitude corrections for low outside air temperature (OAT) operations and awareness of pilot's/controller's responsibilities in applying these corrections.

Pilot-Controller Communication

The company should develop and implement an awareness and training program to improve pilot-controller communication.

Route Familiarization Program

A training program should be implemented for departure, route, approach and airport familiarization, using:

- High-resolution paper material;
- Video display; and/or,
- Visual simulator.

Whenever warranted, a route familiarization check for a new pilot should be conducted by a check airman or with the new pilot as an observer of a qualified flight crew.

CFIT Training

CFIT training should include the following:

- Ground-proximity warning system (GPWS) modes or terrain awareness and warning system (TAWS)[3] modes (the detection limits of each mode, such as inhibitions and protection envelopes, should be emphasized clearly); and,
- Terrain-avoidance (pull-up) maneuver.

Departure Strategies

Briefing

Standard instrument departure (SID) charts and en route charts should be used to cross-check the flight plan and the ATC route clearance. The FMS control display unit (CDU) and the navigation display (ND) should be used for illustration during the cross-check.

The takeoff-and-departure briefing should include the following terrain-awareness items, using all available charts and cockpit displays to support and illustrate the briefing:

- Significant terrain or obstacles along the intended departure course; and,
- SID routing and MSAs.

If available, SID charts featuring terrain depictions with color-shaded contours should be used during the briefing.

Standard Instrument Departure

When conducting a SID, the flight crew should:

- Be aware of whether the departure is radar-monitored by ATC;
- Maintain a "sterile cockpit"[4] below 10,000 feet or below the MSA, particularly at night or in instrument meteorological conditions (IMC);
- Monitor the sequencing of each waypoint and the guidance after waypoint sequencing (i.e., correct

direction of turn and correct "TO" waypoint, in accordance with the SID), particularly after a flight plan revision or after conducting a "DIR TO"; and,

- In the event of incorrect sequencing/lateral guidance, the crew should be alert to conduct a "DIR TO" [an appropriate waypoint] or to revert to selected lateral navigation.

En Route Strategies

Navigation

The en route charts should be accessible if a total loss of FMS navigation occurs or any doubt arises about FMS lateral guidance.

Flight Progress Monitoring

The flight crew should:

- Monitor and cross-check FMS guidance and navigation accuracy;
- Monitor instruments and raw data[5];
- Use all information available (flight deck displays, charts); and,
- Request confirmation or clarification from ATC if any doubt exists about terrain clearance, particularly when receiving radar vectors.

Descent Strategies

Management and Monitoring

When entering the terminal area, FMS navigation accuracy should be checked against raw data.

If the accuracy criteria for FMS lateral navigation in a terminal area and/or for approach are not met, revert to selected lateral navigation with associated horizontal situation indicator (HSI)-type navigation display.

Standard Terminal Arrival

When conducting a STAR, the flight crew should:

- Be aware of whether the arrival is radar-monitored by ATC;
- Maintain a sterile cockpit;
- Monitor the sequencing of each waypoint and the guidance after waypoint sequencing (i.e., correct direction of turn and correct "TO" waypoint, in accordance with the STAR), particularly after a flight plan revision or after conducting a "DIR TO"; and,
- In the event of incorrect sequencing/lateral guidance, the crew should be prepared to conduct a "DIR TO" (to appropriate waypoint) or to revert to selected lateral navigation.

Changes in ATC clearances should be understood before they are accepted and are implemented.

For example, an ATC clearance to descend to a lower altitude should never be understood as a clearance to descend (prematurely) below the MSA or an approach-segment minimum altitude.

When receiving ATC radar vectors, ensure that:

- The controller has identified your radar return by stating "radar contact";
- The pilot-controller confirmation/correction process (communication loop) remains effective at all times;
- The flight crew maintains situational awareness; and,
- The pilot requests confirmation or clarification from the controller without delay if there is any doubt about a clearance.

During the final approach segment, the attention of both pilots should be directed to any required altitude restriction or altitude/distance check prior to reaching the MDA(H) or DA(H).

Unless the airport is near high terrain, the radio-altimeter indication should reasonably agree with the height above airport elevation (obtained by direct reading of the barometric altimeter if using QFE or by computation if using QNH).

In IMC or at night, flight crews should respond immediately to any GPWS/TAWS warning.

Approach Strategies

Briefing

The approach briefing should include information about:

- Descent profile management;
- Energy management;
- Terrain awareness;
- Approach hazards awareness;
- Elements of a stabilized approach (Table 2) and approach gate[6];
- Readiness and commitment to respond to a GPWS/TAWS warning; and,
- Missed approach procedures.

Table 2
Recommended Elements Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

If available, approach charts featuring terrain depictions with color-shaded contours should be used during the approach briefing to enhance terrain awareness.

A thorough briefing should be conducted, regardless of:

- How familiar the destination airport and the approach may be; or,
- How often the pilots have flown together.

The briefing should help the pilot flying (conducting the briefing) and the pilot not flying (acknowledging the briefing) know:

- The main features of the descent, approach and missed approach;
- The sequence of events and actions; and,
- Any special hazards.

The flight crew should include the following terrain-awareness items in the approach briefing:

- MSAs;
- Terrain and man-made obstacles;
- Applicable minimums (ceiling, visibility or runway visual range [RVR]);
- Applicable minimum stabilization height (approach gate);
- Final approach descent gradient (and vertical speed); and,
- Go-around altitude and missed approach initial steps.

The following is an expanded review of the terrain-awareness items to be included in the approach briefing — as practical and as appropriate for the conditions of the flight.

ATIS

Review and discuss the following items:

- Runway in use (type of approach);
- Expected arrival route (standard terminal arrival [STAR] or radar vectors);
- Altimeter setting (QNH or QFE [setting that causes the barometric altimeter to indicate height above the QFE reference datum (i.e., zero feet at touchdown on the runway)], as required); and,
- Transition altitude/level (unless standard for the country or for the airport).

Approach Chart

Review and discuss the following terrain-awareness items using the approach chart and the FMS/ND (as applicable):

- Designated runway and approach type;
- Chart index number and date;
- MSA reference point, sectors and altitudes;
- Let-down navaid frequency and identification (confirm the navaid setup);
- Airport elevation;
- Approach transitions (fixes, holding pattern, altitude and airspeed restrictions, required navaids setup);
- Initial approach fix (IAF) and intermediate approach fix (IF), as applicable (positions and crossing altitudes);

- Final approach course (and lead-in radial);
- Terrain features (location and elevation of hazardous terrain or man-made obstacles);
- Approach profile view:
  – FAF;
  – Final descent point (if different from FAF);
  – Visual descent point (VDP);
  – Missed approach point (MAP);
  – Typical vertical speed at expected final approach groundspeed; and,
  – Touchdown zone elevation (TDZE); and,
- Missed approach:
  – Lateral navigation and vertical navigation; and,
  – Significant terrain or obstacles.

Low-OAT Operation

When OAT is below zero degrees Celsius (32 degrees Fahrenheit), low-temperature correction should be applied to the following published altitudes:

- Minimum en route altitude (MEA) and MSA;
- Transition route altitude;
- Procedure turn altitude (as applicable);
- FAF altitude;
- Step-down altitude(s) and MDA(H) during a nonprecision approach;
- Outer marker (OM) crossing altitude during an ILS approach; and,
- Waypoint-crossing altitudes during a global positioning system (GPS) approach flown with barometric vertical navigation.

In a standard atmosphere, indicated altitude is the true altitude above mean sea level (MSL) and, therefore, provides a reliable indication of terrain clearance.

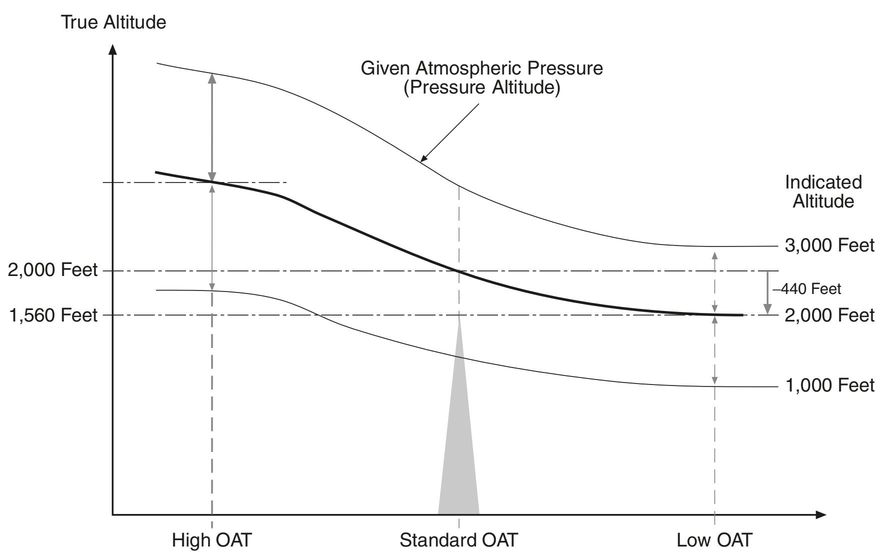
Whenever the temperature is significantly different from the standard temperature, indicated altitude is significantly different from true altitude.

In low temperature, true altitude is lower than indicated altitude, thus creating a lower-than-anticipated terrain clearance and a potential terrain-separation hazard.

Flying into a *low-temperature area* has the same effect as flying into a *low-pressure area*; the aircraft is *lower than the altimeter indicates*.

For example, Figure 1, which is based on low-temperature altimeter corrections published by the International Civil Aviation Organization (ICAO), shows that indicated altitude and true altitude are the same for an aircraft flying at 2,000 feet in an area of standard temperature (15 degrees Celsius [59 degrees Fahrenheit] at the surface); however, for an aircraft flying at 2,000 feet in an area where the surface temperature is –40 degrees Celsius (–40 degrees Fahrenheit), true altitude would be 440 feet lower than indicated altitude.

Effects of Temperature on True Altitude



OAT = Outside air temperature

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 1

Airport Charts

Review and discuss the following terrain-awareness items using the airport charts:

- Approach lighting and runway lighting, and other expected visual references; and,
- Specific hazards (such as man-made obstacles, as applicable).

If another airport is located near the destination airport, relevant details or procedures of that airport should be discussed.

Automation

Discuss the intended use of automation for vertical navigation and lateral navigation:

- FMS or selected modes; and,
- Precision approach, constant-angle nonprecision approach (CANPA) or step-down approach, as required.

Preparation for a Go-around

Company policy should stress the importance of:

- Being prepared and committed for an immediate response to a GPWS/TAWS warning; and,
- Being prepared to go around.

Circling Approaches

When conducting a circling approach, the crew should be aware of and remain within the applicable obstruction clearance protected area.

Factors Affecting Terrain Awareness

The following factors affect situational awareness and, therefore, terrain awareness.

Company accident-prevention strategies and personal lines of defense should be developed to cope with these factors (as practical).

- Aircraft equipment:
  - Lack of navigation display/terrain display/radar display with mapping function;
  - Lack of area navigation (RNAV) capability;
  - Lack of radio altimeter or lack of (automatic) calls; and/or,
  - Lack of GPWS or TAWS;
- Airport environment:
  - Night "black-hole effect"[7] and/or rising or sloping terrain along the approach path;
- Airport equipment:
  - Lack of or restricted radar coverage;
  - Lack of a precision approach, a visual approach slope indicator (VASI) or precision approach path indicator (PAPI); and,
  - Limited approach lighting and runway lighting;
- Navigation charts:
  - Lack of published approach procedure;
  - Lack of color-shaded terrain contours on approach chart; and,
  - Lack of published minimum radar vectoring altitudes;
- Training:
  - Lack of area familiarization and/or airport familiarization; and,
  - Inadequate knowledge of applicable obstacle clearance and/or minimum vectoring altitude;
- SOPs:
  - Inadequate briefings;
  - Monitoring errors (i.e., inability to monitor the aircraft trajectory and instruments while conducting FMS entries or because of an interruption/distraction);
  - Inadequate monitoring of flight progress (being "behind the aircraft");
  - Incorrect use of automation;
  - Omission of a normal checklist or part of a normal checklist (usually because of an interruption/ distraction); and/or,
  - Deliberate or inadvertent deviation from SOPs.
- Pilot-controller communication:
  - Omission of a position report upon first radio contact in an area without radar coverage (i.e., reducing the controller's situational awareness of the aircraft);
  - Breakdown in pilot-controller or crew communication (e.g., readback/hearback errors, failure to resolve doubts or ambiguities, use of nonstandard phraseology); and/or,
  - Accepting an amended clearance without prior evaluation.
- Human factors and crew resource management (CRM):
  - Incorrect CRM practices (e.g., lack of cross-check and backup for mode selections and target entries, late recognition of monitoring errors);
  - Incorrect decision making;
  - Failure to resolve a doubt or confusion;

– Fatigue;

– Complacency;

– Spatial disorientation; and/or,

– Visual illusions.

Summary

Terrain awareness is enhanced by the following:

- SOPs defining crew task-sharing for effective cross-check and backup;
- Correct use of the barometric altimeter and radio altimeter;
- Thorough approach briefings; and,
- Use of GPWS/TAWS.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.2 — Automation*;
- *1.3 — Golden Rules*;
- *1.4 — Standard Calls*;
- *1.5 — Normal Checklists*;
- *1.6 — Approach Briefing*;
- *2.3 — Pilot-Controller Communication*;
- *2.4 — Interruptions/Distractions*;
- *3.1 — Barometric Altimeter and Radar Altimeter*;
- *3.2 — Altitude Deviations*;
- *6.1 — Being Prepared to Go Around*; and,
- *6.3 — Terrain Avoidance (Pull-up) Maneuver*.♦

References

1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

2. The FSF ALAR Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]." Each accident and incident in the study sample involved several causal factors.

3. Terrain awareness and warning system (TAWS) is the term used by the European Joint Aviation Authorities and the U.S. Federal Aviation Administration to describe equipment meeting International Civil Aviation Organization standards and recommendations for ground-proximity warning system (GPWS) equipment that provides predictive terrain-hazard warnings. "Enhanced GPWS" and "ground collision avoidance system" are other terms used to describe TAWS equipment.

4. The *sterile cockpit rule* refers to U.S. Federal Aviation Regulations Part 121.542, which states: "No flight crewmember may engage in, nor may any pilot-in-command permit, any activity during a critical phase of flight which could distract any flight crewmember from the performance of his or her duties or which could interfere in any way with the proper conduct of those duties. Activities such as eating meals, engaging in nonessential conversations within the cockpit and nonessential communications between the cabin and cockpit crews, and reading publications not related to the proper conduct of the flight are not required for the safe operation of the aircraft."

5. The FSF ALAR Task Force defines *raw data* as "data received directly (not via the flight director or flight management computer) from basic navigation aids (e.g., ADF, VOR, DME, barometric altimeter)."

6. The FSF ALAR Task Force defines *approach gate* as "a point in space (1,000 feet above airport elevation in instrument meteorological conditions or 500 feet above airport elevation in visual meteorological conditions) at which a go-around is required if the aircraft does not meet defined stabilized approach criteria."

7. The *black-hole effect* typically occurs during a visual approach conducted on a moonless or overcast night, over water or over dark, featureless terrain where the only visual stimuli are lights on and/or near the airport. The absence of visual references in the pilot's near vision affect depth perception and cause the illusion that the airport is closer than it actually is and, thus, that the aircraft is too high. The pilot may respond to this illusion by conducting an approach below the correct flight path (i.e., a low approach).

Related Reading from FSF Publications

Wilson, Dale R. "Darkness Increases Risks of Flight." *Human Factors & Aviation Medicine* Volume 46 (November–December 1999).

FSF Editorial Staff. "Learjet Strikes Terrain When Crew Tracks False Glideslope Indication and Continues Descent Below Published Decision Height." *Accident Prevention* Volume 56 (June 1999).

FSF Editorial Staff. "B-757 Damaged by Ground Strike During Late Go-around from Visual Approach." *Accident Prevention* Volume 56 (May 1999).

FSF Editorial Staff. "Preparing for Last-minute Runway Change, Boeing 757 Flight Crew Loses Situational Awareness, Resulting in Collision with Terrain." *Accident Prevention* Volume 54 (July–August 1997).

FSF Editorial Staff. "During Nonprecision Approach at Night, MD-83 Descends Below Minimum Descent Altitude and Contacts Trees, Resulting in Engine Flame-out and Touchdown Short of Runway." *Accident Prevention* Volume 54 (April 1997).

FSF Editorial Staff. "Learjet MEDEVAC Flight Ends in Controlled-flight-into-terrain (CFIT) Accident." *Accident Prevention* Volume 54 (January 1997).

FSF Editorial Staff. "Dubrovnik-bound Flight Crew's Improperly Flown Nonprecision Instrument Approach Results in Controlled-flight-into-terrain Accident." *Flight Safety Digest* Volume 15 (July–August 1996)

Enders, John H.; Dodd, Robert; Tarrel, Rick; Khatwa, Ratan; Roelen, Alfred L.C.; Karwal, Arun K. "Airport Safety: A study of Accidents and Available Approach-and-landing Aids." *Flight Safety Digest* Volume 15 (March 1996).

FSF Editorial Staff. "Different Altimeter Displays and Crew Fatigue Likely Contributed to Canadian Controlled-flight-into-terrain Accident." *Accident Prevention* Volume 52 (December 1995).

FSF Editorial Staff. "Poorly Flown Approach in Fog Results in Collision With Terrain Short of Runway." *Accident Prevention* Volume 52 (August 1995).

Duke, Thomas A.; FSF Editorial Staff. "Aircraft Descended Below Minimum Sector Altitude and Crew Failed to Respond to GPWS as Chartered Boeing 707 Flew into Mountain in Azores." *Accident Prevention* Volume 52 (February 1995).

Lawton, Russell. "Captain Stops First Officer's Go-around, DC-9 Becomes Controlled-flight-into-terrain (CFIT) Accident." *Accident Prevention* Volume 51 (February 1994).

Regulatory Resources

International Civil Aviation Organization. *Procedures for Air Navigation Services. Aircraft Operations*. Volume I, *Flight Procedures*. Part VI, *Altimeter Setting Procedures*. Fourth edition – 1993. Reprinted May 2000, incorporating Amendments 1–10.

U.S. Federal Aviation Administration (FAA). *Federal Aviation Regulations (FARs)*. 91.3 "Responsibility and authority of the pilot in command," 91.119 "Minimum safe altitudes: General," 91.121 "Altimeter settings," 91.123 "Compliance with ATC clearances and instructions," 91.155 "Basic VFR weather minimums," 91.157 "Special VFR weather minimums," 91.175 "Takeoff and landing under IFR," 91.185 "IFR operations: Two-way radio communications failure," 97 "Standard Instrument Approach Procedures, Subpart C – TERPS Procedures," 121.97 "Airports: Required data," 121.117 "Airports: Required data," 121.135 "Contents," 121.315 "Cockpit check procedure," 121.443 "Pilot in command qualification: Routes and airports," 121.445 "Pilot in command airport qualification: Special areas and airports," 121.542 "Flight crewmember duties." January 1, 2000.

FAA. *FARs*. 121.360 "Ground proximity warning-glide slope deviation alerting system." March 29, 2000.

Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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Flight Safety Foundation

ALAR

Approach-and-landing Accident Reduction

Tool Kit

FSF ALAR Briefing Note 5.3 —Visual Illusions

Visual illusions result from many factors and appear in many different forms.

Illusions occur when conditions modify the pilot's perception of the environment relative to his or her expectations, possibly resulting in spatial disorientation or landing errors (e.g., landing short or landing long).

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction Task Force found that visual approaches were being conducted in 28 percent of 76 approach-and-landing accidents (ALAs) and serious incidents worldwide in 1984 through 1997.[1]

Visual approaches at night typically present a greater risk because of fewer visual references, and because of visual illusions and spatial disorientation.

The task force found that disorientation or visual illusion was a causal factor[2] in 21 percent of the 76 ALAs and serious incidents, and that poor visibility was a circumstantial factor[3] in 59 percent of the accidents and incidents.

Visual Illusions

The following factors and conditions affect the flight crew's ability to perceive accurately the environment, resulting in visual illusions.

Airport environment:

- Ground texture and features;
- Off-airport light patterns, such as brightly lighted parking lots or streets;
- "Black-hole effect"[4] along the final approach flight path; and/or,
- Uphill-sloping terrain or downhill-sloping terrain in the airport vicinity.

Runway environment:

- Runway dimensions;
- Runway slope (uphill gradient or downhill gradient);
- Terrain drop-off at the approach end of the runway;
- Approach lighting and runway lighting; and/or,
- Runway condition.

Weather conditions:

- Ceiling;
- Visibility; and/or,
- Obstructions to vision.

Pilot's Perception

Visual illusions result from the absence of visual references or the alteration of visual references, which modify the pilot's perception of his or her position (in terms of height, distance and/or intercept angle) relative to the runway threshold.

Visual illusions are most critical when transitioning from instrument meteorological conditions (IMC) and instrument references to visual meteorological conditions (VMC) and visual references.

Visual illusions affect the flight crew's situational awareness, particularly while on base leg and during the final approach.

Visual illusions usually induce crew inputs (corrections) that cause the aircraft to deviate from the vertical flight path or horizontal flight path.

Visual illusions can affect the decision process of when and how rapidly to descend from the minimum descent altitude/ height (MDA[H]).

The following are factors and conditions that create visual illusions that can affect the pilot's perception of:

- The airport and runway environment;
- Terrain separation; and,
- Deviation from the horizontal flight path or vertical flight path.

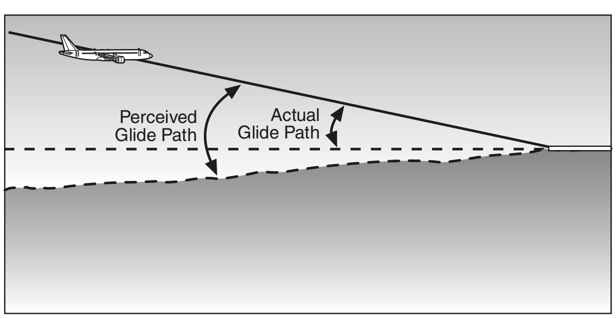
Usually, more than one factor is involved in a given approach.

Airport environment

Conditions that create visual illusions include:

- Black-hole effect along the final approach flight path;
- Uphill-sloping terrain or downhill-sloping terrain:
  - An uphill slope in the approach zone or a drop-off of terrain at the approach end of the runway creates an illusion of being too high (impression of a steep glide path [Figure 1]), thus:
    - Possibly inducing a correction (e.g., increasing the rate of descent) that places the aircraft below the intended glide path; or,
    - Preventing the flight crew from detecting a too-shallow flight path; and,
  - A downhill slope in the approach zone creates an illusion of being too low (impression of a shallow glide path [Figure 2]), thus:
    - Possibly inducing a correction that places the aircraft above the intended glide path; or,
    - Preventing the flight crew from detecting a too-steep flight path.

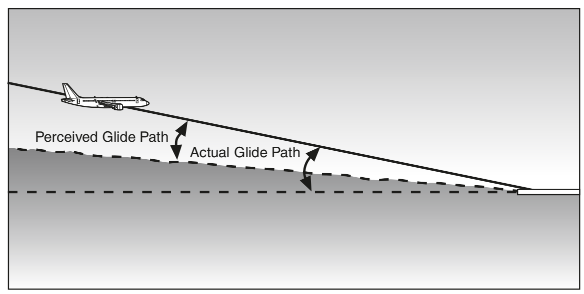
Uphill Slope Creates Illusion That Aircraft Is on Steeper-than-actual Glide Path



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 1

Downhill Slope Creates Illusion That Aircraft Is on Shallower-than-actual Glide Path



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

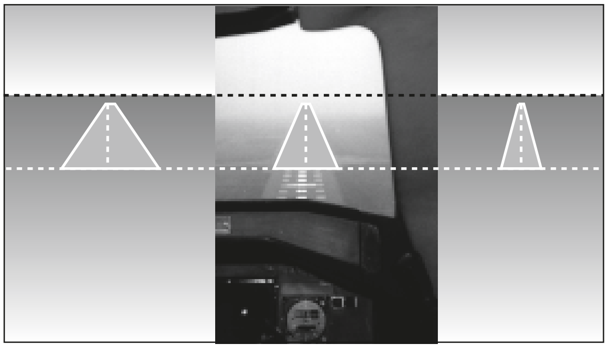
Figure 2

Runway environment

Conditions that create visual illusions include:

- Runway dimensions:
  - The runway aspect ratio (i.e., its length relative to its width) affects the crew's visual perception of the runway (Figure 3, page 105, middle panel, shows the expected image of the runway);
  - A wide or short runway (low aspect ratio) creates an impression of being too low (Figure 3, left panel); and,
  - A narrow or long runway (high aspect ratio) creates an impression of being too high (Figure 3, right panel);
- Runway uphill slope or downhill slope:
  - An uphill slope creates an illusion of being too high (impression of a steep glide path); and,
  - A downhill slope creates an illusion of being too low (impression of a shallow glide path);

Effects of Runway Dimensions on Perception of Height



Note: All three panels show a pilot's sight picture from an aircraft at 200 feet and on a three-degree glide path. The runway in panel A is 150 feet (45 meters) wide and 11,500 feet (3,500 meters) long. The runway in panel B is wider/shorter than the runway in panel A; the crew may believe that the aircraft is on shallower-than-actual glide path. The runway in panel C is narrower/longer than the runway in panel A; the crew may believe that the aircraft is on steeper-than-actual flight path.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3

- Lighting:
  - – Approach lighting and runway lighting (including touchdown-zone lighting) affect depth perception, depending on:
    - Lighting intensity;
    - Daytime conditions or nighttime conditions; and
    - Weather conditions;
  - – Bright runway lights create the impression of being closer to the runway (thus, on a steeper glide path);
  - – Low-intensity lights create the impression of being farther away (thus, on a shallower glide path);
  - – Nonstandard spacing of runway lights modifies the pilot's perception of distance to the runway and glide path; and,
  - – If the runway lighting is partially visible (e.g., while on base leg during a visual approach or circling approach), the runway may appear farther away or at a different angle (e.g., intercept angle is perceived as smaller than actual).

The following runway approach-aid conditions may increase the crew's exposure to visual illusions:

- A glideslope that is unusable beyond a certain point because of terrain or below a certain altitude because of water;
- Offset localizer course; and,
- Two-bar visual approach slope indicator (VASI), if used below (typically) 300 feet height above touchdown (HAT) for glide-path corrections.

Weather conditions

The following weather conditions can create visual illusions:

- Ceiling and visibility (vertical, slant and horizontal visibility):
  - – Flying in light rain, fog, haze, mist, smoke, dust, glare or darkness usually creates an illusion of being too high;
  - – Shallow fog (i.e., a fog layer not exceeding 300 feet thickness) results in a low obscuration and in low horizontal visibility:
    - When on top of a shallow fog layer, the ground (or airport and runway, if flying overhead) can be seen; but when entering the fog layer, forward visibility and slant visibility are lost; and,
    - Entering a fog layer also creates the perception of a pitch-up, which causes the pilot to respond with a nose-down correction that steepens the approach path;
  - – Flying in haze creates the impression that the runway is farther away, inducing a tendency to shallow the glide path and land long;
  - – In light rain or moderate rain, the runway may appear indistinct because of the "rain halo effect," increasing the risk of misperception of the vertical deviation or horizontal deviation during the visual segment (the segment flown after transition from instrument references to visual references);
  - – Heavy rain affects depth perception and distance perception:
    - Rain on a windshield creates refraction effects that cause the crew to believe that the aircraft is too high, resulting in an unwarranted nose-down correction and flight below the desired flight path;
    - In daylight conditions, rain diminishes the apparent intensity of the approach light system (ALS), resulting in the runway appearing to be farther away. As a result of this illusion, the flight crew tends to shallow the flight path, resulting in a long landing; and,
    - In nighttime conditions, rain increases the apparent brilliance of the ALS, making the runway appear to be closer, inducing a pitch-down input and the risk of landing short of the runway threshold;
  - – When breaking out at both ceiling minimums and visibility minimums, the slant visibility may not be sufficient for the crew to see the farther bar(s) of the

VASI or precision approach path indicator (PAPI), thus reducing the available visual clues for the visual segment in reduced visibility;

- Crosswind:
  - In crosswind conditions, the runway lights and environment will appear at an angle to the aircraft heading; the flight crew should maintain the drift correction and resist the tendency to align the aircraft with the runway centerline; and,
- Runway surface condition:
  - A wet runway reflects very little light; this can affect depth perception and cause the flight crew to perceive incorrectly that the aircraft is farther away from the runway. This effect usually results in a late flare and hard landing.

Table 1 provides a summary of visual illusions factors and their effects on the pilot's perception and actions.

Table 1
Factors That Cause Visual Illusions and Result in Incorrect Pilot Responses

Factor	Perception	Action	Result
Narrow or long runway Runway or terrain uphill slope	Too high	Push	Land short/hard
Wide or short runway Runway or terrain downhill slope	Too low	Pull	Land long/ overrun
Bright runway lighting	Too close (too steep)	Push	Land short/hard
Low-intensity lighting	Farther away (too shallow)	Pull	Land long/ overrun
Light rain, fog, haze, mist, smoke, dust	Too high	Push	Land short/hard
Entering fog (shallow layer)	Pitch-up	Push over	Steepen glide path/ (CFIT)
Flying in haze	Farther away (too shallow)	Pull	Land long/ overrun
Wet runway	Farther away (too high)	Late flare	Hard landing
Crosswind	Angled with runway	Cancel drift correction	Drifting off track

CFIT = Controlled flight into terrain

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Lessening the Effects

To lessen the effects of visual illusions, company accident-prevention strategies and personal lines of defense should be developed and implemented based on the following recommendations.

Hazard Awareness

Companies should assess their exposure to visual illusions on their route network and in their operating environment(s).

Flight crews should be trained to recognize and to understand the factors and conditions that cause visual illusions and their effects, including:

- Perception of height/depth, distances and angles; and,
- Assessment of the aircraft's horizontal position and glide path.

Hazard Assessment

Approach hazards should be assessed during the approach briefing by reviewing the following elements:

- Ceiling conditions and visibility conditions;
- Weather:
  - Wind, and turbulence;
  - Rain showers; and/or,
  - Fog or smoke patches;
- Crew experience at the airport and in the airport environment:
  - Surrounding terrain; and/or,
  - Specific airport hazards and runway hazards (obstructions, black-hole effect, off-airport light patterns); and,
- Runway approach aids and visual aids:
  - Type of approach (let-down navaid restriction, such as a glideslope that is unusable beyond a specific point or below a specific altitude);
  - Type of approach lights; and,
  - VASI or PAPI availability.

Terrain Awareness

When requesting or accepting a visual approach, the flight crew should be aware of the surrounding terrain features and man-made obstacles.

At night, an unlighted hillside between a lighted area and the runway may prevent the flight crew from correctly perceiving the rising terrain.

Type of Approach

At night, whenever an instrument approach is available (particularly an instrument landing system [ILS] approach) the instrument approach should be preferred to a visual approach, to reduce the risk of accidents caused by visual illusions.

If an ILS approach is available, fly the ILS and use VASI or PAPI for the visual portion of the approach.

If an ILS approach is not available, a nonprecision approach supported by a VASI or PAPI should be the preferred option.

On a nonprecision approach, do not descend below the MDA(H) before reaching the visual descent point (VDP), even if visual references have been acquired.

To help prevent transitioning too early to visual references and descending prematurely, the pilot flying (PF) should maintain instrument references until reaching the VDP.

During a visual or circling approach, when on the base leg, if the VASI or PAPI indicates that the aircraft is below glide path, level off or climb until the VASI or PAPI indicates on-glide-path.

Flight Path Monitoring

Resisting the tendency to pitch down or to descend intentionally below the appropriate altitude is the greatest challenge during the visual segment of the approach. This includes:

- Pitching down toward the approach lights in an attempt to see the runway during a precision approach; or,
- Descending prematurely because of the incorrect perception of being too high.

The pilot not flying (PNF) must maintain instrument references, including glideslope deviation, during the visual portion of an ILS approach.

Monitoring the VASI or PAPI, whenever available, provides additional visual references to resist the tendency to increase or to decrease the rate of descent.

On runways with an ALS with sequenced flashing lights II (ALSF-II), flight crews should be aware that two rows of red lights are aligned with the touchdown zone lights; this will provide an additional guard against descending prematurely.

The following can counter visual illusions (and prevent a flight crew from descending prematurely):

- Maintain an instrument scan down to touchdown;
- Cross-check instrument indications against outside visual references to confirm glide path;
- Use an ILS approach whenever available;
- Use a VASI or PAPI, if available, down to runway threshold; and,
- Use other available tools, such as an extended runway centerline shown on the flight management system (FMS) navigation display, ILS-DME (distance-measuring equipment) or VOR (very-high-frequency omnidirectional radio)-DME distance, altitude above airport elevation to confirm the glide path (based on a typical 300-feet/one-nautical-mile approach gradient).

Crew Resource Management (CRM)

CRM should ensure continuous monitoring of visual references and instrument references throughout the transition to the visual segment of an instrument approach.

In demanding conditions, the PNF should reinforce his or her monitoring of instrument references and of the flight progress for effective cross-check and backup of the PF.

Altitude calls and excessive-parameter-deviation calls should be the same for instrument approaches and for visual approaches, and should be continued during the visual portion of the (including glideslope deviation during an ILS approach or vertical-speed deviation during a nonprecision approach).

Consequences

The following are cited often in the analysis of approach-and-landing incidents and accidents resulting from visual illusions:

- Unconscious modification of the aircraft trajectory to maintain a constant perception of visual references;
- Natural tendency to descend below the glideslope or the initial glide path;
- The preceding tendencies combined with the inability to judge the proper flare point because of restricted visual references (often resulting in a hard landing before reaching the desired touchdown point);
- Inadequate reference to instruments to support the visual segment;
- Failure to detect the deterioration of visual references; and,
- Failure to monitor the instruments and the flight path because both pilots are involved in the identification of visual references.

Summary

To guard against the adverse effects of visual illusions, flight crews should:

- Be aware of all weather factors;
- Be aware of surrounding terrain and obstacles;
- Assess the airport environment, airport and runway hazards; and,
- Adhere to defined PF-PNF task-sharing after the transition to visual flying, including:
  – Monitoring by the PF of outside visual references while referring to instrument references to support and monitor the flight path during the visual portion of the approach; and,
  – Monitoring by the PNF of head-down references while the PF flies and looks outside, for effective cross-check and backup.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.6 — Approach Briefing*;
- *5.2 — Terrain*;
- *7.3 — Visual References*; and,
- *7.4 — Visual Approaches.*♦

References

1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

2. The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force defined *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]." Each accident and incident in the study sample involved several causal factors.

3. The FSF ALAR Task Force defined *circumstantial factor* as "an event or item that was judged not to be directly in the causal chain of events but could have contributed to the accident [or incident]."

4. The *black-hole effect* typically occurs during a visual approach conducted on a moonless or overcast night, over water or over dark, featureless terrain where the only visual stimuli are lights on and/or near the airport. The absence of visual references in the pilot's near vision affect depth perception and cause the illusion that the airport is closer than it actually is and, thus, that the aircraft is too high. The pilot may respond to this illusion by conducting an approach below the correct flight path (i.e., a low approach).

Related Reading from FSF Publications

Wilson, Dale R. "Darkness Increases Risks of Flight." *Human Factors & Aviation Medicine* Volume 46 (November–December 1999).

Enders, John H.; Dodd, Robert; Tarrel, Rick; Khatwa, Ratan; Roelen, Alfred L.C.; Karwal, Arun K. "Airport Safety: A study of Accidents and Available Approach-and-landing Aids." *Flight Safety Digest* Volume 15 (March 1996).

FSF Editorial Staff. "Fatal Commuter Crash Blamed on Visual Illusion, Lack of Cockpit Coordination." *Accident Prevention* Volume 50 (November 1993).

FSF Editorial Staff. "Spatial Disorientation Linked to Fatal DC-8 Freighter Crash." *Accident Prevention* Volume 50 (March 1993).

Regulatory Resources

International Civil Aviation Organization. *Preparation of an Operations Manual*. Second edition – 1997.

U.S. Federal Aviation Administration. *Federal Aviation Regulations*. 91.175 "Takeoff and landing under IFR." July 1, 2000.

Joint Aviation Authorities. *Joint Aviation Requirements – Operations 1. Commercial Air Transport (Aeroplanes)*. 1.430 "Aerodrome Operating Minima – General," 1.435 – Terminology. July 1, 2000.

Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

Flight Safety Foundation

ALAR

Approach-and-landing Accident Reduction

Tool Kit

FSF ALAR Briefing Note 5.4 — Wind Shear

Flight crew awareness and alertness are key factors in the successful application of wind shear avoidance techniques and recovery techniques.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that adverse wind conditions (i.e., strong crosswinds, tail winds or wind shear) were involved in about 33 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[1]

Definition

Wind shear is a sudden change of wind velocity/direction.

The following types of wind shear exist:

- Vertical wind shear (vertical variations of the horizontal wind component, resulting in turbulence and affecting aircraft airspeed when climbing or descending through the shear layer); and,
- Horizontal wind shear (horizontal variations of the wind component (e.g., decreasing head wind or increasing tail wind, or a shift from a head wind to a tail wind), affecting the aircraft in level flight, climb or descent).

Wind shear is associated usually with the following weather conditions:

- Jet streams;
- Mountain waves;
- Frontal surfaces;
- Thunderstorms and convective clouds; and,
- Microbursts.

Microbursts present two distinct threats to aviation safety:

- A downburst that results in strong downdrafts (reaching 40 knots vertical velocity); and,
- An outburst that results in strong horizontal wind shear and wind-component reversal (with horizontal winds reaching 100 knots).

Avoidance

TThe following information can be used to avoid areas of potential wind shear or observed wind shear:

- Weather reports and forecasts:
  - The low-level wind shear alert system (LLWAS) is used by controllers to warn pilots of existing or impending wind shear conditions:
    - LLWAS consists of a central wind sensor (sensing wind velocity and direction) and peripheral wind sensors located approximately two nautical miles (nm) from the center. Central wind sensor data are averaged over a rolling two-minute period and compared every 10 seconds with the data from the peripheral wind sensors.
    - An alert is generated whenever a difference in excess of 15 knots is detected. The LLWAS may not detect downbursts with a diameter of two nm or less:

– Terminal doppler weather radar (TDWR) detects approaching wind shear areas and, thus, provides pilots with an advance warning of wind shear hazard;

- Pilot reports:

  – Pilot reports (PIREPS) of wind shear causing airspeed fluctuations in excess of 20 knots or vertical-speed changes in excess of 500 feet per minute (fpm) below 1,000 feet above airport elevation should be cause for caution;

- Visual observation:

  – Blowing dust, rings of dust, dust devils (i.e., whirlwinds containing dust or sand) and any other evidence of strong local air outflow near the surface often are indications of wind shear;

- Onboard wind-component and groundspeed monitoring:

  – On approach, a comparison of the head-wind component or tail-wind component aloft (as available) and the surface head-wind component or tail-wind component indicates the likely degree of vertical wind shear;

- Onboard weather radar; and,

- Onboard predictive wind shear system.

Recognition

Timely recognition of wind shear is vital for successful implementation of a wind shear recovery procedure.

Some flight guidance systems can detect a wind shear condition during approach, and during go-around, based on analysis of aircraft flight parameters.

The following are indications of a suspected wind shear condition:

- Indicated airspeed variations in excess of 15 knots;
- Groundspeed variations (decreasing head wind or increasing tail wind, or a shift from head wind to tail wind);
- Vertical-speed excursions of 500 fpm or more;
- Pitch attitude excursions of five degrees or more;
- Glideslope deviation of one dot or more;
- Heading variations of 10 degrees or more; and,
- Unusual autothrottle activity or throttle lever position.

Reactive/Predictive Warnings

In addition to flight director (FD) wind shear recovery guidance, some aircraft provide a “wind shear” warning.

The wind shear warning and FD recovery guidance are referred to as a *reactive wind shear system*, which does not incorporate any forward-looking (anticipation) capability.

To complement the reactive wind shear system and provide an early warning of wind shear activity, some weather radars detect wind shear areas ahead of the aircraft (typically providing a one-minute advance warning) and generate a wind shear warning (red “WIND SHEAR AHEAD”), caution (amber “WIND SHEAR AHEAD”) or advisory alert messages.

This equipment is referred to as a *predictive wind shear system.*

Operating Procedures

The following opportunities are available to enhance wind shear awareness and operating procedures.

Standard Operating Procedures

Standard operating procedures (SOPs) should emphasize the following wind shear awareness items:

- Wind shear awareness and avoidance:

  – Approach briefing; and,

  – Approach hazards awareness;

- Wind shear recognition:

  – Task-sharing for effective cross-check and backup, particularly for excessive parameter deviations;

  – Energy management during approach; and,

  – Elements of a stabilized approach (Table 1) and approach gate[2]; and,

- Wind shear recovery procedure:

  – Readiness and commitment to respond to a wind shear warning.

Training

A wind shear awareness program should be developed and implemented, based on the industry-developed *Windshear Training Aid* or the Flight Safety Foundation-developed *Windshear Training Aid Package*.[3]

Training on the wind shear recovery procedure should be conducted in a full-flight simulator, using wind shear profiles recorded during actual wind shear encounters.

Departure Briefing

The takeoff-and-departure briefing should include the following wind shear awareness items:

- Assessment of the conditions for a safe takeoff based on:

Table 1
Recommended Elements Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

- – Most recent weather reports and forecasts;
- – Visual observations; and,
- – Crew experience with the airport environment and the prevailing weather conditions; and,

- Consideration to delaying the takeoff until conditions improve.

Takeoff and Initial Climb

If wind shear conditions are expected, the crew should:

- Select the most favorable runway, considering the location of the likely wind shear/downburst condition;
- Select the minimum flaps configuration compatible with takeoff requirements, to maximize climb-gradient capability;
- Use the weather radar (or the predictive wind shear system, if available) before beginning the takeoff to ensure that the flight path is clear of hazards;
- Select maximum takeoff thrust;
- After selecting the takeoff/go-around (TOGA) mode, select the flight-path-vector display for the pilot not flying (PNF), as available, to obtain a visual reference of the climb flight path angle; and,
- Closely monitor the airspeed and airspeed trend during the takeoff roll to detect any evidence of impending wind shear.

Wind Shear Recovery

If wind shear is encountered during the takeoff roll or during initial climb, the following actions should be taken without delay:

- Before V_1:
  - – The takeoff should be rejected if unacceptable airspeed variations occur (not exceeding the target V_1) and if there is sufficient runway remaining to stop the airplane;
- After V_1:
  - – Disconnect the autothrottles (A/THR), if available, and maintain or set the throttle levers to maximum takeoff thrust;
  - – Rotate normally at V_R; and,
  - – Follow the FD pitch command if the FD provides wind shear recovery guidance, or set the required pitch attitude (as recommended in the aircraft operating manual [AOM]/quick reference handbook [QRH]);
- During initial climb:
  - – Disconnect the A/THR, if available, and maintain or set the throttle levers to maximum takeoff thrust;
  - – If the autopilot (AP) is engaged and if the FD provides wind shear recovery guidance, keep the AP engaged; or,

    Follow the FD pitch command, if the FD provides wind shear recovery guidance; or,

    Set the required pitch attitude (as recommended in the AOM/QRH);
  - – Level the wings to maximize the climb gradient, unless a turn is required for obstacle clearance;
  - – Closely monitor the airspeed, airspeed trend and flight-path angle (as available);

– Allow airspeed to decrease to stick shaker onset (intermittent stick shaker activation) while monitoring the airspeed trend;

– Do not change the flaps or landing-gear configurations until out of the wind shear condition; and,

– When out of the wind shear condition, increase airspeed when a positive climb is confirmed, retract the landing gear, flaps and slats, then establish a normal climb profile.

Approach Briefing

The approach briefing should include the following:

- Based on the automatic terminal information service (ATIS) broadcast, review and discuss the following items:
  - Runway in use (type of approach);
  - Expected arrival route (standard terminal arrival [STAR] or radar vectors);
  - Prevailing weather; and,
  - Reports of potential low-level wind shear (LLWAS warnings, TDWR data); and,
- Discuss the intended use of automation for vertical navigation and lateral navigation as a function of the suspected or forecasted wind shear conditions.

Descent and Approach

Before conducting an approach that may be affected by wind shear conditions, the crew should:

- Assess the conditions for a safe approach and landing based on:
  - Most recent weather reports and forecasts;
  - Visual observations; and,
  - Crew experience with the airport environment and the prevailing weather conditions;
- Consider delaying the approach and landing until conditions improve, or consider diverting to a suitable airport;
- Whenever downburst/wind shear conditions are anticipated, based on pilot reports from preceding aircraft or based on an alert by the airport LLWAS, *the landing should be delayed or the aircraft should be flown to the destination alternate airport;*
- Select the most favorable runway, considering:
  - The location of the likely wind shear/downburst condition; and,
  - The available runway approach aids;
- Use the weather radar (or the predictive wind shear system, if available) during the approach to ensure that the flight path is clear of potential hazards;
- Select the flight-path vector display for the PNF, as available, to obtain a visual reference of the flight-path angle;
- Select less than full flaps for landing (to maximize climb-gradient capability), if authorized by the aircraft operating manual (AOM/QRH), and adjust the final approach speed accordingly;
- If an instrument landing system (ILS) approach is available, engage the AP for more accurate approach tracking and for warnings of excessive glideslope deviations;
- Select a final approach speed based on the reported surface wind — an airspeed correction (usually a maximum of 15 knots to 20 knots, based on the expected wind shear value) is recommended;
- Compare the head-wind component aloft or the tail-wind component aloft with the surface head-wind component or surface tail-wind component to assess the likely degree of vertical wind shear;
- Closely monitor the airspeed, airspeed trend and groundspeed during the approach to detect any evidence of impending wind shear;
  - Be alert for microbursts, which are characterized by a significant increase of the head-wind component followed by a sudden change to a tail wind; and,
- Be alert to respond without delay to a predictive wind shear warning or to a reactive wind shear warning, as applicable. The response should adhere to procedures in the AOM/QRH.

Recovery During Approach and Landing

If wind shear is encountered during the approach or landing, the following recovery actions should be taken without delay:

- Select the takeoff/go-around (TOGA) mode and set and maintain maximum go-around thrust;
- Follow the FD pitch command (if the FD provides wind shear recovery guidance) or set the pitch-attitude target recommended in the AOM/QRH;
- If the AP is engaged and if the FD provides wind shear recovery guidance, keep the AP engaged; otherwise, disconnect the AP and set and maintain the recommended pitch attitude;
- Do not change the flap configuration or landing-gear configuration until out of the wind shear;
- Level the wings to maximize climb gradient, unless a turn is required for obstacle clearance;
- Allow airspeed to decrease to stick-shaker onset (intermittent stick-shaker activation) while monitoring airspeed trend;

- Closely monitor airspeed, airspeed trend and flight path angle (if flight-path vector is available and displayed for the PNF); and,
- When out of the wind shear, retract the landing gear, flaps and slats, then increase the airspeed when a positive climb is confirmed and establish a normal climb profile.

Awareness

Company accident-prevention strategies and personal lines of defense should be developed to address the following factors:

- Aircraft equipment:
  - Absence of reactive/predictive wind shear system(s); and,
  - Absence of glideslope excessive-deviation warning;
- Airport equipment:
  - Absence of an LLWAS; and,
  - Absence of TDWR;
- Training:
  - Absence of a wind shear awareness program; and/or,
  - Absence of wind shear recovery (escape) simulator training;
- SOPs:
  - Inadequate briefings;
  - Inadequate monitoring of flight progress; and/or,
  - Incorrect use of automation; and,
- Human factors and crew resource management (CRM):
  - Absence of cross-checking (for excessive parameter deviations);
  - Absence of backup (standard calls); and/or,
  - Fatigue.

Summary

Avoidance

- Assess the conditions for a safe approach and landing, based on all available meteorological data, visual observations and on-board equipment;
- As warranted, consider delaying the approach, or consider diverting to a more suitable airport; and,
- Be prepared and committed to respond immediately to a wind shear warning.

Recognition

- Be alert for wind shear conditions, based on all available weather data, onboard equipment and aircraft flight parameters and flight path; and,
- Monitor the instruments for evidence of impending wind shear.

Recovery

- Avoid large thrust variations or trim changes in response to sudden airspeed variations;
- If a wind shear warning occurs, follow the FD wind shear recovery pitch guidance or apply the recommended escape procedure; and,
- Make maximum use of aircraft equipment, such as the flight-path vector (as available).

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.2 — Automation*;
- *1.3 — Golden Rules*;
- *1.4 — Standard Calls*;
- *1.6 — Approach Briefing*;
- *5.1 — Approach Hazards Overview*; and,
- *6.1 — Being Prepared to Go Around*.♦

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1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

2. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *approach gate* as "a point in space (1,000 feet above airport elevation in instrument meteorological conditions or 500 feet above airport elevation in visual meteorological conditions) at which a go-around is required if the aircraft does not meet defined stabilized approach criteria."

3. The two-volume *Windshear Training Aid*, developed primarily for operators of air carrier aircraft, is available for purchase from the U.S. National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161 U.S.A. Telephone: (800) 553-6847 (U.S.) or +1 (703) 605-6000. Fax: +1 (703) 605-6900. Internet site: www.ntis.gov. Each volume costs US$123 plus shipping-and-handling charges.

The multimedia *Windshear Training Aid Package*, developed by Flight Safety Foundation for operators of regional, on-demand, business and other general aviation aircraft, is available for purchase from NTIS for $330, plus shipping-and-handling charges.

Related Reading from FSF Publications

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FAA. Advisory Circular 00-54, *Pilot Windshear Guide*. November 25, 1988.

Notice

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- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
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- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

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Tool Kit

FSF ALAR Briefing Note 6.1 — Being Prepared to Go Around

The importance of being *go-around-prepared* and being *go-around-minded* must be emphasized, because a go-around is not a frequent occurrence. This requires having a clear mental image of applicable briefings, standard calls, sequences of actions, task-sharing and cross-checking, and being prepared to abandon the approach if requirements are not met in terms of:

- Weather minimums; or,
- Criteria for a stabilized approach (Table 1, page 118).

The sequence of events leading to a go-around can begin at the top of descent, so the following recommendations begin with descent preparation.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that failure to recognize the need for and to execute a missed approach when appropriate is a primary cause of approach-and-landing accidents (ALAs), including those involving controlled flight into terrain (CFIT).[1]

The task force found that inadequate professional judgment/airmanship was a causal factor[2] in 74 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.

Among the flight crew errors committed in these occurrences was failure to conduct a go-around when required by: an unstabilized approach; excessive glideslope/localizer deviations; absence of adequate visual references at the minimum descent altitude/height (MDA[H]) or decision altitude/height (DA[H]); confusion regarding aircraft position; and automation-interaction problems.

The task force found that only 17 percent of the accident/incident flight crews initiated go-arounds when conditions indicated that go-arounds should have been conducted.

General

Being go-around-prepared and go-around-minded implies the following:

- Knowledge of applicable briefings, standard calls, sequences of actions, task-sharing and cross-checking;
- Being ready to abandon the approach if the weather minimums or the criteria for a stabilized approach are not met, or if doubt exists about the aircraft's position or about aircraft guidance; and,
- After the go-around is initiated, the flight crew must fly the published missed approach procedure.

Operational Recommendations

Task-sharing

Adherence to the defined pilot flying-pilot not flying (PF-PNF) task-sharing procedures for normal operations and abnormal operations is a major part of preparing for a go-around and of conducting a safe go-around.

Descent Preparation

Descent preparation and the approach briefing should be planned and should be conducted to prevent delaying the initiation of the descent and to prevent rushed management of the descent profile.

Approach Briefing

To be go-around-prepared, the approach briefing should include a discussion of the primary elements of the go-around maneuver and the published missed approach procedure. The discussion should include the following:

- Approach gate[3];
- Go-around call (e.g., a loud and clear "go around/flaps");
- PF-PNF task-sharing (flow of respective actions, including desired guidance, mode selection, airspeed target, go-around altitude, deviations calls); and,
- Missed approach vertical navigation and lateral navigation (including airspeed and altitude restrictions).

Achieving Flight Parameters

The flight crew must "stay ahead of the aircraft" throughout the flight. This includes achieving desired flight parameters (e.g., aircraft configuration, aircraft position, energy condition, track, altitude, vertical speed, airspeed and attitude) during the descent, approach and landing. Any indication that a desired flight parameter will not be achieved should prompt immediate corrective action or the decision to go around.

Descent Profile Monitoring

The descent profile should be monitored, using all available instrument references (including flight management system [FMS] vertical navigation [VNAV]).

The descent profile also may be monitored or may be adjusted based on a *typical 10 nautical mile per 3,000 feet descent gradient* (corrected for the prevailing head-wind component or tail-wind component) while adhering to the required altitude/airspeed restrictions (deceleration management).

If the flight path is significantly above the desired descent profile (e.g., because of an air traffic control [ATC] restriction or greater-than-expected tail wind), the desired flight path can be recovered by:

- Reverting from FMS VNAV to a selected vertical mode, with an appropriate airspeed target or vertical-speed target;
- Maintaining a high airspeed and a high descent rate as long as practical;
- Using speed brakes;
- Extending the landing gear, if the use of speed brakes is not sufficient; or,
- As a last resort, conducting a 360-degree turn (as practical, and with ATC clearance).

If the desired descent flight path cannot be established, ATC should be notified for timely coordination.

Final Approach

Because the approach briefing was conducted at the end of the cruise phase, the crew should review primary elements of

Table 1
Recommended Elements
Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met*:

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000) the go-around maneuver and the missed approach procedure at an appropriate time during final approach.

To be prepared to take over manually when flying with the autopilot (AP) engaged, the following should be considered:

- Seat adjustment and armrest adjustment (this is of primary importance for effective aircraft handling in a dynamic phase of flight); and,
- Flying with one hand on the control column and one hand on the throttle levers.

Transitioning Back to Instrument Flying

One of the most frequent reasons for conducting a go-around is weather.

When approaching the minimum descent altitude/height (MDA[H]) or the decision altitude/height (DA[H]), one pilot attempts to acquire the required visual references. During this time, the pilot is in *almost-visual* flying conditions.

If a go-around is initiated, an immediate transition to instrument flying should occur.

It is, therefore, of primary importance that the other pilot maintain instrument references and be ready to make appropriate calls if any flight parameter (airspeed, pitch attitude, bank angle, thrust) deviates from the normal value.

To ease this transition back to instrument flying, all efforts should be made to initiate the go-around with wings level and with no roll rate.

The above discussion does not apply when captain/first officer task-sharing is accomplished in accordance with an operating policy known as the *shared approach, monitored approach* or *delegated handling approach.* [See FSF ALAR Briefing Note 7.3 — *Visual References*.]

Summary

Because a go-around is not a frequent occurrence, the importance of being go-around-prepared and go-around-minded should be emphasized.

If the criteria for safe continuation of the approach are not met, the crew should initiate a go-around and fly the published missed approach.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.3 — Golden Rules*;
- *1.4 — Standard Calls*;
- *1.6 — Approach Briefing*;
- *4.1 — Descent-and-approach Profile Management*;
- *4.2 — Energy Management*;
- *6.2 — Manual Go-around*;
- *7.1 — Stabilized Approach*; and,
- *7.3 — Visual References.*♦

References

1. Flight Safety Foundation. “Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents.” *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.
2. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *causal factor* as “an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident].” Each accident and incident in the study sample involved several causal factors.
3. The FSF ALAR Task Force defines *approach gate* as “a point in space (1,000 feet above airport elevation in instrument meteorological conditions or 500 feet above airport elevation in visual meteorological conditions) at which a go-around is required if the aircraft does not meet defined stabilized approach criteria.”

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FSF ALAR Briefing Note 6.2 — Manual Go-around

The importance of being *go-around-prepared* and being *go-around-minded* must be emphasized, because a go-around is not a frequent occurrence.

This requires that the pilots have a clear mental image of applicable briefings, standard calls, sequences of actions, task-sharing and cross-checking, and that the pilots are prepared to abandon the approach if requirements are not met in terms of:

- Weather minimums; or,
- Criteria for a stabilized approach (Table 1, page 122).

After the go-around is initiated, the flight crew must fly the missed approach procedure as published (i.e., following the published vertical navigation and lateral navigation).

Recommendations

Task-sharing

The following task-sharing principles are important in the very dynamic phase of initiating a go-around.

The pilot flying (PF) is responsible for controlling vertical navigation and lateral navigation, and for energy management, by either:

- Supervising autopilot vertical guidance and lateral guidance, and autothrottle (A/THR) operation; and maintaining awareness of flight-mode annunciator (FMA) status and FMA changes; or,
- Flying manually, with flight director (FD) guidance and an adapted (e.g., horizontal situation indicator [HSI]-type) navigation display (ND) mode.

If manual thrust is selected, the pilot not flying (PNF) should monitor closely the airspeed, airspeed trend and thrust, and call any excessive deviation (e.g., airspeed decreasing below V_{REF}).

The PNF is responsible for monitoring tasks and for conducting actions requested by the PF, including:

- Conducting the standard PNF tasks:
  - Performing standard operating procedures (SOPs);
  - Conducting selections on the automatic flight system (AFS) control panel when in manual flight; and,
  - Reading abnormal checklists or emergency checklists (electronic and/or paper checklists) and conducting required actions in case of failure;
- Monitoring the thrust setting;
- Monitoring vertical speed and radio-altimeter altitude; and,
- Monitoring pitch attitude, bank angle, airspeed and airspeed trend, and calling out any excessive deviation.

Understanding the Flight Dynamics of the Go-around

Unlike the takeoff rotation, in which the aircraft is pre-trimmed and the thrust is already set, the initiation of a go-around

Table 1
Recommended Elements Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met*:

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
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9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

requires a very dynamic sequence of actions and changes (thrust, configuration) affecting the pitch balance**.**

Pitch effects depend largely on the location of engines (i.e., mounted under the wings or on the tail) and other aircraft or systems features.

Pitch effects are amplified:

- At low gross weight, low altitude and low outside air temperature (hence, at a high thrust-to-weight ratio); and/or,
- With all engines operative, as compared to a one-engine-inoperative go-around.

The pitch effects of underwing-mounted engines are discussed in this briefing note.

When initiating a go-around at decision altitude/height (DA[H]), *the PF is expected to minimize the altitude loss*: *The PF must apply simultaneously nose-up pitch pressure on the control column, advance the throttle levers and select the takeoff/go-around (TOGA) mode.*

Pitch is affected by the following factors:

- The nose-up elevator input initiates a pitch-attitude change that minimizes altitude loss;
- Within a few seconds, thrust increases (resulting in an additional nose-up pitch effect); and,
- Retracting one step of flaps results usually in a slight nose-up pitch effect.

As a result of these three nose-up pitch effects:

- The pitch-attitude rate increases; and,
- The nose-up pitch force required to maintain the pitch-attitude target decreases until a nose-down pitch force is required to prevent an excessive nose-up pitch attitude.

To maintain the desired pitch-attitude target (and prevent overshooting this target), the PF must:

- Release back (nose-up) pressure on the control column;
- Apply progressively, as thrust increases, forward (nose-down) pressure on the control column; and,
- Re-trim the aircraft (nose-down), as necessary.

Stated simply, the PF should aviate (fly the aircraft) while closely monitoring the primary flight display (PFD).

If the pitch attitude is not controlled *positively*, pitch will continue to increase and will reach values at which airspeed will decrease despite the go-around thrust.

Flying a Manual Go-around

For a safe go-around, the following "three Ps" constitute a golden rule:

- Pitch:
  - Set and maintain the pitch-attitude target;
- Power:
  - Set and check the go-around thrust; and,
- Performance:

– Check aircraft performance: positive rate of climb, airspeed at or above V_{REF} (reference landing speed), speed brakes retracted, radio-altimeter indications and barometric-altimeter indications increasing, wings level, gear up, flaps as required.

The operational recommendations and task-sharing for the safe conduct of a manual go-around can be expanded as follows:

For the PF:

- When calling "go-around/flaps," *without delay*:
  - Select the TOGA mode and follow through the A/THR operation;
  - Rotate (at the same rate as for takeoff, typically three degrees per second);
  - Follow the FD pitch command (but do not exceed the maximum pitch attitude applicable to the aircraft type);
  - Check go-around power (thrust); and,
  - Check go-around performance:
    - Positive rate of climb;
    - Airspeed at or above V_{REF};
    - Speed brakes retracted;
    - Radio-altimeter indication and barometric-altimeter indication increasing;
    - Wings level;
    - Gear up; and,
    - Flaps as required;
- As thrust increases, be prepared to counteract the nose-up pitch effect (i.e., apply increasing forward pressure — nose-down input — on the control column); and,
- Trim the aircraft nose-down, as required.

The pitch attitude should not be allowed to exceed an *ultimate value* (e.g., 25 degrees), because such a pitch attitude would result in a significant airspeed reduction.

Immediate and firm elevator nose-down input (together with a nose-down pitch trim adjustment), however, may allow recovering the pitch-attitude target.

For the PNF:

- When hearing the "go-around/flaps" call, *without delay*:
  - Set flaps as appropriate;
  - Announce "positive climb" and retract the landing gear on PF command;
  - Monitor:
    - Airspeed and airspeed trend;
    - Pitch attitude and bank angle; and,
    - Thrust increase (confirm the thrust-limit mode, as applicable, and actual thrust on fan-speed [N_1] or engine-pressure-ratio [EPR] indicators);
  - Check the FMA:
    - Announce in a loud and clear voice the FMA-thrust mode, vertical-mode and lateral-mode selection;
    - Check the autopilot (AP) status; call "AP engaged" or "hand-flying"); and,
    - Check FD engagement status; and,
  - Continue monitoring the flight parameters and call any excessive deviation:
    - "Speed," if dropping below V_{REF};
    - "Speed trend," if negative;
    - "Pitch attitude," if approaching the ultimate value (e.g., at 20 degrees if the ultimate value is 25 degrees);
    - "Bank angle," if in excess of 15 degrees (30 degrees if the missed approach procedure requires a turn); and/or,
    - "Thrust," if a significant thrust reduction is observed.

Summary

To manually fly a safe go-around, adhere to the three-Ps golden rule:

- Pitch:
  - Set and maintain the pitch-attitude target;
- Power:
  - Set and check go-around thrust; and,
- Performance:
  - Check the aircraft performance: positive rate of climb, airspeed at or above V_{REF}, speed brakes retracted, radio-altimeter indication and barometric-altimeter indication increasing, wings level, gear up, flaps as required.

While conducting the go-around, adherence to the defined PF-PNF task-sharing and the optimum use of crew resource management (e.g., for monitoring flight parameters and calling any excessive flight-parameter deviation) are of paramount importance.

The manual go-around technique must:

- Minimize the initial altitude loss; and,

- Prevent an excessive nose-up pitch attitude by following FD pitch commands, not exceeding the ultimate pitch attitude applicable to the aircraft type.

Should any warning be triggered or any other abnormal condition occur during the go-around, the PF must concentrate his or her attention on flying the aircraft (controlling the vertical flight path and the lateral flight path).

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.3 — Golden Rules*;
- *1.4 — Standard Calls*;
- *6.1 — Being Prepared to Go Around*; and,
- *7.1 — Stabilized Approach.*♦

Related Reading from FSF Publications

Flight Safety Foundation (FSF). "Killers in Aviation: FSF Task Force Presents Facts about Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17–18 (November–December 1998, January–February 1999).

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- Manufacturers'/operators' standard operating procedures; and,
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Approach-and-landing Accident Reduction

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FSF ALAR Briefing Note
6.3 — Terrain-avoidance (Pull-up) Maneuver

A typical training program to reduce approach-and-landing accidents (ALAs), including those involving controlled flight into terrain (CFIT), includes the following:

- Alert flight crews to the factors that may cause ALAs and CFIT;
- Ensure that situational awareness is maintained at all times;
- Ensure that crews attain proficiency in conducting approach procedures for their aircraft type;
- Provide crews with adequate knowledge of the capabilities and limitations of the ground-proximity warning system (GPWS) or terrain awareness and warning system (TAWS)[1] installed on their aircraft; and,
- Ensure that crews are proficient in conducting the terrain-avoidance maneuver required in response to a GPWS warning or a TAWS warning (as published in the aircraft operating manual [AOM]/quick reference handbook [QRH]).

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that CFIT was involved in 37 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[2]

GPWS/TAWS Training

The rigorous application of standard operating procedures (SOPs) to reinforce situational awareness and the optimum use of automated systems and displays during approach procedures should be incorporated in transition training and recurrent training programs developed by the aircraft manufacturer or by the company's training department.

A training program should include:

- An instructor-led classroom briefing or a self-briefing based on the *FSF ALAR Tool Kit*;
- A complete discussion about the operation of the GPWS/TAWS;
- The FSF *Controlled Flight Into Terrain: An Encounter Avoided* video;
- Exercises to be incorporated in simulator training sessions during transition training/recurrent training (three typical sample exercises are described later); and,
- A simulator briefing for nonprecision approaches to emphasize CFIT risks and the advantages of using a constant-angle nonprecision approach (CANPA).

Simulator Requirements

- The flight simulator database should include terrain in the vicinity of the airports selected for training. The terrain database should extend to an area with a radius (centered on the airfield reference point) of 25 nautical miles (nm) to 30 nm (45 kilometers to 55 kilometers). This terrain also should be displayed by the visual system;

- The capability should be available to insert an "electronic mountain" from the instructor's panel at a selected point on the aircraft's projected flight path.

  Inserting an electronic mountain at an airport that does not have such terrain, however, may result in the trainee dismissing the GPWS/TAWS warning as a spurious warning, thus resulting in negative training.

  The slope and height of the mountain should be tailored to a particular aircraft at a representative gross weight (e.g., maximum landing weight [MLW]), so that maximum performance is required to avoid striking the mountain.

  The slope of the mountain therefore should be adjustable to match the climb gradients that can be achieved in the pull-up maneuver; and,

- To prevent negative training, the simulator must represent realistically the handling qualities and performance as airspeed reduces to stick-shaker speed or minimum airspeed.

Simulator Exercises

All GPWS/TAWS modes should be demonstrated. The objective should be to ensure an understanding of the capabilities and limitations of the GPWS/TAWS installed on the aircraft type.

These exercises can be conducted in either a fixed-base simulator (FBS) or a full-flight simulator (FFS).

The following scenarios, to be conducted in an FFS, are designed to increase CFIT awareness and to allow the pilot to practice the correct response to GPWS/TAWS warnings without significantly increasing the training time. The scenarios should be modified in accordance with the company's training requirements or operating environment.

Pull-up in VMC Exercise

Objectives. Demonstrate GPWS/TAWS warnings, *that a pull-up maneuver must be immediate*, the pull-up technique (with special emphasis on pitch force and attitude) and crew coordination.

Briefing. Explain the objectives and emphasize that this is a training exercise. Describe the pull-up technique required for the particular aircraft type.

Initial Conditions. Establish initial approach configuration and airspeed, at or near the MLW, in a shallow descent or in level flight.

Procedure. The instructor inserts an electronic mountain ahead of the aircraft and talks to the flight crew throughout the maneuver, insisting on an immediate and aggressive response.

Ensure proper crew coordination, with the pilot not flying (PNF) calling radio altitudes and trend (e.g., "300 feet decreasing").

Continue the maneuver at maximum performance until mountain is cleared. The duration of the maneuver should be sufficient for the crew to demonstrate proficiency in maintaining maximum climb performance.

Repeat the exercise, as needed, until crew proficiency is achieved.

Debriefing. Review the exercise, as appropriate.

Pull-up in IMC Exercise

Objective. Reinforce and confirm correct response to a GPWS/TAWS warning in instrument meteorological conditions (IMC), including pilot technique and crew coordination.

Briefing. Explain the objective. Although the trainees will know that the exercise is to be conducted, explain that it is intended to simulate an inadvertent descent below minimum safe altitude (MSA) because of a loss of situational awareness (e.g., because of a lateral navigation error, an incorrect altitude selection or an incorrect nonprecision approach procedure).

Initial Conditions. Either of the following two scenarios can be used:

- Establish initial approach configuration and airspeed, at or near the MLW, in a shallow descent or in level flight; or,
- Establish landing configuration and approach speed, at or near MLW, on a typical three-degree descent.

Procedure. The instructor inserts an electronic mountain ahead of the aircraft and talks to the flight crew throughout the maneuver, insisting on an immediate and aggressive response.

Ensure proper crew coordination, with the PNF calling radio altitudes and trend (e.g., "300 feet decreasing").

Continue the maneuver at maximum performance until the terrain is cleared. The duration of the maneuver should be sufficient for the crew to demonstrate proficiency in maintaining the maximum climb performance.

Repeat the exercise, as needed, until crew proficiency is achieved.

Debriefing. Review the exercise, as appropriate.

Unexpected GPWS/TAWS Warning

This scenario should be included during a line-oriented flight training (LOFT) session, which normally is programmed at the end of transition training and during periodic recurrent training LOFT sessions.

Objective. To maintain crew awareness of the CFIT hazard and to confirm crew proficiency in responding to a GPWS/TAWS warning.

Briefing. None.

Initial Conditions. Establish either initial-approach configuration and airspeed, or clean configuration and maneuvering speed, at MLW, descending or in level flight.

Procedure. The instructor clears the crew to descend to an altitude below the MSA or provides radar vectors toward high terrain.

If the flight crew takes corrective action before any GPWS/TAWS warning (as expected), an electronic mountain can be inserted at a later stage in the session.

Verify crew response to GPWS/TAWS and crew coordination during the pull-up maneuver.

Debriefing. Review the exercise, as appropriate.

Summary

The following should be emphasized when discussing CFIT awareness and response to a GPWS/TAWS warning:

- Situational awareness must be maintained at all times;
- Preventive actions (ideally) must be taken *before* a GPWS/TAWS warning;
- Response to a GPWS/TAWS warning by the pilot flying (PF) must be immediate;
- The PNF must monitor and call the radio altitude and its trend throughout the terrain-avoidance maneuver; and,
- The pull-up maneuver must be continued at maximum climb performance until the warning has ceased and terrain is cleared (radio altimeter).

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.2 — Automation*;
- *2.3 — Pilot-Controller Communication*;
- *3.1 — Barometric Altimeter and Radio Altimeter*;
- *3.2 — Altitude Deviations*;
- *5.2 — Terrain*;
- *7.1 — Stabilized Approach*;
- *7.2 — Constant-angle Nonprecision Approach*;
- *7.3 — Visual References*; and,
- *7.4 — Visual Approaches.*♦

References

1. Terrain awareness and warning system (TAWS) is the term used by the European Joint Aviation Authorities and the U.S. Federal Aviation Administration to describe equipment meeting International Civil Aviation Organization standards and recommendations for ground-proximity warning system (GPWS) equipment that provides predictive terrain-hazard warnings. "Enhanced GPWS" and "ground collision avoidance system" are other terms used to describe TAWS equipment.

2. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

Related Reading from FSF Publications

Flight Safety Foundation (FSF) Editorial Staff. "Preparing for Last-minute Runway Change, Boeing 757 Flight Crew Loses Situational Awareness, Resulting in Collision with Terrain." *Accident Prevention* Volume 54 (July–August 1997).

FSF Editorial Staff. "Unaware That They Have Encountered a Microburst, DC-9 Flight Crew Executes Standard Go-around; Aircraft Flies Into Terrain." *Accident Prevention* Volume 53 (February 1996).

Duke, Thomas A.; FSF Editorial Staff. "Aircraft Descended Below Minimum Sector Altitude and Crew Failed to Respond to GPWS as Chartered Boeing 707 Flew into Mountain in Azores." *Accident Prevention* Volume 52 (February 1995).

Regulatory Resources

International Civil Aviation Organization. *International Standards and Recommended Practices, Annex 6 to the Convention of International Civil Aviation, Operation of*

Aircraft. Part I, *International Commercial Air Transport – Aeroplanes*. Chapter 6, "Aeroplane Instruments, Equipment and Flight Documents," 6.15. Appendix 2, "Contents of an Operations Manual," 5.23. Seventh edition – July 1998, incorporating Amendments 1–25.

U.S. Federal Aviation Administration. *Federal Aviation Regulations*. 91.223 "Terrain awareness and warning system," 121.360 "Ground proximity warning-glide slope deviation alerting system," 121.354 "Terrain awareness and warning system," 135.154 "Terrain awareness and warning system. March 29, 2000.

Joint Aviation Authorities. *Joint Aviation Requirements – Operations 1. Commercial Air Transport (Aeroplanes)*. 1.665 "Ground proximity warning system. July 1, 2000.

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- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

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FSF ALAR Briefing Note 6.4 — Bounce Recovery – Rejected Landing

A rejected landing (also called an aborted landing) is a go-around maneuver initiated after touchdown of the main landing gear. A rejected landing is a challenging maneuver and typically is recommended only when an aircraft bounces more than approximately five feet (1.5 meters) off the runway after touchdown.

No global statistical data are available on rejected-landing incidents or accidents. Nevertheless, the following are possible consequences of an incorrect decision to conduct a rejected landing:

- Tail strike following a go-around initiated because of directional control difficulties after thrust reverser selection;
- Aircraft performance limitation following the inappropriate selection of reverse thrust during a touch-and-go landing and failure of one reverser to stow; and,
- Loss of control following a go-around initiated after thrust reverser selection and failure of one reverser to stow.

Touch-and-go Training

A touch-and-go landing is a training exercise. Nevertheless, the conditions required for the safe conduct of this maneuver provide a valuable introduction to the discussion of bounce recovery/rejected landing.

Preconditions

Four preconditions (usually referred to as the "four-no rule") must be observed before initiating a touch-and-go:

- No ground spoilers:
  - Ground spoilers must not be armed or manually selected after touchdown;
- No autobrake system:
  - Autobrakes must not be armed;
- No reverse:
  - Thrust reversers must not be selected upon touchdown; and,
- No pedal braking:
  - Pedal braking must not be used after touchdown.

The above preconditions show that conducting a rejected landing during a nontraining flight (i.e., with ground spoilers and autobrakes armed, and being ready to select reverse thrust upon touchdown) involves an added challenge.

Aircraft Reconfiguration

After touchdown during a planned touch-and-go, the aircraft must be reconfigured for the takeoff configuration:

- Flaps reset;
- Pitch trim reset;
- Rudder trim reset; and,
- Throttle-lever “stand-up” (i.e., initial movement of the throttle levers to a straight-up position) for symmetric engine acceleration.

Task-sharing

Conducting a touch-and-go also is dynamic and demanding in terms of task-sharing:

- The pilot flying (PF) is responsible for:
  - Tracking the runway centerline; and,
  - Advancing initially the throttle levers slightly above idle;
- The pilot not flying (PNF) is responsible for:
  - Reconfiguring the aircraft for takeoff;
  - Resetting systems, as required;
  - Monitoring engine parameters and flight-mode annunciations;
  - Conducting the takeoff calls;
  - Deciding to reject the takeoff, if required; and,
  - Ensuring backup of the PF during rotation and initial climb.

Conducting a rejected landing further amplifies the importance of adherence to defined task-sharing by the PF and the PNF.

Bouncing and Bounce Recovery

Bouncing during a landing usually is the result of one or more of the following factors:

- Loss of visual references;
- Excessive sink rate;
- Late flare initiation;
- Incorrect flare technique;
- Excessive airspeed; and/or,
- Power-on touchdown (preventing the automatic extension of ground spoilers, as applicable).

The bounce-recovery technique varies with each aircraft type and with the height reached during the bounce.

Recovery From a Light Bounce (Five Feet or Less)

When a light bounce occurs, a typical recovery technique can be applied:

- Maintain or regain a normal landing pitch attitude (do not increase pitch attitude, because this could lead to a tail strike);
- Continue the landing;
- Use power as required to soften the second touchdown; and,
- Be aware of the increased landing distance.

Recovery From a High Bounce (More Than Five Feet)

When a more severe bounce occurs, do not attempt to land, because the remaining runway may be insufficient for a safe landing.

The following go-around technique can be applied:

- Maintain or establish a normal landing pitch attitude;
- Initiate a go-around by activating the go-around levers/switches and advancing the throttle levers to the go-around thrust position;
- Maintain the landing flaps configuration or set a different flaps configuration, as required by the aircraft operating manual (AOM)/quick reference handbook (QRH).
- Be prepared for a second touchdown;
- Be alert to apply forward pressure on the control column and reset the pitch trim as the engines spool up (particularly with underwing-mounted engines);
- When safely established in the go-around and when no risk remains of touchdown (steady positive rate of climb), follow normal go-around procedures; and,
- Reengage automation, as desired, to reduce workload.

Commitment to a Full-stop Landing

Landing incidents and accidents have demonstrated that after the thrust reversers have been deployed (even at reverse idle), the landing must be completed to a full stop because a successful go-around may not be possible.

The following occurrences have resulted in a significantly reduced rate of climb or in departure from controlled flight:

- Thrust asymmetry resulting from asymmetric engine spool-up (i.e., asymmetric engine acceleration characteristics as thrust increases from a ground-idle level);
- Thrust asymmetry resulting from asymmetric stowing of thrust reversers (i.e., one reverser going to the stowed position faster than the other); and,
- Severe thrust asymmetry resulting from one thrust reverser failing to stow.

Commitment to Go Around

If a go-around is elected, the flight crew must be committed to conduct the go-around. The crew must not change the go-around decision and must not retard the throttle levers in an attempt to complete the landing.

Such a change of decision usually is observed when the decision to reject the landing and the go-around are initiated by the first officer (as PF) but are overridden by the captain.

Runway overruns, collisions with obstructions and major aircraft damage (or postimpact fire) often are the consequences of landing after a go-around is initiated.

Summary

The flight crew should adhere to decision criteria for:

- Committing to a full-stop landing; or,
- Committing to a rejected landing and a go-around.

These criteria (adapted for each individual aircraft type) should be incorporated in the standard operating procedures (SOPs)/ supplementary techniques of each AOM/QRH.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *6.1 — Being Prepared to Go Around*;
- *7.1 —Stabilized Approach*; and,
- *8.1 — Runway Excursions and Runway Overruns.*♦

Related Reading From FSF Publications

FSF Editorial Staff. "Airplane's Low-energy Condition and Degraded Wing Performance Cited in Unsuccessful Go–around Attempt." *Accident Prevention* Volume 56 (July 1999).

FSF Editorial Staff. "Attempted Go-around with Deployed Thrust Reversers Leads to Learjet Accident." *Accident Prevention* Volume 56 (January 1999).

Flight Safety Foundation (FSF). "Killers in Aviation: FSF Task Force Presents Facts about Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17–18 (November–December 1998, January–February 1999).

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FSF ALAR Briefing Note 7.1 — Stabilized Approach

Unstabilized approaches are frequent factors in approach-and-landing accidents (ALAs), including those involving controlled flight into terrain (CFIT).

Unstabilized approaches are often the result of a flight crew who conducted the approach without sufficient time to:

- Plan;
- Prepare; and,
- Conduct a stabilized approach.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that unstabilized approaches (i.e., approaches conducted either low/slow or high/fast) were a causal factor[1] in 66 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[2]

The task force said that although some low-energy approaches (i.e., low/slow) resulted in loss of aircraft control, most involved CFIT because of inadequate vertical-position awareness.

The task force said that the high-energy approaches (i.e., high/fast) resulted in loss of aircraft control, runway overruns and runway excursions, and contributed to inadequate situational awareness in some CFIT accidents.

The task force also found that flight-handling difficulties (i.e., the crew's inability to control the aircraft to the desired flight parameters [e.g., airspeed, altitude, rate of descent]) were a causal factor in 45 percent of the 76 approach-and-landing accidents and serious incidents.

The task force said that flight-handling difficulties occurred in situations that included rushing approaches, attempts to comply with demanding ATC clearances, adverse wind conditions and improper use of automation.

Definition

An approach is stabilized only if all the criteria in company standard operating procedures (SOPs) are met before or when reaching the applicable minimum stabilization height.

Table 1 (page 134) shows stabilized approach criteria recommended by the FSF ALAR Task Force.

Note: Flying a stabilized approach that meets the recommended criteria discussed below does not preclude flying a delayed-flaps approach (also referred to as a decelerated approach) to comply with air traffic control (ATC) instructions.

The following minimum stabilization heights are recommended to achieve a stabilized approach:

- 1,000 feet above airport elevation in instrument meteorological conditions (IMC); or,
- 500 feet above airport elevation in visual meteorological conditions (VMC).

At the minimum stabilization height and below, a call should be made by the pilot not flying (PNF) if any flight parameter exceeds criteria shown in Table 1 (page 134).

Table 1
Recommended Elements Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met*:

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

Any time an approach is not stabilized at the minimum stabilization height or becomes unstabilized below the minimum stabilization height, a go-around should be conducted.

Benefits of a Stabilized Approach

Conducting a stabilized approach increases the flight crew's overall situational awareness, including:

- Horizontal awareness, by closely monitoring the horizontal flight path;
- Vertical awareness, by monitoring the vertical flight path and the rate of descent;
- Airspeed awareness, by monitoring airspeed trends; and,
- Energy-condition awareness, by maintaining the engine thrust at the level required to fly a three-degree approach path at the target final approach speed (or at the minimum groundspeed, as applicable). This also enhances go-around capability.

In addition, a stabilized approach provides:

- More time and attention for monitoring ATC communications, weather conditions and systems operation;
- More time for monitoring and backup by the PNF;
- Defined flight-parameter-deviation limits and minimum stabilization heights to support the decision to land or to go around; and,
- Landing performance consistent with published performance.

Factors in Unstabilized Approaches

Unstabilized approaches are attributed to:

- Fatigue;
- Pressure of flight schedule (making up for delays);
- Any crew-induced or ATC-induced circumstances resulting in insufficient time to plan, prepare and conduct a safe approach. This includes accepting requests from ATC to fly higher/faster or to fly shorter routings than desired;
- ATC instructions that result in flying too high/too fast during the initial approach;
- Excessive altitude or excessive airspeed (e.g., inadequate energy management) early in the approach;
- Late runway change (lack of ATC awareness of the time required by the flight crew to reconfigure the aircraft for a new approach);
- Excessive head-down work (e.g., flight management system [FMS] reprogramming);
- Short outbound leg or short downwind leg (e.g., because of traffic in the area);
- Late takeover from automation (e.g., because the autopilot [AP] fails to capture the glideslope);
- Premature descent or late descent caused by failure to positively identify the final approach fix (FAF);
- Inadequate awareness of wind conditions, including:
  - Tail-wind component;

– Low-altitude wind shear;

– Local wind gradient and turbulence (because of terrain or buildings); or,

– Recent weather along the final approach path (e.g., wind shift or downdrafts caused by a descending cold air mass following a rain shower);

- Incorrect anticipation of aircraft deceleration characteristics in level flight or on a three-degree glide path;
- Failure to recognize deviations or failure to adhere to the excessive-parameter-deviation limits;
- Belief that the aircraft will be stabilized at the minimum stabilization height or shortly thereafter;
- Excessive confidence by the PNF that the pilot flying (PF) will achieve a timely stabilization;
- PF-PNF too reliant on each other to call excessive deviations or to call for a go-around; and,
- Visual illusions.

Deviations in Unstabilized Approaches

One or more of the following deviations often are involved in unstabilized approaches:

- Entire approach flown at idle thrust down to touchdown, because of excessive airspeed and/or excessive altitude from early in the approach;
- Steep approach (above desired flight path with excessive vertical speed). Steep approaches are conducted typically twice as often as shallow approaches;
- Shallow approach (below desired glide path);
- Low-airspeed maneuvering (energy deficit);
- Excessive bank angle when capturing the final approach course;
- Activation of the ground-proximity warning system (GPWS) or the terrain awareness and warning system (TAWS)[3]:

  – Mode 1: "sink rate";

  – Mode 2A: "terrain" (not full flaps); or,

  – Mode 2B: "terrain" (full flaps);
- Late extension of flaps, or flaps-load-relief-system activation resulting in the late extension of flaps;
- Excessive flight-parameter deviation when crossing the minimum stabilization height:

  – Excessive airspeed;

  – Not aligned with runway;

  – Excessive bank angle;

  – Excessive vertical speed; or,

  – Flight path above glideslope;
- Excessive bank angle, excessive sink rate or excessive maneuvering while conducting a side-step maneuver;
- Speed brakes remain extended on short-final approach;
- Excessive flight-parameter deviation down to runway threshold;
- High at runway threshold crossing (i.e., more than 50 feet above threshold); and,
- Extended flare and extended touchdown.

Company Accident-prevention Strategies and Personal Lines of Defense

Preventing unstabilized approaches can be achieved by developing recommendations for the early detection and correction of factors that contribute to an unstabilized approach.

The following strategy is recommended:

- Anticipate;
- Detect;
- Correct; and,
- Decide.

Anticipate

Some factors likely to result in an unstabilized approach can be anticipated. For example, pilots and controllers should avoid situations that result in rushing approaches.

The approach briefing provides opportunities to identify and discuss factors such as nonstandard altitude, airspeed restrictions and energy management. The flight crew should agree on the management of the descent, deceleration and stabilization. This agreement will constitute a common objective for the PF and PNF.

Detect

The purpose of defined excessive-parameter-deviation limits and minimum stabilization heights is to provide the PF and PNF with a common reference for effective monitoring (early detection of deviations) and backup (timely and precise calls for effective corrections).

To ensure monitoring and backup, the following should be avoided:

- Late briefings;
- Unnecessary radio calls (e.g., company calls);

- Unnecessary actions (e.g., use of airborne communications addressing and reporting system [ACARS]); and,
- Nonpertinent conversations on the flight deck (i.e., breaking the "sterile cockpit rule"[4]).

Reducing workload and flight deck interruptions/distractions also allows the flight crew to:

- Better cope with fatigue;
- Comply with an unexpected ATC request (e.g., runway change);
- Adapt to changing weather conditions; and,
- Manage a system malfunction (e.g., flaps jamming or landing gear failing to extend).

Correct

Positive corrective actions should be taken before deviations develop into a challenging situation or a hazardous situation in which the only safe action is a go-around.

Corrective actions may include:

- The timely use of speed brakes or landing gear to correct excessive height or excessive airspeed; and,
- Extending the outbound leg or downwind leg.

Decide

If the approach is not stabilized before reaching the minimum stabilization height, or if any flight parameter exceeds deviation limits (other than transiently) when below the minimum stabilization height, a go-around must be conducted immediately.

The following behaviors often are involved when unstabilized approaches are continued:

- Excessive confidence in a quick recovery (postponing the go-around decision when flight parameters are converging toward excessive-deviation limits);
- Excessive confidence because of a long-and-dry runway and a low gross weight, although airspeed or vertical speed may be excessive;
- Inadequate preparation or lack of commitment to conduct a go-around. A change of mindset should take place from "we will land unless …" to "let's be prepared for a go-around, and we will land if the approach is stabilized and if we have sufficient visual references to make a safe approach and landing"; and,
- Absence of decision making (failure to remember the applicable excessive-deviation limits) because of fatigue or workload.

Achieving Flight Parameters

The flight crew must "stay ahead of the aircraft" throughout the flight. This includes achieving desired flight parameters (e.g., aircraft configuration, aircraft position, energy condition, track, vertical speed, altitude, airspeed and attitude) during the descent, approach and landing. Any indication that a desired flight parameter will not be achieved should prompt immediate corrective action or the decision to go around.

The minimum stabilization height constitutes an *approach gate*[5] on the final approach; a go-around must be initiated if:

- The required configuration and airspeed are not established, or the flight path is not stabilized when reaching the minimum stabilization height; or,
- The aircraft becomes unstabilized below the minimum stabilization height.

Transition to Visual Flying

When transitioning from instrument flight to visual flight, the pilot's perception of the runway and outside environment should be kept constant by maintaining:

- Drift correction, to continue tracking the runway centerline (i.e., resisting the tendency to align the aircraft with the runway centerline);
- The aiming point, to remain on the correct glide path until flare height (resisting the tendency to advance the aiming point and, thus, descend below the correct glide path); and,
- The final approach speed to maintain the energy condition.

Summary

Three essential parameters must be stabilized for a safe approach:

- Aircraft track;
- Flight path angle; and,
- Airspeed.

Depending on the type of approach and aircraft equipment, the most appropriate level of automation, as well as available visual references, should be used to establish and to monitor the stabilization of the aircraft.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *4.1 — Descent-and-approach Profile Management*;
- *4.2 — Energy Management*;

- *6.1 — Being Prepared to Go Around*;
- *7.2 —Constant-angle Nonprecision Approach*;
- *8.2 — Final Approach Speed*; and,
- *8.3 — Landing Distances*.♦

References

1. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]." Each accident and incident in the study sample involved several causal factors.

2. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

3. Terrain awareness and warning system (TAWS) is the term used by the European Joint Aviation Authorities and the U.S. Federal Aviation Administration to describe equipment meeting International Civil Aviation Organization standards and recommendations for ground-proximity warning system (GPWS) equipment that provides predictive terrain-hazard warnings. "Enhanced GPWS" and "ground collision avoidance system" are other terms used to describe TAWS equipment.

4. The *sterile cockpit* rule refers to U.S. Federal Aviation Regulations Part 121.542, which states: "No flight crewmember may engage in, nor may any pilot-in-command permit, any activity during a critical phase of flight which could distract any flight crewmember from the performance of his or her duties or which could interfere in any way with the proper conduct of those duties. Activities such as eating meals, engaging in nonessential conversations within the cockpit and nonessential communications between the cabin and cockpit crews, and reading publications not related to the proper conduct of the flight are not required for the safe operation of the aircraft. For the purposes of this section, critical phases of flight include all ground operations involving taxi, takeoff and landing, and all other flight operations below 10,000 feet, except cruise flight." [The FSF ALAR Task Force says that "10,000 feet" should be height above ground level during flight operations over high terrain.]

5. The FSF ALAR Task Force defines *approach gate* as "a point in space (1,000 feet above airport elevation in instrument meteorological conditions or 500 feet above airport elevation in visual meteorological conditions) at which a go-around is required if the aircraft does not meet defined stabilized approach criteria."

Related Reading from FSF Publications

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FSF Editorial Staff. "Learjet Strikes Terrain When Crew Tracks False Glideslope Indication and Continues Descent Below Published Decision Height." *Accident Prevention* Volume 56 (June 1999).

FSF Editorial Staff. "Boeing 767 Descends Below Glide Path, Strikes Tail on Landing." *Accident Prevention* Volume 55 (February 1998).

FSF Editorial Staff. "MD-88 Strikes Approach Light Structure in Nonfatal Accident." *Accident Prevention* Volume 54 (December 1997).

FSF Editorial Staff. "During Nonprecision Approach at Night, MD-83 Descends Below Minimum Descent Altitude and Contacts Trees, Resulting in Engine Flame-out and Touchdown Short of Runway." *Accident Prevention* Volume 54 (April 1997).

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FSF Editorial Staff. "Captain's Inadequate Use of Flight Controls During Single-engine Approach and Go-around Results in Loss of Control and Crash of Commuter." *Accident Prevention* Volume 52 (November 1995).

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Lawton, Russell. "Steep Turn by Captain During Approach Results in Stall and Crash of DC-8 Freighter." *Accident Prevention* Volume 51 (October 1994).

Lawton, Russell. "Breakdown in Coordination by Commuter Crew During Unstabilized Approach Results in Controlled-flight-into-terrain Accident." *Accident Prevention* Volume 51 (September 1994).

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Regulatory Resources

International Civil Aviation Organization (ICAO). *International Standards and Recommended Practices, Annex 6 to the Convention of International Civil Aviation, Operation of Aircraft.* Part I, *International Commercial Air Transport – Aeroplanes*. Appendix 2, "Contents of an Operations Manual," 5.18, 5.19. Seventh edition – July 1998, incorporating Amendments 1–25.

ICAO. *Preparation of an Operations Manual*. Second edition – 1997.

U.S. Federal Aviation Administration. *Air Transportation Operations Inspector's Handbook*. Volume 4, "Aircraft Equipment and Operational Authorizations." Chapter 2, "All-weather Terminal Area Operations," Section 3, "Factors Affecting All-Weather Terminal Area Operations." August 26, 1998, incorporating changes 1–12.

Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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ALAR

Approach-and-landing Accident Reduction

Tool Kit

FSF ALAR Briefing Note 7.2 — Constant-angle Nonprecision Approach

Planning and conducting a nonprecision approach are challenging tasks that involve:

- Decision making on strategies and options;
- Task-sharing;
- Crew resource management (e.g., crew coordination, cross-check and backup); and,
- Controlled-flight-into-terrain (CFIT) risk awareness (e.g., awareness of the requirement for immediate response to a ground-proximity warning system [GPWS] warning or a terrain awareness and warning system [TAWS][1] warning).

Nonprecision approaches have common features but require approach-specific techniques, depending on the navaids being used or on the strategy being used for:

- Lateral navigation and vertical navigation;
- Descent from the final approach fix (FAF) to the minimum descent altitude/height (MDA[H]); and,
- Decision making before or upon reaching the MDA(H).

Note: The charted MDA(H) is referenced either to the touchdown zone elevation (TDZE) or to the airport elevation, which is the highest point in the landing area. The International Civil Aviation Organization (ICAO) defines MDA(H) as: obstacle clearance altitude/height (OCA[H]) plus 30 feet.[2]

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that CFIT was involved in 37 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997, and that 57 percent of the CFIT accidents and incidents occurred during step-down nonprecision approaches.[3]

The task force recommended expedited implementation worldwide of constant-angle nonprecision approach (CANPA) procedures and training flight crews to properly use such procedures.

Definition

A nonprecision approach is an instrument approach that does not incorporate vertical guidance (i.e., no glideslope).

This discussion will include nonprecision instrument approaches that use the following navaids: nondirectional beacon (NDB), very-high-frequency omnidirectional radio (VOR), localizer (LOC), VOR-DME (distance-measuring equipment), LOC-DME and LOC back course (BC).

Instrument approaches normally include three approach segments:

- Initial approach:

– Beginning at an initial approach fix (IAF) and ending at the intermediate fix (IF), if defined; and,

– With obstacle clearance of 1,000 feet;

- Intermediate approach:

– From the IF to the final approach fix (FAF); and,

– With obstacle clearance of 500 feet; and,

- Final approach:

– From the FAF to the MDA(H), visual descent point (VDP) or missed approach point (MAP); and,

– With obstacle clearance of 250 feet.

During the intermediate approach, the aircraft is configured for the final approach as follows:

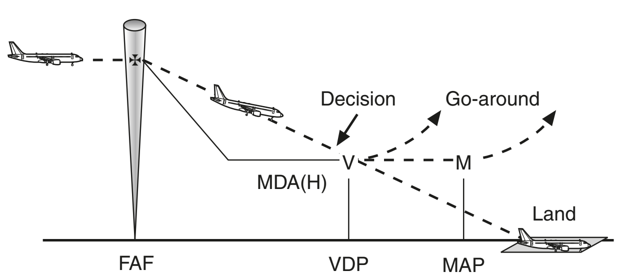
- Configuration established (landing flaps and landing gear extended);
- Airspeed stabilized at the final approach speed;
- Aircraft aligned with the final approach course; and,
- Landing checklist and briefings completed.

The CANPA final approach features *a constant-angle descent* using the vertical-speed mode or the flight-path vector (as available), with altitude-distance checks.

VDP Concept

The VDP is the location at the MDA(H) where the aircraft can be flown on approximately a three-degree glide path to the runway (Figure 1).

Visual Descent Point Provides Normal Descent to Runway



FAF = Final approach fix
MDA(H) = Minimum descent altitude/height
VDP = Visual descent point
MAP = Missed approach point

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 1

The VDP location is defined by:

- Distance from a VOR-DME or LOC-DME; or,
- Time from the FAF.

The VDP should be considered the last point from which a stabilized approach can be conducted (Table 1).

CANPA Benefits

Traditional step-down approaches are based on an *obstacle-clearance profile*; such approaches are not optimum for modern turbine aircraft and turboprop aircraft.

Table 1
Recommended Elements Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met*:

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

Flying a constant-angle approach profile:

- Provides a more stabilized flight path;
- Reduces workload; and,
- Reduces the risk of error.

Strategies and Options

Planning for a nonprecision approach requires several decisions on the following strategies and options:

- Lateral navigation:
  - Use of selected modes (heading or localizer); or,
  - Use of the flight management system (FMS) lateral-navigation (LNAV) mode down to MDA(H) or until LOC interception;
- Vertical navigation:
  - Use of selected modes (altitude hold and vertical speed); or,
  - Use of the FMS vertical-navigation (VNAV) mode down to the FAF (or beyond, as applicable in accordance with the aircraft operating manual [AOM]/quick reference handbook [QRH]), and use of the vertical-speed mode down to the MDA(H); and,
- Final descent from the FAF:
  - Constant-angle descent with the decision made before or upon reaching MDA(H).

    The requirement to make the final-descent decision before or upon reaching the MDA(H) depends upon applicable operating regulations about descent below the MDA(H) during a go-around maneuver. The CANPA MDA(H) may be considered a DA(H) only if the approach has been surveyed and approved by the appropriate regulatory authorities.

A nonprecision approach may be conducted using either:

- Lateral-navigation guidance, with monitoring of raw data[4];
- Raw data only;
- Flight-path director, with or without the autopilot (AP) engaged; or,
- Raw data supported by the flight-path vector (as available on the primary flight display [PFD] or head-up display [HUD]).

A nonprecision approach may be conducted with the AP engaged.

The autothrottle system should remain in the "speed" mode.

CFIT Awareness

During the final descent to the MDA(H), both pilots must monitor the flight path to ensure that descent is not continued through a charted step-down altitude before reaching the associated charted fix (DME distance or other reference).

A GPWS/TAWS warning in instrument meteorological conditions (IMC) or night conditions demands an immediate pull-up maneuver.

Descending Below MDA(H)

During a nonprecision approach, the pilot flying (PF) is either hand-flying the aircraft or supervising AP operation; the pilot not flying (PNF) is responsible for acquiring and calling out the visual references.

Continuing the approach below the MDA(H) is permitted only if at least one of the required visual references is distinctly visible and identifiable by the PF.

A nonprecision approach is completed visually with a hand-flown landing, or a go-around is conducted.

SOPs and Standard Calls

Task-sharing, standard calls and altitude-deviation and parameter-deviation calls are especially important during a nonprecision approach.

The following overview outlines the actions and standard calls required by standard operating procedures (SOPs) and illustrates the typical phases of the approach and the sequence of decisions involved in a nonprecision approach.

Descent/Approach Preparation

- Anticipate and confirm the runway in use and the type of approach to be conducted;
- Define the approach strategy for lateral navigation:
  - Select heading mode and raw data (or VOR mode, if allowed for navigation in terminal areas); or,
  - Select FMS LNAV mode with monitoring of raw data, provided that the approach is defined in the FMS navigation database and that FMS navigation accuracy meets the criteria for approach;
- Define the approach strategy for vertical navigation:
  - Vertical-speed mode; or,
  - FMS VNAV mode down to the FAF (or beyond, as applicable, in accordance with the AOM/QRH), then vertical-speed mode down to the MDA(H);

- Insert the desired standard terminal arrival (STAR) and approach (from the database) in the FMS flight plan;
- Enter the descent winds and surface winds on the appropriate FMS page, as applicable;
- Enter the landing configuration and wind correction on the appropriate FMS page, as applicable;
- If the VNAV mode is authorized after the FAF, enter the MDA(H) on the appropriate FMS page, as applicable;
- Set up navaids (identify, as required); and,
- Plan the descent to reach the IAF at the prescribed altitude and planned airspeed.

Approach Briefing

- Check FMS navigation accuracy (usually by ensuring that the FMS bearing/distance to a tuned VOR-DME and the radio magnetic indicator [RMI] raw data agree according to criteria defined in SOPs) and confirm strategies for lateral navigation and vertical navigation (i.e., FMS or selected guidance);
- Review terrain features, location of obstacles and obstacle clearances;
- Confirm the minimum safe altitude (MSA);
- Review the approach procedure (altitudes, bearings and headings);
- Review the approach vertical profile (step-down altitudes) and MDA(H);
- Set and check the MDA(H) on the barometric-altimeter bug;
- Review the expected visual references (approach lighting and runway lighting);
- Review the missed approach procedure;
- Confirm the timing from the FAF to the MAP or to the VDP, or confirm the DME reading for the VDP;
- Confirm the navaids (frequencies, courses and identifications);
- Compute the expected groundspeed;
- Confirm the published vertical speed or computed vertical speed for the final descent; and,
- Confirm use of the flight director (FD) or the flight-path director (as applicable).

Before Reaching the IAF/Holding Fix

- Keep the AP engaged with FMS or selected lateral-navigation mode and vertical-navigation mode, as desired;
- Keep both navigation displays (NDs) in "MAP" mode (unless FMS navigation accuracy is greater than one nautical mile [nm], or per applicable SOPs);
- If the FMS LNAV mode is used:
  – Check the FMS navigation accuracy level (e.g., "R/I" or "HIGH" or […], depending on the FMS type and standard);
  – Check the NDs for correct flight plan and for correct "TO WPT";
  – Confirm that the FMS LNAV mode is shown on the flight-mode annunciator (FMA); and,
  – Maintain both NDs in "MAP" mode (in accordance with the AOM/QRH);
- Adjust the descent rate to reach the IAF at the charted/prescribed altitude and target airspeed;
- Establish the desired configuration (clean or slats extended) and airspeed; and,
- Adjust weather radar gain and tilt, as applicable, for optimum use of the system for weather avoidance or enhanced horizontal situational awareness.

Upon Reaching the IAF or Holding Fix

- If the FMS LNAV mode will be used beyond the IAF or holding fix, keep both NDs in "MAP" mode if the FMS is certified as "sole means of navigation for approach" — otherwise, one ND must be used to monitor raw data;
- If selected heading mode or localizer mode will be used to capture and to track the final approach course, set the PF's ND to the arc or horizontal situation indicator (HSI)-type display; and,
- The PNF may keep the ND in "MAP" mode (with display of airspeed and altitude restrictions) for situational awareness.

While Holding or When Appropriate

Configure the aircraft (slats extended only or approach flaps) and establish the associated maneuvering speed.

Exiting the Holding Pattern

Select the holding "EXIT" prompt to allow the correct sequencing of the FMS flight plan.

After Leaving the Holding Pattern

- If the FMS LNAV mode is not used, use the selected heading mode (or the VOR mode, if allowed for terminal area navigation; or the track mode, as available) to intercept the final approach course, as follows:

– For an NDB approach, set the final approach course on the ILS course selector; this will set the ILS course pointer on the ND and provide a course reference;

– For a VOR or VOR-DME approach, set the final approach course on the VOR course selector, but do not arm the VOR mode. Capture and track the VOR course using the selected heading/track mode; or,

– For a LOC or LOC-DME approach, set the final approach course on the ILS course selector and arm the localizer mode; and,

- To prepare for re-engaging the LNAV mode for a go-around, check the correct FMS flight plan sequencing (the "TO WPT" must be the FAF; if not, program a "DIR TO" the FAF).

Before Reaching the FAF

- Align the aircraft within five degrees of the final approach course;
- Extend the landing gear;
- Arm the ground spoilers;
- Set landing flaps;
- Enter the target final approach speed;
- Set the go-around altitude (if the go-around altitude is the same as the FAF crossing altitude, set the go-around altitude only after beginning the final descent);
- Conduct the "LANDING" checklist;
- If the FMS VNAV mode will be used after the FAF, enter the published or computed vertical speed and course;
- If the flight-path vector will be used after the FAF (as available on the PFD or HUD), enter the published or computed flight-path angle and track; and,
- If the VNAV mode is not authorized beyond the FAF, deselect the VNAV mode by selecting the altitude-hold mode or the vertical-speed mode, as required.

Approaching the FAF

Typically 0.3 nautical mile (nm) to 0.2 nm before reaching the FAF, to begin descent at the FAF on profile:

- Engage the VNAV mode and check mode engagement on the FMA;
- Enter the published (or computed) vertical speed, as a function of the groundspeed;
- Select the flight-path vector display (as available);
- Start timing (as required); and,
- Cross-check and call the next fix (or DME distance, as applicable) and crossing altitude.

During the Descent to the MDA(H)

- Monitor the raw data (vertical speed, flight-path vector [as available], course, distances, altitudes) and call the vertical profile for correct slope and track (i.e., at each altitude/distance check):

  – Cross-check and call the altitude deviation;

  – Adjust vertical speed, as required; and,

  – Call the next fix (or DME distance) and crossing altitude; and,

- Set the altitude selector per applicable SOPs (usually, the go-around altitude).

Approaching the MDA(H)

At an altitude corresponding to the MDA(H) plus 1/10 the rate of descent (typically MDA[H] plus 50 feet to 100 feet), anticipate a go-around decision to avoid descent below the MDA(H), as required by applicable regulations.

At the MDA(H)

If adequate visual references are acquired:

- Disconnect the AP and continue the approach visually (the autothrottles may remain engaged in speed mode down to the retard point, as applicable).

If adequate visual references are not acquired:

- Initiate a go-around climb; and,
- Overfly the MAP (to guarantee obstacle clearance during the go-around) and fly the published missed approach procedure.

(ICAO says that although the flight crew should overfly the MAP before conducting the published missed approach procedure, "this does not preclude flying over the [MAP] at an altitude/height greater than that required by the procedure" [as shown in Figure 1].) [5]

Nonprecision Approach Factors

Training feedback and line-operations experience have shown that the nonprecision approach is affected by:

- Incorrect or outdated instrument approach chart;
- Late descent preparation;
- FMS navigation accuracy not checked;
- FMS flight plan not correctly programmed;
- Failure to monitor raw data;
- Navaids not tuned correctly (frequency or course);
- Incomplete briefing;

- Incorrect choice of autopilot modes;
- Incorrect entry of autopilot targets (e.g., airspeed, heading, altitude) or autothrottle targets;
- Inadequate cross-check and backup by the PF/PNF;
- Inaccurate tracking of the final approach course, using the selected heading (or track) mode;
- Late configuration of aircraft;
- Final approach speed not stabilized at FAF;
- Failure to include prevailing head-wind component in computing the vertical speed for the final constant-angle descent;
- No timing or positive identification of the VDP or MAP;
- Inadequate monitoring of raw data;
- Incorrect identification of the FAF;
- Go-around altitude not entered; and,
- Premature descent to the next step-down altitude (if multiple step-downs) or below the MDA(H).

Summary

Successful nonprecision approaches include:

- Determining the type of guidance to be used;
- Preparing the FMS, as applicable;
- Completing an approach briefing;
- Planning aircraft configuration setup;
- Monitoring descent;
- Managing aircraft energy condition during intermediate approach and final approach;
- Not descending below an altitude before reaching the associated fix;
- Determining the correct angle (vertical speed) for the final descent;
- Beginning the descent at the correct point;
- Maintaining the correct flight-path angle (vertical speed) during the final descent;
- Acquiring visual references and making the decision to land; and,
- Preparing for a go-around.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.4 — Standard Calls*;
- *1.6 — Approach Briefing*;
- *4.2 — Energy Management*;
- *7.1 —Stabilized Approach*; and,
- *7.3 — Visual References.*♦

References

1. Terrain awareness and warning system (TAWS) is the term used by the European Joint Aviation Authorities and the U.S. Federal Aviation Administration to describe equipment meeting International Civil Aviation Organization standards and recommendations for ground-proximity warning system (GPWS) equipment that provides predictive terrain-hazard warnings. “Enhanced GPWS” and “ground collision avoidance system” are other terms used to describe TAWS equipment.
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4. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *raw data* as “data received directly (not via the flight director or flight management computer) from basic navigation aids (e.g., ADF, VOR, DME, barometric altimeter).”
5. ICAO. *Manual of All-Weather Operations*. Second edition – 1991.

Related Reading from FSF Publications

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FSF Editorial Staff. “During Nonprecision Approach at Night, MD-83 Descends Below Minimum Descent Altitude and Contacts Trees, Resulting in Engine Flame-out and Touchdown Short of Runway.” *Accident Prevention* Volume 54 (April 1997).

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Lawton, Russell. "Breakdown in Coordination by Commuter Crew During Unstabilized Approach Results in Controlled-flight-into-terrain Accident." *Accident Prevention* Volume 51 (September 1994).

Regulatory Resource

U.S. Federal Aviation Administration. Special Notice to Airmen AFS-420 (11/26/99).

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FSF ALAR Briefing Note 7.3 — Visual References

The transition from instrument references to external visual references is an important element of any type of instrument approach.

Some variations exist in company operating philosophies about flight crew task-sharing for:

- Acquiring visual references;
- Conducting the landing; and,
- Conducting the go-around.

For task-sharing during approach, two operating philosophies are common:

- Pilot flying-pilot not flying (PF-PNF) task-sharing with differences about the acquisition of visual references, depending on the type of approach and on the use of automation:
  - Nonprecision and Category (CAT) I instrument landing system (ILS) approaches; or,
  - CAT II/CAT III ILS approaches (the captain usually is the PF, and only an automatic approach and landing is considered); and,
- Captain-first officer (CAPT-FO) task-sharing, which usually is referred to as a *shared approach*, *monitored approach* or *delegated-handling approach*.

Differences in the philosophies include:

- The transition to flying by visual references; and,
- Using and monitoring the autopilot.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that flight crew omission of action/inappropriate action was a causal factor[1] in 25 percent of 287 fatal approach-and-landing accidents worldwide in 1980 through 1996 involving jet aircraft and turboprop aircraft with maximum takeoff weights above 12,500 pounds/5,700 kilograms.[2] The task force said that these accidents typically involved the following errors:

- Descending below the minimum descent altitude/height (MDA[H]) or decision altitude/height (DA[H]) without adequate visual references or having acquired incorrect visual references (e.g., a lighted area in the airport vicinity, a taxiway or another runway); and,
- Continuing the approach after the loss of visual references (e.g., because of a fast-moving rain shower or fog patch).

Altitude-deviation and Terrain Avoidance

During the final-approach segment, the primary attention of both pilots should be directed to published minimum approach altitudes and altitude-distance checks prior to reaching the MDA(H) or DA(H).

An immediate pull-up is required in response to a ground-proximity warning system (GPWS) warning or a terrain awareness and warning system (TAWS)[3] warning in instrument meteorological conditions (IMC) or at night.

Definition

Whenever a low-visibility approach is anticipated, the approach briefing must include a thorough review of the approach light system (ALS) by using the instrument approach chart and the airport chart.

Depending on the type of approach and prevailing ceiling and visibility conditions, the crew should discuss the lighting system(s) expected to be observed upon first visual contact.

For example, U.S. Federal Aviation Regulations (FARs) Part 91.175 says that at least one of the following references must be distinctly visible and identifiable before the pilot descends below DA(H) on a CAT I ILS approach or MDA(H) on a nonprecision approach:

- "The approach light system, except that the pilot may not descend below 100 feet above the touchdown zone elevation using the approach lights as a reference unless the red terminating bars or the red side-row bars are also distinctly visible and identifiable;
- "The [runway] threshold;
- "The threshold markings;
- "The threshold lights;
- "The runway end identifier lights;
- "The visual approach slope indicator;
- "The touchdown zone or touchdown zone markings;
- "The touchdown zone lights;
- "The runway or runway markings; [or,]
- "The runway lights."

The International Civil Aviation Organization says that *required visual reference* "means that section of the visual aids or of the approach area which should have been in view for sufficient time for the pilot to have made an assessment of the aircraft position and rate of change of position in relation to the desired flight path."

When using external references, the visual references must be adequate for the pilot to assess horizontal flight path and vertical flight path.

After adequate visual references have been acquired to allow descent below the MDA(H) or DA(H), the different elements of the various ALSs provide references for position, drift angle, distance and rates of change for the final phase of the approach.

Visual References

The task-sharing for the acquisition of visual references and for the monitoring of the flight path and aircraft systems varies, depending on:

- The type of approach; and,
- The level of automation being used:
  - Hand-flying (using the flight director [FD]); or,
  - Autopilot (AP) monitoring (single or dual AP).

Nonprecision and CAT I ILS Approaches

Nonprecision approaches and CAT I ILS approaches can be flown by hand with reference to raw data[4] or to the FD commands, or with the AP engaged.

The PF is engaged directly in either:

- Hand-flying the airplane, by actively following the FD commands and monitoring the raw data; or,
- Supervising AP operation and being ready to take manual control of the aircraft, if required.

The PNF is responsible for progressively acquiring and calling the visual references while monitoring flight progress and backing up the PF.

The PNF scans alternately inside and outside, calls flight-parameter deviations and calls:

- "One hundred above" then "minimum" (if no automatic call) if adequate visual references are not acquired; or,
- "Visual" (or whatever visual reference is in sight) if adequate visual references are acquired.

  The PNF should not lean forward while attempting to acquire visual references. If the PNF calls "visual" while leaning forward, the PF might not acquire the visual reference because his/her viewing angle will be different.

The PF then confirms the acquisition of visual references and calls "landing" (or "go around" if visual references are not adequate).

If "landing" is called, the PF progressively transitions from instrument references to external visual references.

CAT II/CAT III ILS Approaches

CAT II/CAT III ILS approaches are flown using the automatic landing system (as applicable for the aircraft type).

CAT II automatic approaches can be completed with a hand-flown landing (although the standard operating procedure is to use the automatic landing capability).

In CAT III weather conditions, automatic landing is mandatory usually.

Consequently, *visual reference* does not have the same meaning for CAT II and CAT III approaches.

For CAT II approaches, visual reference means *being able to see to land* (i.e., being able to conduct a hand-flown landing).

For CAT III approaches, visual references means *being able to see to verify aircraft position*.

FARs Part 91.189 and Joint Aviation Requirements–Operations 1.430 consider these meanings in specifying minimum visual references that must be available at the DA(H).

For a CAT III approach with no DA(H), no visual reference is specified, but recommended practice is for the PF to look for visual references before touchdown, because visual references are useful for monitoring AP guidance during the roll-out phase.

During an automatic approach and landing, the flight path is monitored by the AP (autoland warning) and supervised by the PNF (excessive-deviation calls).

Thus, the PF can concentrate his or her attention on the acquisition of visual references, progressively increasing external scanning as the DH is approached.

When an approach is conducted near minimums, the time available for making the transition from instrument references to visual references is extremely short; the PF therefore must concentrate on the acquisition of visual references.

The PNF maintains instrument references throughout the approach and landing (or go-around) to monitor the flight path and the instruments, and to be ready to call any flight-parameter excessive deviation or warning.

Shared Approach/Monitored Approach/ Delegated-handling Approach

Shared approach/monitored approach/delegated-handling approach provides an alternative definition of the PF and PNF functions, based on CAPT-FO task-sharing.

This operating policy can be summarized as follows:

- Regardless of who was the PF for the sector, the FO is always the PF for the approach;
- The CAPT is PNF and monitors the approach and the acquisition of visual references;
- Before or upon reaching the DA(H), depending on the company's policy:
  - If visual references are acquired, the CAPT calls "landing," takes over the controls and lands; or,
  - If visual references are not acquired, the CAPT calls "go-around," and the FO initiates the go-around and flies the missed approach.

Whatever the decision, landing or go-around, the FO maintains instrument references for the complete approach and landing (or go-around and missed approach).

Depending on the FO's experience, the above roles can be reversed.

This operating policy minimizes the problem of transitioning from instrument flying to visual flying and, in a go-around, the problem of resuming instrument flying. Nevertheless, this operating policy involves a change of controls (i.e., PF/PNF change) and requires the development of appropriate SOPs and standard calls.

Depending on the company's operating philosophy, this technique is applicable to:

- CAT II/CAT III approaches only (for all other approaches, the PF is also the pilot landing); or,
- All types of approaches (except automatic landings where the CAPT resumes control earlier, typically from 1,000 feet radio altitude to 200 feet radio altitude).

Implementation

Implementation of the shared approach/monitored approach/ delegated-handling approach requires the development of corresponding standard operating procedures (SOPs) and standard calls.

Of particular importance is that the sequence of planned actions or conditional actions and calls must be briefed accurately during the approach briefing.

Such actions and calls usually include the following:

For the CAPT:

- If adequate visual references are acquired before or at DA(H):
  - Call "landing"; and,
  - Take over flight controls and thrust levers, and call "I have control" or "my controls," per company SOPs;
- If adequate visual references are not acquired at DA(H):
  - Call "go-around," cross-check and back up the FO during the go-around initiation and missed approach.

For the FO:

- If CAPT calls "landing, I have controls" or "landing, my controls":
  - Call "you have control" or "your controls," per company SOPs; and,

– Continue monitoring instrument references;

- If CAPT calls "go-around":
  – *Initiate immediately the go-around and fly the missed approach*;
- If CAPT does not make any call or does not take over the flight controls and throttle levers (e.g., because of subtle incapacitation):
  – *Call "go-around" and initiate immediately the go-around*.

Standard Calls

The importance of task-sharing and standard calls during the final portion of the approach cannot be overemphasized.

Standard calls for confirming the acquisition of visual references vary from company to company.

"Visual" or [acquired visual reference (e.g., "runway in sight")] usually is called if adequate visual references are acquired and the aircraft is correctly aligned and on the approach glide path; otherwise, the call "visual" or "[acquired visual reference]" is followed by an assessment of the lateral deviation or vertical deviation (offset).

The CAPT determines whether the lateral deviation or vertical deviation can be corrected safely and calls "continue" (or "landing") or "go-around."

Recovery From a Deviation

Recovering from a lateral deviation or vertical deviation when transitioning to visual references requires careful control of the pitch attitude, bank angle and power with reference to raw data to help prevent crew disorientation by visual illusions.

The PNF is responsible for monitoring the instruments and for calling any excessive deviation.

Vertical Deviation

A high sink rate with low thrust when too high may result in a hard landing or in a landing short of the runway.

The crew should establish the correct flight path, not exceeding the maximum permissible sink rate (usually 1,000 feet per minute).

A shallow approach with high thrust when too low may result in an extended flare and a long landing.

The crew should establish level flight until the correct flight path is established.

Lateral Deviation

Establish an aiming point on the extended runway centerline, approximately half the distance to the touchdown point, and aim toward the point while maintaining the correct flight path, airspeed and thrust setting.

To avoid overshooting the runway centerline, anticipate the alignment by beginning the final turn shortly before crossing the extended runway-inner-edge line.

Loss of Visual References Below MDA(H) or DA(H)

If loss of adequate visual references occurs below the MDA(H) or DA(H), a go-around must be initiated immediately.

For example, FARs Part 91.189 requires that "each pilot operating an aircraft shall immediately execute an appropriate missed approach whenever [the conditions for operating below the authorized DA(H)] are not met."

Summary

- During nonprecision approaches and CAT I ILS approaches, ensure that both the PF and PNF have acquired the same — and the correct — visual references; and,
- During CAT II/CAT III ILS approaches and during all shared/monitored/delegated-handling approaches, the FO must remain head-down, monitoring flight instruments, for approach and landing or go-around.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.2 — Automation*;
- *1.4 — Standard Calls*; and,
- *5.3 — Visual Illusions.*♦

References

1. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident." Each accident in the study sample involved several causal factors.

2. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts

presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

3. Terrain awareness and warning system (TAWS) is the term used by the European Joint Aviation Authorities and the U.S. Federal Aviation Administration to describe equipment meeting International Civil Aviation Organization standards and recommendations for ground-proximity warning system (GPWS) equipment that provides predictive terrain-hazard warnings. "Enhanced GPWS" and "ground collision avoidance system" are other terms used to describe TAWS equipment.

4. The FSF ALAR Task Force defines *raw data* as "data received directly (not via the flight director or flight management computer) from basic navigation aids (e.g., ADF, VOR, DME, barometric altimeter)."

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JAA. *Joint Aviation Requirements – All Weather Operations*. August 1, 1996.

Notice

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The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

Flight Safety Foundation

ALAR

Approach-and-landing Accident Reduction

Tool Kit

FSF ALAR Briefing Note 7.4 — Visual Approaches

Accepting an air traffic control (ATC) clearance for a visual approach or requesting a visual approach should be balanced carefully against the following:

- Ceiling and visibility conditions;
- Darkness;
- Weather:
  - Wind, turbulence;
  - Rain or snow; and/or,
  - Fog or smoke;
- Crew experience with airport and airport environment:
  - Surrounding terrain; and/or,
  - Specific airport and runway hazards (obstructions, etc.); and,
- Runway visual aids:
  - Type of approach light system (ALS); and,
  - Availability of visual approach slope indicator (VASI) or precision approach path indicator (PAPI).

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that visual approaches were being conducted in 41 percent of 118 fatal approach-and-landing accidents worldwide in 1980 through 1996 involving jet aircraft and turboprop aircraft with maximum takeoff weights above 12,500 pounds/5,700 kilograms, and in which the type of approach being conducted was known.[1]

Definition

Although slightly different definitions are provided by the International Civil Aviation Organization (ICAO), the European Joint Aviation Authorities and the U.S. Federal Aviation Administration (FAA), the following definition, from the FAA *Aeronautical Information Manual*, will be used in this discussion:

- "[A visual approach is] an approach conducted on an instrument flight rules (IFR) flight plan which authorizes the pilot to proceed visually and clear of clouds to the airport;
- "The pilot must, at all times, have either the airport or the preceding aircraft in sight;
- "[The visual] approach must be authorized and under the control of the appropriate air traffic control facility; [and],
- "Reported weather at the airport must be ceiling at or above 1,000 feet and visibility three miles or greater."

Visual Approach at Night

During a visual approach at night, fewer visual references are usable, and visual illusions and spatial disorientation occur more frequently.

Visual illusions (such as the "black-hole effect"[2]) affect the flight crew's vertical situational awareness and horizontal situational awareness, particularly on the base leg and when turning final.

A visual approach at night should be considered only if:

- Weather is suitable for flight under visual flight rules (VFR);
- A close-in pattern is used (or a published visual approach is available);
- A pattern altitude is defined; and,
- The flight crew is familiar with airport hazards and obstructions. (This includes the availability of current notices to airmen [NOTAMS].)

At night, whenever an instrument approach is available (particularly an instrument landing system [ILS] approach), an instrument approach should be preferred to a visual approach.

If a precision approach is not available, select an approach supported by VASI or PAPI.

Overview

The following overview provides a description of the various phases and techniques associated with visual approaches.

References

Visual approaches should be conducted with reference to either:

- A published visual approach chart for the intended runway; or,
- The visual approach procedure (altitude, aircraft configuration and airspeed) published in the aircraft operating manual (AOM)/quick reference handbook (QRH) or the pattern published in the AOM/QRH

Terrain Awareness

When selecting or accepting a visual approach, the flight crew should be aware of the surrounding terrain and man-made obstacles.

For example, at night, with an unlighted hillside between a lighted area and the runway, the flight crew may not see the rising terrain.

Objective

The objective of a visual approach is to conduct an approach:

- Using visual references; and,
- Being stabilized by 500 feet above airport elevation according to company standard operating procedures (SOPs). (See Table 1.)

If the aircraft is not stabilized by 500 feet above airport elevation or if the approach becomes unstabilized below 500 feet above airport elevation, go around.

Table 1
Recommended Elements
Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met*:

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

Automated Systems

Automated systems (autopilot, flight director, autothrottles) should be adapted to the type of visual approach (i.e., visual approach chart or AOM/QRH visual approach procedure/pattern) and to the ATC environment (radar vectors or crew navigation).

During the final phase of the approach, the crew should disconnect the autopilot, clear the flight director command bars, maintain the autothrottles in speed mode and select the flight-path vector symbol (as available on the primary flight display [PFD] or head-up display [HUD]).

Initial/Intermediate Approach

The flight management system (FMS) may be used to build the teardrop outbound leg or the downwind leg, for enhanced situational awareness. This should be done when programming the FMS before reaching the top-of-descent point.

As applicable, set navaids for the instrument approach associated with the landing runway (for monitoring and in case of loss of visual references).

Review the primary elements of the visual approach and the primary elements of the associated instrument approach.

Review the appropriate missed approach procedure.

Extend slats and fly at the corresponding maneuvering speed.

Barometric-altimeter and radio-altimeter bugs may be set (per company SOPs) for enhanced terrain awareness.

Outbound/Downwind Leg

To be aligned on the final approach course and stabilized at 500 feet above airport elevation, the crew should intercept typically the final approach course at *three nautical miles from the runway threshold* (time the outbound leg or downwind leg accordingly, as a function of the prevailing airspeed and wind component).

Maintain typically 1,500 feet above airport elevation (or the charted altitude) until beginning the final descent or turning base leg.

Configure the aircraft per SOPs, typically turning base leg with approach flaps, landing gear extended and ground spoilers armed.

Do not exceed a 30-degree bank angle when turning onto base leg.

Base Leg

Resist the tendency to fly a continuous closing-in turn toward the runway threshold.

Before turning final (depending on the distance from the runway threshold), extend landing flaps and begin reducing to the target final approach speed.

Estimate the glide-path angle to the runway threshold based on available visual references (e.g., VASI) or raw data[3] (ILS glideslope or altitude/distance). (Glideslope indications and VASI indications are reliable only within 30 degrees of the final approach course.)

Do not exceed a 30-degree bank angle when tuning final.

Anticipate the crosswind effect (as applicable) to complete the turn correctly established on the extended runway centerline with the required drift correction.

Final Approach

Plan to be aligned with the runway (wings level) and stabilized at the final approach speed by 500 feet above airport elevation.

Monitor groundspeed variations (for wind shear awareness) and call altitudes and excessive flight-parameter deviations as for instrument approaches.

Maintain visual scanning toward the aiming point (typically 1,000 feet from the runway threshold) to avoid any tendency to inadvertently descend below the final approach path (use raw data or the VASI/PAPI, as available, for a cross-check).

Visual Approach Factors

The following factors often are cited when discussing unstabilized visual approaches:

- Pressure of flight schedule (making up for delays);
- Crew-induced circumstances or ATC-induced circumstances resulting in insufficient time to plan, prepare and conduct a safe approach;
- Excessive altitude or excessive airspeed (e.g., inadequate energy management) early in the approach;
- Downwind leg too short (visual pattern) or interception too close (direct base-leg interception);
- Inadequate awareness of tail-wind component and/or crosswind component;
- Incorrect anticipation of aircraft deceleration characteristics in level flight or on a three-degree glide path;
- Failure to recognize deviations or failure to adhere to excessive-parameter-deviation criteria;
- Belief that the aircraft will be stabilized at the minimum stabilization height or shortly thereafter;
- Excessive confidence by the pilot not flying (PNF) that the pilot flying (PF) will achieve a timely stabilization, or reluctance by the PNF to challenge the PF;
- PF/PNF too reliant on each other to call excessive deviations or to call for a go-around;
- Visual illusions;
- Inadvertent modification of the aircraft trajectory to maintain a constant view of visual references; and,
- Loss of ground visual references, airport visual references or runway visual references, with the PF and the PNF both looking outside to reacquire visual references.

Unstabilized Visual Approaches

The following deviations are typical of unstabilized visual approaches:

- Steep approach (high and fast, with excessive rate of descent);
- Shallow approach (below desired glide path);
- Ground-proximity warning system (GPWS)/terrain awareness warning system (TAWS)[4] activation:
  - Mode 1: "sink rate";
  - Mode 2A: "terrain" (less than full flaps);
  - Mode 2B: "terrain" (full flaps);
- Final-approach-course interception too close to the runway threshold because of an inadequate outbound teardrop leg or downwind leg;
- Laterally unstabilized final approach because of failure to correct for crosswind;
- Excessive bank angle and maneuvering to capture the extended runway centerline or to conduct a side-step maneuver;
- Unstabilized approach with late go-around decision or no go-around decision; and,
- Inadvertent descent below the three-degree glide path.

Summary

The following should be discussed and understood for safe visual approaches:

- Weighing the time saved against the risk;
- Awareness of all weather factors;
- Awareness of surrounding terrain and obstacles;
- Awareness of airport environment, airport and runway hazards;
- Use of a visual approach chart or AOM/QRH procedures/ pattern;
- Tuning and monitoring all available navaids;
- Optimizing use of automation with timely reversion to hand-flying;
- Adhering to defined PF/PNF task-sharing (monitoring by PNF of head-down references [i.e., instrument references] while PF flies and looks outside);
- Maintaining visual contact with the runway and other traffic at all times; and,
- Announcing altitudes and excessive flight-parameter deviations, and adhering to the go-around policy for instrument approaches.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.2 — Automation*;
- *1.3 — Golden Rules*;
- *1.4 — Standard Calls*;
- *1.5 — Normal Checklists*;
- *1.6 — Approach Briefing*;
- *3.1 — Barometric Altimeter and Radio Altimeter*;
- *4.2 — Energy Management*;
- *5.2 — Terrain*;
- *5.3 — Visual Illusions*; and,
- *7.1 — Stabilized Approach.*♦

References

1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

2. The *black-hole effect* typically occurs during a visual approach conducted on a moonless or overcast night, over water or over dark, featureless terrain where the only visual stimuli are lights on and/or near the airport. The absence of visual references in the pilot's near vision affect depth perception and cause the illusion that the airport is closer than it actually is and, thus, that the aircraft is too high. The pilot may respond to this illusion by conducting an approach below the correct flight path (i.e., a low approach).

3. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *raw data* as "data received directly (not via the flight director or flight management computer) from basic navigation aids (e.g., ADF, VOR, DME, barometric altimeter)."

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Flight Safety Foundation

ALAR

Approach-and-landing Accident Reduction

Tool Kit

FSF ALAR Briefing Note 8.1 — Runway Excursions And Runway Overruns

Runway excursions occur when:

- Aircraft veer off the runway during the landing roll; and,
- Aircraft veer off the runway or taxiway when exiting the runway.

Runway overruns occur when the aircraft roll-out extends beyond the end of the landing runway.

Runway excursions and runway overruns can occur after any type of approach in any light condition or environmental condition.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that runway excursions and runway overruns were involved in 20 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[1]

Factors Involved in Runway Excursions

Runway excursions are usually the result of one or more of the following factors:

Weather Factors

- Runway condition (wet or contaminated by standing water, snow, slush or ice);
- Wind shear;
- Crosswind;
- Inaccurate information on wind conditions and/or runway conditions; and,
- Reverse-thrust effect in a crosswind and on a wet runway or a contaminated runway.

Crew Technique/Decision Factors

- Incorrect crosswind landing technique (e.g., drifting during the transition from a wings-level crosswind approach [“crabbed” approach] to a steady-sideslip crosswind approach, or failing to transition from a wings-level approach to a steady-sideslip approach [“decrab”] when landing in strong crosswind conditions);
- Inappropriate differential braking by the crew;
- Use of the nosewheel-steering tiller at airspeeds that are too fast; and,
- Airspeed too fast on the runway to exit safely.

Systems Factors

- Asymmetric thrust (i.e., forward thrust on one side, reverse thrust on the opposite side); or,
- Uncommanded differential braking.

Factors Involved in Runway Overruns

Runway overruns are usually the result of one or more of the following factors:

Weather Factors

- Unanticipated runway condition (i.e., worse than anticipated);

- Inaccurate surface wind information; and,
- Unanticipated wind shear or tail wind.

Performance Factors

- Incorrect assessment of landing distance following a malfunction or minimum equipment list (MEL)/dispatch deviation guide (DDG) condition affecting aircraft configuration or braking capability; and,
- Incorrect assessment of landing distance for prevailing wind and runway conditions.

Crew Technique/Decision Factors

- Unstable approach path (steep and fast):
  - Landing fast; and,
  - Excessive height over threshold, resulting in landing long;
- No go-around decision when warranted;
- Decision by captain (pilot not flying) to land, countermanding first officer's decision to go around;
- Extended flare (allowing the aircraft to float and to decelerate [bleed excess airspeed] in the air uses typically three times more runway than decelerating on the ground);
- Failure to arm ground spoilers (usually associated with thrust reversers being inoperative);
- Power-on touchdown (i.e., preventing the auto-extension of ground spoilers, as applicable);
- Failure to detect nondeployment of ground spoilers (e.g., absence of related standard call);
- Bouncing and incorrect bounce recovery;
- Late braking (or late takeover from autobrake system, if required); and,
- Increased landing distance resulting from the use of differential braking or the discontinued use of reverse thrust to maintain directional control in crosswind conditions.

Systems Factors

- Loss of pedal braking;
- Anti-skid system malfunction; or,
- Hydroplaning.

Accident-prevention Strategies and Lines of Defense

The following company accident-prevention strategies and personal lines of defense are recommended:

Policies

- Define policy to promote readiness and commitment to go around (discouraging any attempt to "rescue" a situation that is likely to result in a hazardous landing);
- Define policy to ensure that inoperative brakes ("cold brakes") are reported in the aircraft logbook and that they receive attention in accordance with the MEL/DDG;
- Define policy for a rejected landing (bounce recovery);
- Define policy prohibiting landing beyond the touchdown zone; and,
- Define policy encouraging a firm touchdown when operating on a contaminated runway.

Standard Operating Procedures (SOPs)

- Define criteria and standard calls for a stabilized approach, and define minimum stabilization heights in SOPs (Table 1, page 161);
- Define task-sharing and standard calls for final approach and roll-out phases in SOPs; and,
- Incorporate in SOPs a standard call for "… [feet or meters] runway remaining" or "… [feet or meters] to go" in low-visibility conditions, based on:
  - Runway-lighting color change;
  - Runway-distance-to-go markers (as available); or,
  - Other available visual references (such as runway/taxiway intersections).

Performance Data

- Publish data and define procedures for adverse runway conditions; and,
- Provide flight crews with specific landing-distance data for runways with a downhill slope/high elevation.

Procedures

- Publish SOPs and provide training for crosswind-landing techniques;
- Publish SOPs and provide training for flare techniques;
- Publish SOPs for the optimum use of autobrakes and thrust reversers on contaminated runways;
- Provide recommendations for the use of rudder and differential braking/nosewheel steering for directional control, depending on airspeed and runway condition; and,
- Publish specific recommendations for aircraft lateral control and directional control after a crosswind landing.

Crew Awareness

- Ensure flight crew awareness and understanding of all factors affecting landing distances;
- Ensure flight crew awareness and understanding of conditions conducive to hydroplaning;

Table 1
Recommended Elements Of a Stabilized Approach

All flights must be stabilized by 1,000 feet above airport elevation in instrument meteorological conditions (IMC) and by 500 feet above airport elevation in visual meteorological conditions (VMC). *An approach is stabilized when all of the following criteria are met:*

1. The aircraft is on the correct flight path;
2. Only small changes in heading/pitch are required to maintain the correct flight path;
3. The aircraft speed is not more than V_{REF} + 20 knots indicated airspeed and not less than V_{REF};
4. The aircraft is in the correct landing configuration;
5. Sink rate is no greater than 1,000 feet per minute; if an approach requires a sink rate greater than 1,000 feet per minute, a special briefing should be conducted;
6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
7. All briefings and checklists have been conducted;
8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 feet above airport elevation; and,
9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

An approach that becomes unstabilized below 1,000 feet above airport elevation in IMC or below 500 feet above airport elevation in VMC requires an immediate go-around.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force (V1.1 November 2000)

- Ensure flight crew awareness and understanding of crosswind and wheel-cornering issues;
- Ensure flight crew awareness of wind shear and develop corresponding procedures (particularly for the monitoring of groundspeed variations during approach);
- Ensure flight crew awareness of the relationships among braking action, friction coefficient and runway-condition index, and maximum crosswind components recommended for runway conditions; and,
- Ensure flight crew awareness of runway lighting changes when approaching the runway end:
  – Standard centerline lighting: white lights changing to alternating red and white lights between 3,000 feet and 1,000 feet from runway end, and to red lights for the last 1,000 feet; and,
  – Runway edge lighting (high-intensity runway light system): white lights changing to yellow lights on the last 2,000 feet of the runway.

Summary

Runway excursions and runway overruns can be categorized into six families of events, depending on their primary causal factor:

- Events resulting from unstabilized approaches;
- Events resulting from incorrect flare technique;
- Events resulting from unanticipated or more-severe-than-expected adverse weather conditions;
- Events resulting from reduced braking or loss of braking;
- Events resulting from an abnormal configuration (e.g., because the aircraft was dispatched under MEL conditions or dispatch deviation guide [DDG] conditions, or because of an in-flight malfunction); and,
- Events resulting from incorrect crew action and coordination, under adverse conditions.

Corresponding company accident-prevention strategies and personal lines of defense can be developed to help prevent runway excursions and runway overruns by:

- Adherence to SOPs;
- Enhanced awareness of environmental factors;
- Enhanced understanding of aircraft performance and handling techniques; and,
- Enhanced alertness for flight-parameter monitoring, deviation calls and crew cross-check.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.1 — Operating Philosophy*;
- *1.4 — Standard Calls*;
- *6.4 — Bounce Recovery — Rejected Landing*;
- *7.1 — Stabilized Approach*;
- *8.2 — The Final Approach Speed*;
- *8.3 — Landing Distances*;
- *8.4 — Braking Devices*;
- *8.5 — Wet or Contaminated Runways*; and,
- *8.7 — Crosswind Landings*.♦

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1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and

Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

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Notice

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The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
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- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

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FSF ALAR Briefing Note 8.2 — The Final Approach Speed

Assuring a safe landing requires achieving a balanced distribution of safety margins between:

- The computed *final approach speed* (also called the *target threshold speed*); and,
- The resulting landing distance.

Statistical Data

Computation of the final approach speed rarely is a factor in runway overrun events, but an approach conducted significantly faster than the computed target final approach speed is cited often as a causal factor.

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that "high-energy" approaches were a causal factor[1] in 30 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[2]

Defining the Final Approach Speed

The final approach speed is the airspeed to be maintained down to 50 feet over the runway threshold.

The final approach speed computation is the result of a decision made by the flight crew to ensure the safest approach and landing for the following:

- Gross weight;
- Wind;
- Flap configuration (when several flap configurations are certified for landing);
- Aircraft systems status (airspeed corrections for abnormal configurations);
- Icing conditions; and,
- Use of autothrottle speed mode or autoland.

The final approach speed is based on the reference landing speed, V_{REF}.

V_{REF} usually is defined by the aircraft operating manual (AOM) and/or the quick reference handbook (QRH) as:

1.3 x stall speed with full landing flaps or with selected landing flaps.

Final approach speed is defined as:

$$V_{REF} + \textit{corrections.}$$

Airspeed corrections are based on operational factors (e.g., wind, wind shear or icing) and on landing configuration (e.g., less than full flaps or abnormal configuration).

The resulting final approach speed provides the best compromise between handling qualities (stall margin or controllability/maneuverability) and landing distance.

Factors Affecting the Final Approach Speed

The following airspeed corrections usually are not cumulative; only the highest airspeed correction should be added to V_{REF} (unless otherwise stated in the AOM/QRH):

- Airspeed correction for wind;
- Airspeed correction for ice accretion;
- Airspeed correction for autothrottle speed mode or autoland; or,
- Airspeed correction for forecast turbulence/wind shear conditions.

Gross Weight

Because V_{REF} is derived from the stall speed, the V_{REF} value depends directly on aircraft gross weight.

The AOM/QRH usually provides V_{REF} values as a function of gross weight in a table or graphical format for normal landings and for overweight landings.

Wind Conditions

The wind correction provides an additional stall margin for airspeed excursions caused by turbulence and wind shear.

Depending on aircraft manufacturers and aircraft models, the wind correction is defined using different methods, such as the following:

- Half of the steady headwind component plus the entire gust value, limited to a maximum value (usually 20 knots);
- One-third of the tower-reported average wind velocity or the gust velocity, whichever is higher, limited to a maximum value (usually 15 knots); or,
- A graphical assessment based on the tower-reported wind velocity and wind angle, limited to a maximum value (usually 15 knots).

The gust velocity is not used in this graphical assessment, but the resulting wind correction usually is very close to the second method.

Usually, no wind correction is applied for tail winds.

On some aircraft models, the wind correction can be entered on the appropriate flight management system (FMS) page.

Flap Configuration

When several flap configurations are certified for landing, V_{REF} (for the selected configuration) is defined by manufacturers as either:

- V_{REF} full flaps plus a correction for the selected flap setting; or,
- V_{REF} selected flaps.

In calm-wind conditions or light-and-variable wind conditions, V_{REF} (or V_{REF} corrected for the selected landing flap setting) plus five knots is a typical target final approach speed.

Abnormal Configuration

System malfunctions (e.g., the failure of a hydraulic system or the jamming of slats/flaps) require an airspeed correction to restore:

- The stall margin; or,
- Controllability/maneuverability.

For a given primary malfunction, the airspeed correction provided in the AOM/QRH usually considers all the consequential effects of the malfunction (i.e., no combination of airspeed corrections is required normally).

In the unlikely event of two unrelated malfunctions — both affecting controllability/maneuverability or stall margin — the following recommendations are applied usually:

- If both malfunctions affect the stall margin, the airspeed corrections must be added;
- If both malfunctions affect controllability/maneuverability, only the higher airspeed correction must be considered; and,
- If one malfunction affects the stall margin and the other malfunction affects controllability/maneuverability, only the higher airspeed correction must be considered.

Use of Autothrottle Speed Mode

Whenever the autothrottle system is used for maintaining the target final approach speed, the crew should consider an airspeed correction (typically five knots) to V_{REF} to allow for the accuracy of the autothrottle system in maintaining the target final approach speed.

This airspeed correction ensures that an airspeed equal to or greater than V_{REF} is maintained down to 50 feet over the runway threshold.

CAT II/CAT III Autoland

For Category (CAT) II instrument landing system (ILS) approaches using the autothrottles, CAT III ILS approaches and autoland approaches (regardless of weather minimums), the five-knot airspeed correction to V_{REF} — to allow for the accuracy of the autothrottle system — is required by certification regulations.

Ice Accretion

When severe icing conditions are encountered, an airspeed correction (typically five knots) must be considered for the possible accretion of ice on the unheated surfaces of the aircraft and on the wing surfaces above and below fuel tanks containing cold-soaked fuel.

Wind Shear

Whenever wind shear is anticipated based on pilot reports from preceding aircraft or on an alert issued by the airport low-level wind shear alert system (LLWAS), *the landing should be delayed or the crew should divert to the alternate airport.*

If neither a delayed landing nor a diversion is suitable, an airspeed correction (usually up to 15 knots to 20 knots, based on the expected wind shear value) is recommended.

Landing with less than full flaps should be considered to maximize the climb gradient capability (as applicable, in compliance with the AOM/QRH), and the final approach speed should be adjusted accordingly.

Wind shear is characterized usually by a significant increase of the head-wind component preceding a sudden change to a tail-wind component. Whenever wind shear is expected, groundspeed should be monitored closely to enhance wind shear awareness.

Combine Airspeed Corrections

The various airspeed corrections either are combined or not combined to distribute equally the safety margins of the following objectives:

- Stall margin;
- Controllability/maneuverability; and,
- Landing distance.

When a system malfunction results in a configuration correction to V_{REF}, the final approach speed becomes:

$$V_{REF} + \textit{configuration correction} + \textit{wind correction.}$$

The wind correction is limited usually to a maximum value (typically 15 knots to 20 knots).

The configuration correction is determined by referring to the AOM/QRH.

The configuration correction and wind correction are combined usually according to the following rules (as applicable, based on the AOM/QRH):

- If the configuration correction is equal to or greater than a specific limit (e.g., 20 knots), no wind correction is added; or,
- If the configuration correction is lower than a given value (e.g., 20 knots), then the configuration correction and wind correction are combined but limited to a maximum value (e.g., 20 knots).

The five-knot airspeed correction for the use of autothrottles and the five-knot airspeed correction for ice accretion (as applicable) may be disregarded if the other airspeed corrections exceed five knots.

Some manufacturers recommend combining the configuration correction and the wind correction in all cases. (When a system malfunction requires a configuration correction, autoland is not permitted usually.)

Summary

Data provided by the manufacturer in the AOM/QRH are designed to achieve a balanced distribution of safety margins between:

- The target final approach speed; and,
- The resulting landing distance.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *7.1 — Stabilized Approach*;
- *8.1 — Runway Excursions and Runway Overruns*;
- *8.3 — Landing Distances*; and,
- *8.4 — Braking Devices*.♦

References

1. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]."

2. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

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FAA. AC 120-28D, *Criteria for Approval of Category III Landing Weather Minima for Takeoff, Landing, and Rollout.* July 13, 1999.

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FSF ALAR Briefing Note 8.3 — Landing Distances

When discussing landing distance, two categories must be considered:

- *Actual landing distance* is the distance used in landing and braking to a complete stop (on a dry runway) after crossing the runway threshold at 50 feet; and,

- *Required landing distance* is the distance derived by applying a factor to the actual landing distance.

Actual landing distances are determined during certification flight tests without the use of thrust reversers.

Required landing distances are used for dispatch purposes (i.e., for selecting the destination airport and alternate airports).

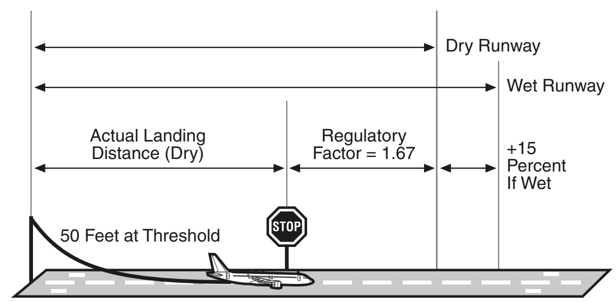
Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that runway overruns were involved in 12 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[1]

Defining Landing Distances

Figure 1 shows the definitions of actual landing distances and required landing distances used by the European Joint Aviation Authorities (JAA) and by the U.S. Federal Aviation Administration (FAA). Figure 2 (page 168) shows the definitions of actual landing distance and required landing distance used by the U.K. Civil Aviation Authority (CAA).

Required Runway Length — JAA/FAA



Required runway length (dry) = Actual landing distance (dry) x 1.67
Required runway length (wet) = Actual landing distance (dry) x 1.92

JAA = (European) Joint Aviation Authorities
FAA = (U.S.) Federal Aviation Administration

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

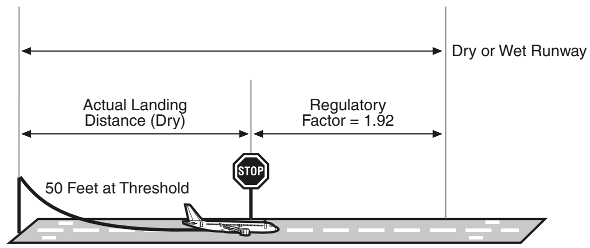
Figure 1

Factors Affecting Landing Distance

Actual landing distance is affected by various operational factors, including:

- High airport elevation or high density altitude, resulting in increased groundspeed;
- Runway gradient (i.e., slope);
- Runway condition (dry, wet or contaminated by standing water, slush, snow or ice);
- Wind conditions;

Required Runway Length — U.K. CAA



Required runway length (dry or wet) = Actual landing distance (dry) x 1.92

CAA = Civil Aviation Authority

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 2

- Type of braking (pedal braking or autobrakes, use of thrust reversers);
- Anti-skid system failure;
- Final approach speed;
- Landing technique (e.g., height and airspeed over the threshold, thrust reduction and flare);
- Standard operating procedures (SOPs) deviations (e.g., failure to arm ground spoilers);
- Minimum equipment list (MEL)/dispatch deviation guide (DDG) conditions (e.g., thrust reversers, brake unit, anti-skid or ground spoilers inoperative); and,
- System malfunctions (e.g., increasing final approach speed and/or affecting lift-dumping capability and/or braking capability).

The approximate effects of these factors on landing distance are shown in Figure 3 (page 169).

Airport Elevation

High airport elevation or high density altitude results in a higher true airspeed (TAS) and groundspeed, and a corresponding longer landing distance, compared to low airport elevation or low density altitude.

For example, at 1,000 feet airport elevation, a landing distance factor of 1.05 to 1.10 (depending on runway condition) must be applied to the landing distance achieved at sea-level airport elevation.

Runway Slope

Runway slope (gradient) has a direct effect on landing distance.

For example, a 1 percent downhill slope increases landing distance by 10 percent (factor of 1.1). However, this effect is accounted for in performance computations only if the runway downhill slope exceeds 2 percent.

Runway Conditions

Although runway contamination increases rolling resistance and spray-impingement drag (i.e., drag caused by water or slush sprayed by tires onto the aircraft), it also affects braking efficiency.

The following landing distance factors are typical:

- Wet runway: 1.3 to 1.4;
- Standing-water or slush-contaminated runway: 2.0 to 2.3;
- Compacted-snow-covered runway: 1.6 to 1.7; and,
- Icy runway: 3.5 to 4.5.

Wind Conditions

Certification regulations and operating regulations require correction factors to be applied to actual landing distances to compensate for:

- Fifty percent of the head-wind component; and,
- One hundred fifty percent of the tail-wind component.

Type of Braking

Actual landing distances are determined during certification flight testing under the following conditions:

- Flying an optimum flight segment from 50 feet over the runway threshold to the flare;
- Achieving a firm touchdown (i.e., not extending the flare); and,
- Using maximum pedal braking, beginning at main-landing-gear touchdown.

Published actual landing distances seldom can be achieved in line operations.

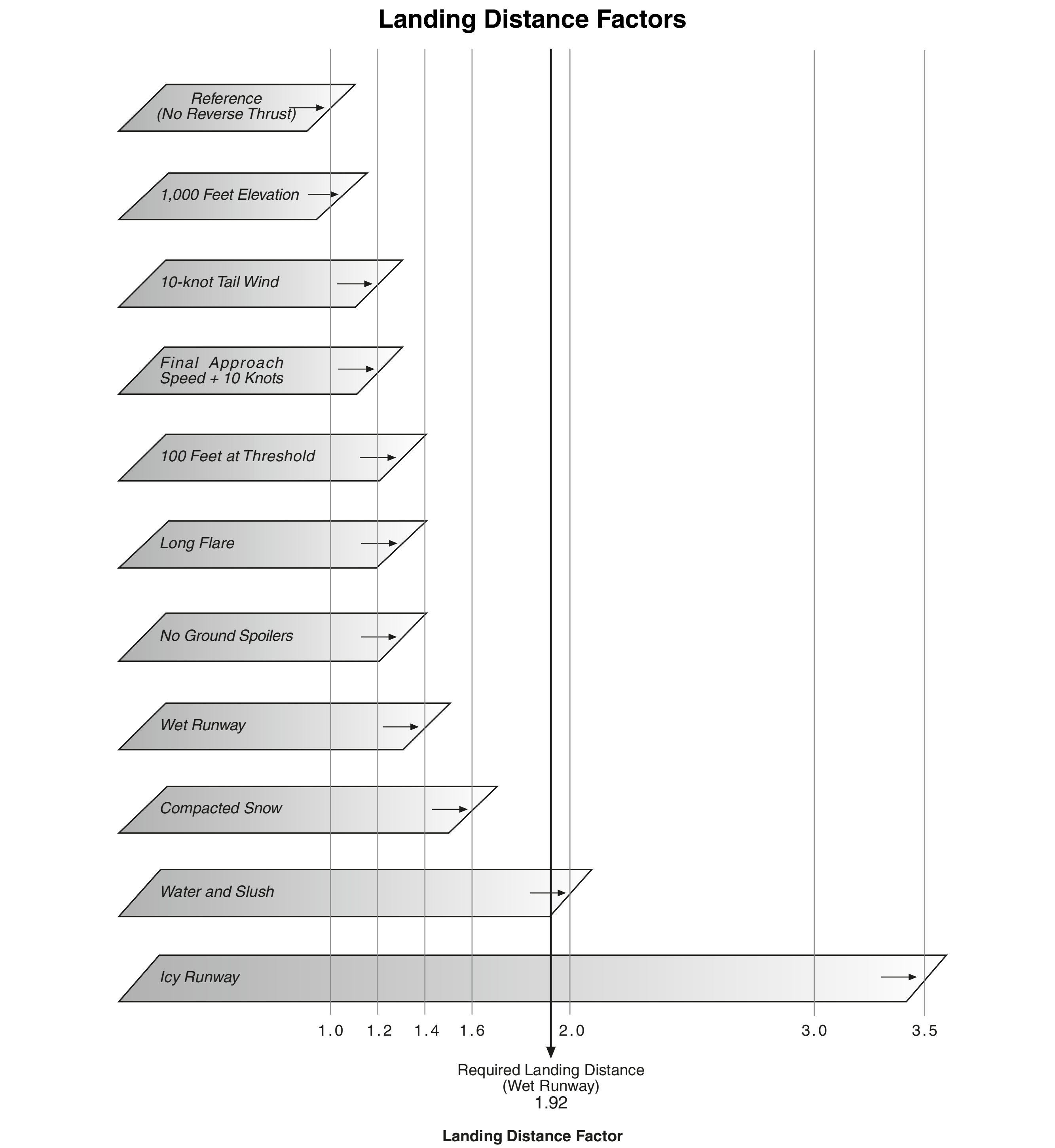
Landing distances published for automatic landings with autobrakes are more achievable in line operations.

Airspeed Over Runway Threshold

A 10 percent increase in final approach speed results in a 20 percent increase in landing distance. This assumes a normal flare and touchdown (i.e., not allowing the aircraft to float and bleed excess airspeed).

Height Over Threshold

Crossing the runway threshold at 100 feet (50 feet higher than recommended) results in an increase in landing distance of



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3

about 1,000 feet (305 meters), regardless of runway condition and aircraft model (Figure 4, page 170).

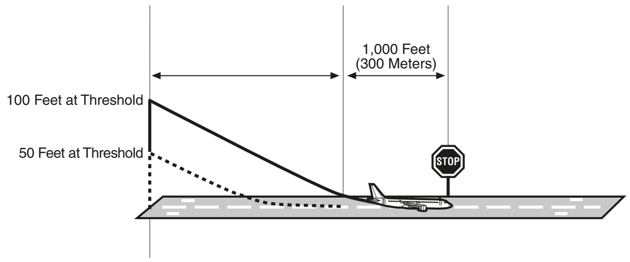
Flare Technique

Extending the flare (i.e., allowing the aircraft to float and bleed excess airspeed) increases the landing distance.

For example, a 5 percent increase in final approach speed increases landing distance by:

- Ten percent, if a normal flare and touchdown are conducted (deceleration on the ground); or,
- Thirty percent, if touchdown is delayed (deceleration during an extended flare).

Effect of Threshold-crossing Height On Landing Distance



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4

Ground Spoilers Not Armed

Several runway-overrun events have been caused by ground spoilers not being armed while the aircraft were being operated with thrust reversers inoperative.

On most transport category aircraft, the ground spoilers extend when reverse thrust is selected (regardless of whether the ground spoilers are armed or not); *this design feature must not be relied upon*. The ground spoilers must be armed per SOPs.

Failure to arm the spoilers results in a typical landing distance factor of 1.3 (1.4 if combined with inoperative thrust reversers).

The automatic extension of ground spoilers should be monitored. Failure of the ground spoilers to deploy automatically should be called; the crew then should manually activate the ground spoilers.

Delay in lowering the nose landing gear to the runway maintains lift, resulting in less load on the main landing gear and, hence, less braking capability. This also delays the nosewheel spin-up signal, which is required for optimum operation of the anti-skid system on some aircraft.

MEL/DDG Conditions

When operating with an MEL/DDG condition affecting landing speed or braking capability, the applicable landing speed correction and landing distance factor must be included in landing-distance computation.

System Malfunctions

System malfunctions, such as hydraulic system low pressure, may result in multiple adjustments to landing speed and landing distance, such as:

- Increased landing speed because of inoperative slats/flaps (stall margin);
- Increased landing speed because of inoperative roll spoilers (maneuverability);
- Increased landing distance because of inoperative ground spoilers (lift-dumping capability); and,
- Increased landing distance because of inoperative normal braking system (braking capability).

The aircraft operating manual (AOM) and the quick reference handbook (QRH) provide the applicable landing speed corrections and landing distance corrections for many malfunctions (including their effects).

Landing Distance Factors

Landing distance factors result from either:

- A landing speed correction (e.g., because of a failure affecting stall margin or maneuverability); or,
- Reduced lift-dumping capability or reduced braking capability (e.g., because of a failure affecting ground spoilers or brakes).

Whether published in the AOM/QRH or computed by the pilot, the combination of landing distance factors for multiple failures usually complies with the following:

- If landing speed corrections are added, the corresponding landing distance factors must be multiplied;
- If only the highest airspeed correction is considered, then only the greatest landing distance factor must be considered; or,
- If two landing distance factors are considered, and one (or both) are related to lift-dumping or braking, the landing distance factors must be multiplied.

Figure 3 shows typical landing distance factors for various runway conditions and operational factors.

Summary

When assessing the landing distance for a given landing, all the following factors should be considered and should be combined as specified in the applicable AOM/QRH:

- MEL/DDG dispatch conditions, as applicable;
- In-flight failures, as applicable;
- Weather conditions (e.g., wind and gusts, suspected wind shear, icing conditions/ice accretion);
- Runway condition;
- Use of braking devices (e.g., thrust reversers, autobrakes); and,
- Airport elevation and runway slope.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *1.4 — Standard Calls*;
- *8.2 — The Final Approach Speed*;
- *8.4 — Braking Devices*; and,
- *8.5 — Wet or Contaminated Runways*.♦

Reference

1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

Related Reading from FSF Publications

Flight Safety Foundation (FSF) Editorial Staff. "Business Jet Overruns Wet Runway After Landing Past Touchdown Zone." *Accident Prevention* Volume 56 (December 1999).

FSF Editorial Staff. "Unaware of Strong Crosswind, Fokker Crew Loses Control of Aircraft on Landing." *Accident Prevention* Volume 56 (November 1999).

Yager, Thomas J. "The Joint FAA/NASA Aircraft/Ground Vehicle Runway Friction Program." *Flight Safety Digest* Volume 8 (March 1989).

Regulatory Resources

International Civil Aviation Organization (ICAO). *Preparation of an Operations Manual*. Second edition – 1997.

U.S. Federal Aviation Administration (FAA). *Federal Aviation Regulations*. 121.97 "Airports: Required data," 121.117 "Airports: Required data," 121.171 "Applicability," 121.195 "Airplanes: Turbine-engine-powered: Landing limitations: Destination airports." 121.197 "Airplanes: Turbine-engine-powered: Landing limitations: Alternate airports." January 1, 2000.

FAA. Advisory Circular 91-6A, *Water, Slush, and Snow on the Runway*. May 24, 1978.

Joint Aviation Authorities. *Joint Aviation Requirements – Operations 1. Commercial Air Transportation (Aeroplanes)*. 1.515 "Landing – Dry Runways," 1.520 "Landing – Wet and contaminated runways." March 3, 1998.

U.K. Civil Aviation Authority (CAA). Aeronautical Information Circular (AIC) 11/98, *Landing Performance of Large Transport Aeroplanes*. January 27, 1998.

U.K. CAA. AIC 61/1999, *Risks and Factors Associated with Operations on Runways Affected by Snow, Slush or Water*. June 3, 1999.

Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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FSF ALAR Briefing Note 8.4 — Braking Devices

The following braking devices are used to decelerate the aircraft until it stops:

- Ground spoilers;
- Wheel brakes (including anti-skid systems and autobrake systems); and,
- Thrust-reverser systems.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that runway excursions and runway overruns were involved in 20 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[1]

The task force also found that delayed braking action during the landing roll-out was involved in some of the accidents and serious incidents in which slow/delayed crew action was a causal factor.[2] Slow/delayed crew action was a causal factor in 45 percent of the 76 accidents and serious incidents.

Braking Devices

Ground Spoilers

Ground spoilers usually deploy automatically (if armed) upon main-landing-gear touchdown or upon activation of thrust reversers.

Ground spoilers provide two aerodynamic effects:

- Increased aerodynamic drag, which contributes to aircraft deceleration; and,
- Lift-dumping, which increases the load on the wheels and, thus, increases wheel-brake efficiency (Figure 1, page 174).

Wheel Brakes

Braking action results from the friction force between the tires and the runway surface.

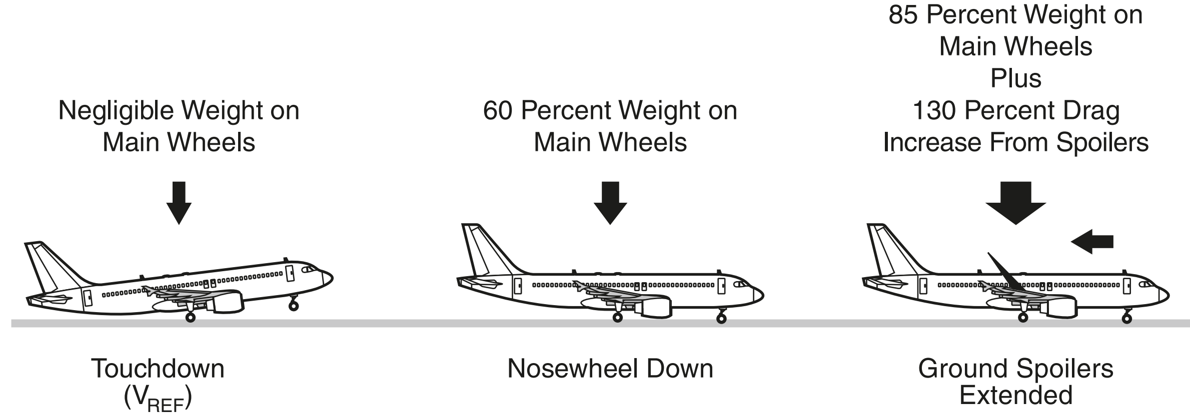
The friction force is affected by:

- Aircraft speed;
- Wheel speed (i.e., free-rolling, skidding or locked);
- Tire condition and pressure (i.e., friction surface);
- Runway condition (i.e., runway friction coefficient);
- The load applied on the wheel; and,
- The number of operative brakes (as shown by the minimum equipment list [MEL]/dispatch deviation guide [DDG]).

Braking force is equal to the load applied on the wheel multiplied by the runway friction coefficient.

Anti-skid systems are designed to maintain the wheel-skidding factor (also called the slip ratio) near the point providing the maximum friction force, which is approximately 10 percent on a scale from zero percent (free-rolling) to 100 percent (locked wheel), as shown by Figure 2 (page 174).

Effects of Nosewheel Contact and Ground Spoilers On Weight-on-wheels and Aerodynamic Drag

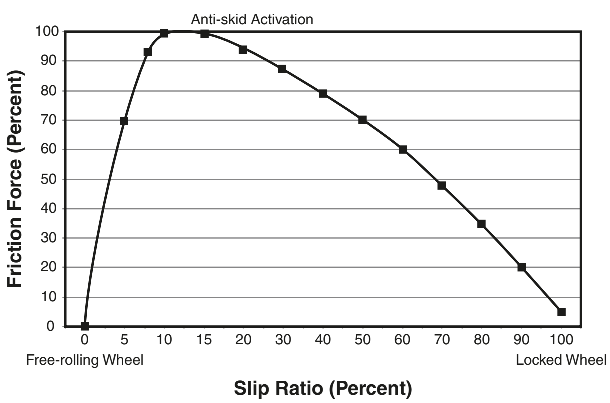


V_{REF} = Reference landing speed

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 1

Effect of Anti-skid on Friction Force And Slip Ratio



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 2

With anti-skid operative, maximum pedal braking results typically in a deceleration rate of eight knots to 10 knots per second.

Autobrake systems are designed to provide a selectable deceleration rate, typically between three knots per second and six knots per second.

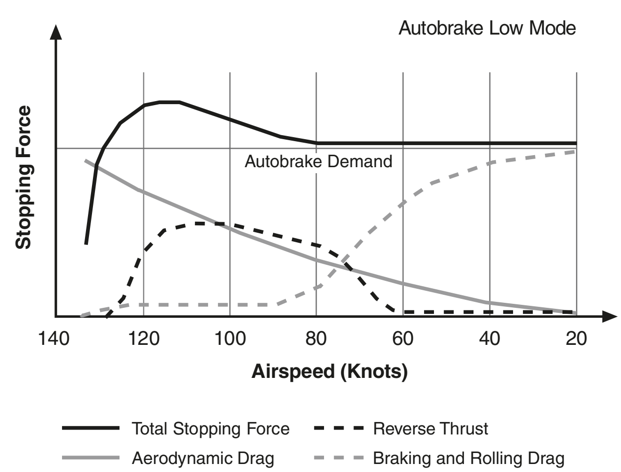
When a low autobrake deceleration rate (referred to hereafter as a "LOW" mode) is selected, brake pressure is applied usually after a specific time delay to give priority to the thrust-reverser deceleration force at high airspeed.

Thrust Reversers

Thrust reversers provide a deceleration force that is independent of runway condition.

Thrust-reverser efficiency is higher at high airspeed (Figure 3); therefore, thrust reversers must be selected as early as possible after touchdown (in accordance with standard operating procedures [SOPs]).

Typical Decelerating Forces During Landing Roll



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3

Thrust reversers should be returned to reverse idle at low airspeed (to prevent engine stall or foreign object damage) and stowed at taxi speed.

Nevertheless, maximum reverse thrust can be maintained to a complete stop in an emergency.

Runway Conditions

Runway contamination increases impingement drag (i.e., drag caused by water or slush sprayed by the tires onto the aircraft) and displacement drag (i.e., drag created as the tires move through a fluid contaminant [water, slush, loose snow] on the runway), and affects braking efficiency.

The following landing distance factors are typical:

- Wet runway, 1.3 to 1.4;
- Water-contaminated or slush-contaminated runway, 2.0 to 2.3;
- Compacted-snow-covered runway, 1.6 to 1.7; and,
- Icy runway, 3.5 to 4.5.

Typical Landing Roll

Figure 3 shows a typical landing roll and the relation of the *different deceleration forces* to the total stopping force as a function of *decelerating airspeed* (from touchdown speed to taxi speed).

The ground spoilers are armed and the autobrakes are selected to the "LOW" mode (for time-delayed brake application).

The autobrake demand in "LOW" mode (typically, three knots per second constant deceleration rate) is equivalent, at a given gross weight, to a constant deceleration force.

At touchdown, the ground spoilers automatically extend and maximum reverse thrust is applied.

The resulting total stopping force is the combined result of:

- Aerodynamic drag (the normal drag of the airplane during the roll-out, not the drag produced by the incorrect technique of keeping the nose high during an extended landing flare);
- Reverse thrust; and,
- Rolling drag.

Autobrake activation is inhibited because the total stopping force exceeds the selected rate of the autobrakes or because of the autobrake time delay.

As airspeed decreases, total stopping force decreases because of a corresponding decrease in:

- Aerodynamic drag; and,
- Reverse thrust efficiency.

When the total stopping force becomes lower than the autobrake setting or when the autobrake time delay has elapsed, the wheel brakes begin contributing to the total deceleration and stopping force.

Typically, at 60 knots indicated airspeed (KIAS) to 80 KIAS, the thrust-reverser levers are returned to the reverse-idle position (then to the stow position at taxi speed).

As a result, the wheel brakes' contribution to stopping force increases to maintain the desired deceleration rate (autobrake demand) to a complete stop or until the pilot takes over with pedal braking.

Ground Spoilers, Thrust Reversers and Brakes Stop the Aircraft

Figure 4 (page 176) shows the respective contributions of the different braking devices to total *stopping energy*, as a function of the achieved or desired *stopping distance*.

Figure 4 shows the following:

- For a given braking procedure (maximum pedal braking or autobrake mode), the stopping distance; and,
- For a desired or required stopping distance, the necessary braking procedure (maximum pedal braking or autobrake mode).

Factors Affecting Braking

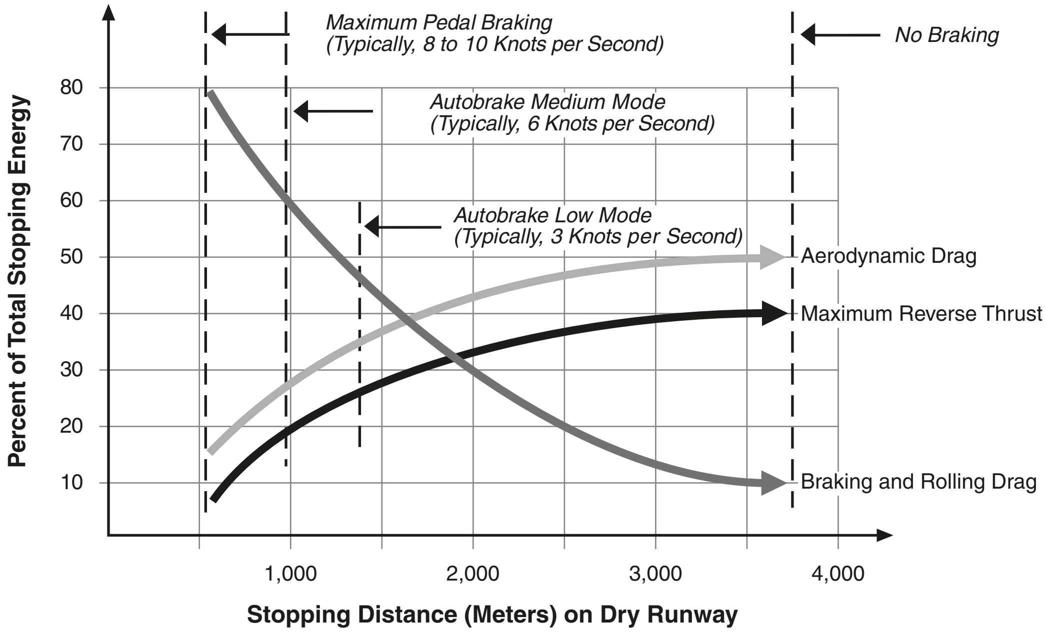
The following factors have affected braking in runway excursions or runway overruns:

- Failure to arm ground spoilers, with thrust reversers deactivated (e.g., reliance on a thrust-reverser signal for ground-spoilers extension, as applicable);
- Failure to use any braking devices (i.e., reliance on the incorrect technique of maintaining a nose-high attitude after touchdown to achieve aerodynamic braking);

(The nosewheel should be lowered onto the runway as soon as possible to increase weight-on-wheels and activate aircraft systems associated with the nose-landing-gear squat switches.)

- Asymmetric thrust (i.e., one engine above idle in forward thrust or one engine failing to go into reverse thrust);
- Brake unit inoperative (e.g., reported as a "cold brake" [i.e., a brake whose temperature is lower, by a specified amount, than the other brakes on the same landing gear]);

Effect of Braking Devices on Stopping Energy and Stopping Distance



Note: Examples assume that airplane touches down at maximum landing weight and at landing reference speed (V_{REF}) on a dry runway at sea level and standard pressure and temperature.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4

- Spongy pedals (air in the hydraulic wheel-braking system);
- Anti-skid tachometer malfunction;
- Failure to adequately recover from loss of the normal braking system;
- Late selection of thrust reversers;
- No takeover or late takeover from autobrakes, when required;
- No switching or late switching from normal braking to alternate braking or to emergency braking in response to abnormal braking; or,
- Crosswind landing and incorrect braking technique.

Summary

The following can ensure optimum braking during the landing roll:

- Arm ground spoilers;
- Arm autobrakes with the most appropriate mode for prevailing conditions (short runway, low visibility, contaminated runway);
- Select thrust reversers as soon as appropriate with maximum reverse thrust (this increases safety on dry runways and wet runways, and is mandatory on runways contaminated by standing water, snow, slush or ice);
- Monitor and call "spoilers" extension;
- Be ready to take over from the autobrakes, if required;
- Monitor engine operation in reverse thrust (exhaust gas temperature [EGT], evidence of surge);
- Monitor airspeed indication (or fluctuations) and return engines to reverse idle at the published indicated airspeed;
- If required, use maximum pedal braking; and,
- As a general rule, do not stop braking until assured that the aircraft will stop within the remaining runway length.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *8.3 — Landing Distances*;
- *8.5 — Wet or Contaminated Runways*; and,
- *8.7 — Crosswind Landings*.♦

References

1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.
2. The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force defines *causal factor* as "an event or item judged to be directly instrumental in the causal chain of events leading to the accident [or incident]." Each accident and incident in the study sample involved several causal factors.

Related Reading from FSF Publications

FSF Editorial Staff. "Managing Aircraft-tire Wear and Damage Requires Adherence to Removal Limits." *Aviation Mechanics Bulletin* Volume 47 (May–June 1999).

FSF Editorial Staff. "Monitoring Aircraft-tire Pressure Helps Prevent Hazardous Failures." *Aviation Mechanics Bulletin* Volume 47 (March–April 1999).

FSF Editorial Staff. "Attempted Go-around with Deployed Thrust Reversers Leads to Learjet Accident." *Accident Prevention* Volume 56 (January 1999).

King, Jack L. "During Adverse Conditions, Decelerating to Stop Demands More from Crew and Aircraft." *Flight Safety Digest* Volume 12 (March 1993).

Yager, Thomas J. "The Joint FAA/NASA Aircraft/Ground Vehicle Runway Friction Program." *Flight Safety Digest* Volume 8 (March 1989).

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U.S. Federal Aviation Administration (FAA). *Federal Aviation Regulations*. 121.97 "Airports: Required data," 121.117 "Airports: Required data," 121.171 "Applicability," 121.195 "Airplanes: Turbine-engine-powered: Landing limitations: Destination airports." 121.197 "Airplanes: Turbine-engine-powered: Landing limitations: Alternate airports." January 1, 2000.

FAA. Advisory Circular 91-6A, *Water, Slush, and Snow on the Runway*. May 24, 1978.

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U.K. Civil Aviation Authority (CAA). Aeronautical Information Circular (AIC) 11/98, *Landing Performance of Large Transport Aeroplanes*. January 27, 1998.

U.K. CAA. AIC 61/1999, *Risks and Factors Associated with Operations on Runways Affected by Snow, Slush or Water*. June 3, 1999.

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- Autobrakes;
- Thrust reversers;
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FSF ALAR Briefing Note 8.5 — Wet or Contaminated Runways

The conditions and factors associated with landing on a wet runway or a runway contaminated by standing water, snow, slush or ice should be assessed carefully before beginning the approach.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that wet runways were involved in 11 approach-and-landing accidents and serious incidents involving runway overruns and runway excursions worldwide in 1984 through 1997.[1]

Defining Runway Condition

Dry Runway

The European Joint Aviation Authorities (JAA)[2] defines *dry runway* as "one which is neither wet nor contaminated, and includes those paved runways which have been specially prepared with grooves or porous pavement and maintained to retain 'effectively dry' braking action even when moisture is present."

Damp Runway

JAA says that a runway is considered damp "when the surface is not dry, but when the moisture on it does not give it a shiny appearance."

Wet Runway

JAA says that a runway is considered wet "when the runway surface is covered with water, or equivalent, less than specified [for a contaminated runway] or when there is sufficient moisture on the runway surface to cause it to appear reflective, but without significant areas of standing water."

Contaminated Runway

JAA says that a runway is contaminated "when more than 25 percent of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by the following:

- "Surface water more than 3.0 mm [millimeters] (0.125 in [inch]) deep, or by slush or loose snow, equivalent to more than 3.0 mm (0.125 in) of water;
- "Snow which has been compressed into a solid mass which resists further compression and will hold together or break into lumps if picked up (compacted snow); or,
- "Ice, including wet ice."

The U.S. Federal Aviation Administration[3] says that a runway is considered contaminated "whenever standing water, ice, snow, slush, frost in any form, heavy rubber, or other substances are present."

Factors and Effects

Braking Action

The presence on the runway of a fluid contaminant (water, slush or loose snow) or a solid contaminant (compacted snow or ice) adversely affects braking performance (stopping force) by:

- Reducing the friction force between the tires and the runway surface. The reduction of friction force depends on the following factors:

– Tire-tread condition (wear) and inflation pressure;

– Type of runway surface; and,

– Anti-skid system performance; and,

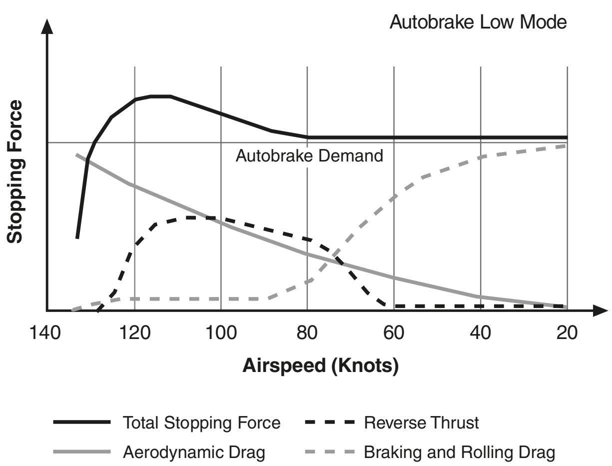
- Creating a layer of fluid between the tires and the runway, thus reducing the contact area and creating a risk of hydroplaning (partial or total loss of contact and friction between the tires and the runway surface).

Fluid contaminants also contribute to stopping force by:

- Resisting forward movement of the wheels (i.e., causing *displacement drag*); and,
- Creating spray that strikes the landing gear and airframe (i.e., causing *impingement drag)*. Certification regulations require spray to be diverted away from engine air inlets.

The resulting braking action is the net effect of the above stopping forces (Figure 1 and Figure 2, page 181).

Typical Decelerating Forces During Landing Roll



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 1

Hydroplaning (Aquaplaning)

Hydroplaning occurs when the tire cannot squeeze any more of the fluid-contaminant layer between its tread and lifts off the runway surface.

Hydroplaning results in a partial or total loss of contact and friction between the tire and the runway, and in a corresponding reduction of friction coefficient.

Main wheels and nosewheels can be affected by hydroplaning. Thus, hydroplaning affects nosewheel steering, as well as braking performance.

Hydroplaning always occurs to some degree when operating on a fluid-contaminated runway.

The degree of hydroplaning depends on the following factors:

- Absence of runway surface roughness and inadequate drainage (e.g., absence of transverse saw-cut grooves);
- Depth and type of contaminant;
- Tire inflation pressure;
- Groundspeed; and,
- Anti-skid operation (e.g., locked wheels).

A minimum hydroplaning speed is defined usually for each aircraft type and runway contaminant.

Hydroplaning may occur at touchdown, preventing the wheels from spinning and from sending the wheel-rotation signal to various aircraft systems.

Conducting a firm touchdown can reduce hydroplaning at touchdown.

Directional Control

On a contaminated runway, directional control should be maintained using the rudder pedals; do not use the nosewheel-steering tiller until the aircraft has slowed to taxi speed.

On a wet runway or a contaminated runway, use of nosewheel steering above taxi speed may cause the nosewheels to hydroplane and result in the loss of nosewheel cornering force with consequent loss of directional control.

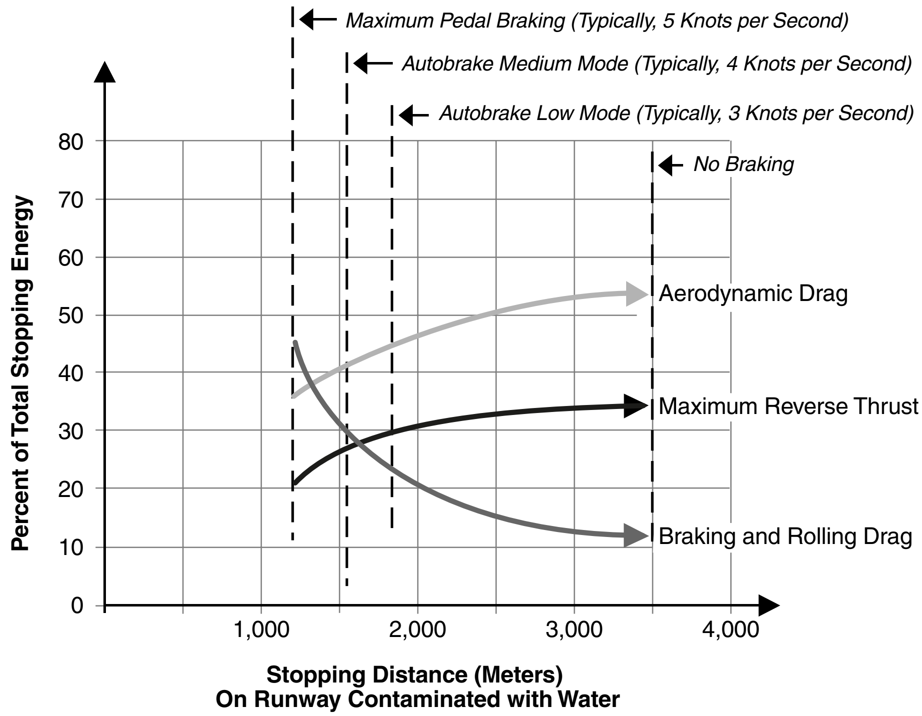
If differential braking is necessary, pedal braking should be applied on the required side and should be released on the opposite side to regain directional control. (If braking is not completely released on the opposite side, brake demand may continue to exceed the anti-skid regulated braking; thus, no differential braking may be produced.)

Landing Distances

Landing distances usually are published in aircraft operating manuals (AOMs)/quick reference handbooks (QRHs) for dry runways and for runway conditions and contaminants such as the following:

- Wet;
- 6.3 millimeters (0.25 inch) of standing water;
- 12.7 millimeters (0.5 inch) of standing water;
- 6.3 millimeters (0.25 inch) of slush;
- 12.7 millimeters (0.5 inch) of slush;
- Compacted snow; and,
- Ice.

Effect of Braking Devices on Stopping Energy and Stopping Distance



Note: Examples assume that airplane touches down at maximum landing weight and at reference landing speed (V_{REF}) on a runway contaminated with 6.3 millimeters (0.25 inch) of water at sea level and standard pressure and temperature.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 2

Landing distances are published for all runway conditions, and assume:

- An even distribution of the contaminant;
- Maximum pedal braking, beginning at touchdown; and,
- An operative anti-skid system.

Landing distances for automatic landing (autoland) using the autobrake system are published for all runway conditions.

In addition, correction factors (expressed in percentages) are published to compensate for the following:

- Airport elevation:
  - Typically, +5 percent per 1,000 feet;
- Wind component:
  - Typically, +10 percent per five-knot tail-wind component; and,
  - Typically, −2.5 percent per five-knot head-wind component; and,
- Thrust reversers:
  - The thrust-reverser effect depends on runway condition and type of braking.

Stopping Forces

Figure 1 shows the distribution of the respective *stopping forces* as a function of decreasing airspeed during a typical landing roll using autobrakes in “LOW” mode (for a low deceleration rate) and maximum reverse thrust.

Total stopping force is the combined result of:

- Aerodynamic drag (the term refers to drag on the airplane during the roll-out [including impingement drag on a fluid-contaminated runway]);
- Reverse thrust; and,
- Rolling drag.

Distribution of Stopping Energy on a Contaminated Runway

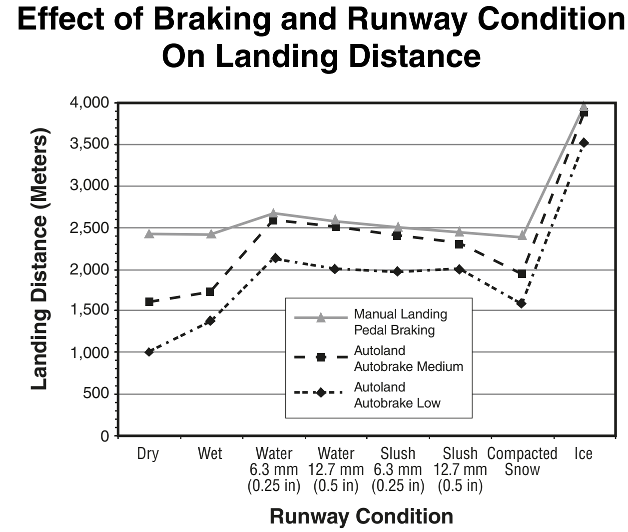
Figure 2 shows the contribution to the total *stopping energy* of various braking devices as a function of the desired or achieved landing distance on a runway contaminated with water.

Figure 2 can be used to determine:

- For a given braking procedure (pedal braking or an autobrake mode), the resulting landing distance; or,
- For a desired or required landing distance, the necessary braking procedure (pedal braking or an autobrake mode).

Figure 2 shows that on a runway contaminated with standing water (compared to a dry runway):

- The effect of aerodynamic drag increases because of impingement drag;
- The effect of braking and rolling drag (balance of braking force and displacement drag) decreases; and,
- *Thrust-reverser stopping force is independent of runway condition*, and its effect is greater when the deceleration rate is lower (i.e., autobrakes with time delay vs. pedal braking [see Figure 1]).



mm = millimeters   in = inch

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3

Factors Affecting Landing Distance

Runway Condition and Type of Braking

Figure 3 shows the effect of runway condition on landing distance for various runway conditions and for three braking procedures (pedal braking, use of "LOW" autobrake mode and use of "MEDIUM" autobrake mode).

Figure 3 is based on a 1,000-meter (3,281-foot) landing distance (typical manual landing on a dry runway with maximum pedal braking and no reverse thrust).

For each runway condition, the landing distances for a manual landing with maximum pedal braking and an automatic landing with autobrakes can be compared.

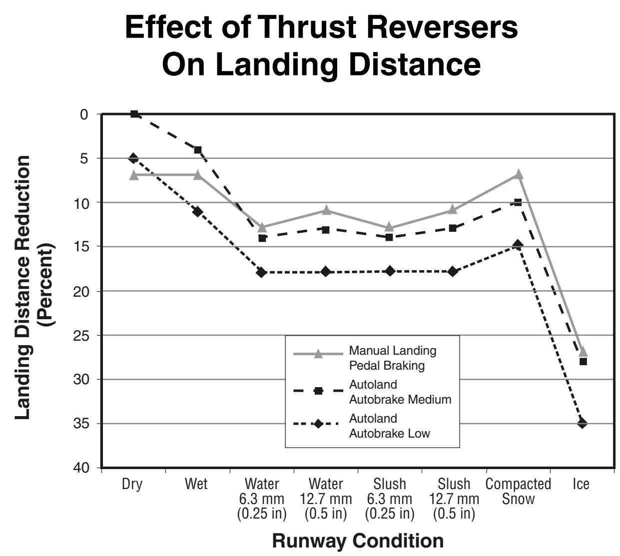
Similarly, for a manual landing or an autoland (with autobrakes), the effect of the runway condition can be seen.

When autobrakes are used, braking efficiency is a function of the selected autobrake mode and of the anti-skid activation point, whichever is achieved first, as shown by Figure 3 and Figure 4.

On a runway contaminated with standing water or slush, the landing distances with a "MEDIUM" or a "LOW" autobrake mode are similar because the deceleration rate is affected primarily by aerodynamic drag, rolling drag and reverse thrust, and because the selected autobrake deceleration rate (e.g., "MEDIUM" mode) cannot be achieved.

Thrust Reversers

Figure 4 shows the effect of reverse thrust with both thrust reversers operative.



mm = millimeters   in = inch

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4

When autobrakes are used, the thrust reverser effect (i.e., contribution to landing-distance reduction) is a function of:

- The selected deceleration rate and the time delay on autobrake activation, as applicable; and,
- Runway condition (contribution of contaminant to the deceleration rate).

On a dry runway or on a wet runway, the effect of the thrust reversers on landing distance depends on the selected autobrake mode and on the associated time delay (e.g., "MEDIUM" mode without time delay vs. "LOW" mode with time delay), as shown by Figure 1 and Figure 4.

Operational Guidelines

When the destination-airport runways are wet or contaminated, the crew should:

- Consider diverting to an airport with better runway conditions or a lower crosswind component when actual conditions significantly differ from forecast conditions or when a system malfunction occurs;
- Anticipate asymmetric effects at landing that would prevent efficient braking or directional control (e.g., crosswind);
- Avoid landing on a contaminated runway without anti-skid or with only one thrust reverser operational;
- For inoperative items affecting braking or lift-dumping capability, refer to the applicable:
  - AOM/QRH for in-flight malfunctions; or,
  - Minimum equipment list (MEL) or dispatch deviation guide (DDG) for known dispatch conditions;
- Select autobrake mode per SOPs (some AOMs/QRHs recommend not using autobrakes if the contaminant is not evenly distributed);
- Approach on glide path and at the target final approach speed;
- Aim for the touchdown zone;
- Conduct a firm touchdown;
- Use maximum reverse thrust as soon as possible after touchdown (because thrust reverser efficiency is higher at high airspeed);
- Confirm the extension of ground spoilers;
- Do not delay lowering the nosewheel onto the runway. This increases weight-on-wheels and activates aircraft systems associated with the nose-landing-gear squat switches;
- Monitor the autobrakes (on a contaminated runway, the selected deceleration rate may not be achieved);
- As required or when taking over from autobrakes, apply the pedal brakes normally with a steady pressure;
- For directional control, use rudder pedals (and differential braking, as required); do not use the nosewheel-steering tiller;
- If differential braking is necessary, apply braking on the required side and release the braking on the opposite side; and,
- After reaching taxi speed, use nosewheel steering with care.

Summary

Conditions associated with landing on a wet runway or a runway contaminated by standing water, snow, slush or ice require a thorough review before beginning the approach.

The presence on the runway of water, snow, slush or ice adversely affects the aircraft's braking performance by:

- Reducing the friction force between the tires and the runway surface; and,
- Creating a layer of fluid between the tires and the runway, which reduces the contact area and leads to a risk of hydroplaning.

Directional control should be maintained on a contaminated runway by using the rudder pedals and differential braking, as required; nosewheel steering should not be used at speeds higher than taxi speed because the nosewheels can hydroplane.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *7.1 — Stabilized Approach*;
- *8.3 — Landing Distances*;
- *8.4 — Braking Devices*; and,
- *8.7 — Crosswind Landings*.♦

References

1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.
2. Joint Aviation Authorities. *Joint Aviation Requirements — Operations*. 1.480 "Terminology."
3. U.S. Federal Aviation Administration. *Flight Services, 7110.10N*. Appendix A "Pilot/Controller Glossary."

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U.K. Civil Aviation Authority (CAA). Aeronautical Information Circular (AIC) 11/98, *Landing Performance of Large Transport Aeroplanes*. January 27, 1998.

U.K. CAA. AIC 61/1999, *Risks and Factors Associated with Operations on Runways Affected by Snow, Slush or Water*. June 3, 1999.

Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

Flight Safety Foundation

ALAR

Approach-and-landing Accident Reduction

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FSF ALAR Briefing Note 8.6 — Wind Information

Wind information is available to the flight crew from two primary sources:

- Air traffic control (ATC); and,
- Aircraft systems.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that adverse wind conditions (i.e., strong crosswinds, tail winds or wind shear) were involved in about 33 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[1]

Reporting Standards

Recommendations for measuring and reporting wind information have been developed by the International Civil Aviation Organization (ICAO).

They have been implemented by ICAO member states' national weather services (NWSs) and local airport weather services (AWSs).

Average Wind and Gust

Wind direction and wind velocity are sampled every second by wind sensors that may be distant from the runway touchdown zone.

Data averaged over the past two-minute period provide the automatic terminal information service (ATIS) or tower-reported "average wind."

The average wind is available to the controller on a display terminal. (Some control towers, however, have instantaneous indications of wind direction and wind velocity.)

A wind profile of data collected over the past 10-minute period shows the maximum (peak) wind value recorded during this period; this value is reported as the *gust*.

ICAO recommends that gusts be reported if the 10-minute peak value exceeds the two-minute average wind by 10 knots or more.[2] Nevertheless, gust values lower than 10 knots often are provided by AWSs.

Figure 1 (page 186) shows a 10-minute wind profile with:

- A two-minute average wind of 15 knots; and,
- A gust of 10 knots (i.e., a 25-knot peak wind velocity) during the 10-minute period.

This wind condition would be shown in an aviation routine weather report (METAR) as "XXX15G25KT," where XXX is the wind direction, referenced to true north. ATIS and tower-reported winds are referenced to magnetic north.

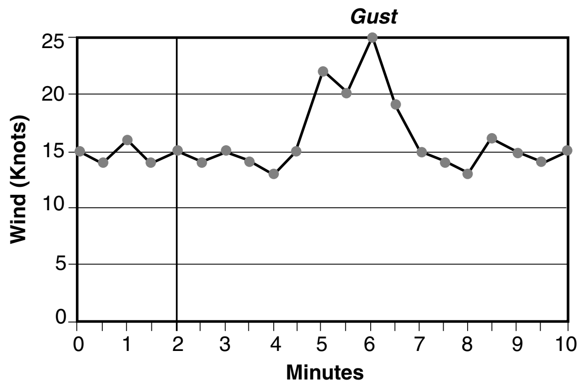
If the peak wind value is observed during the past two-minute period, the gust becomes part of the average wind (Figure 2, page 186).

Such a wind condition would be shown as:

- "XXX20G25KT"; or,
- "XXX20KT" (if the five-knot gust is not included).

Average-wind values and gust values displayed to a controller are updated every minute.

Wind Profile Resulting in ATC/ATIS Report of 15-Knot Wind Velocity And Gusts to 25 Knots

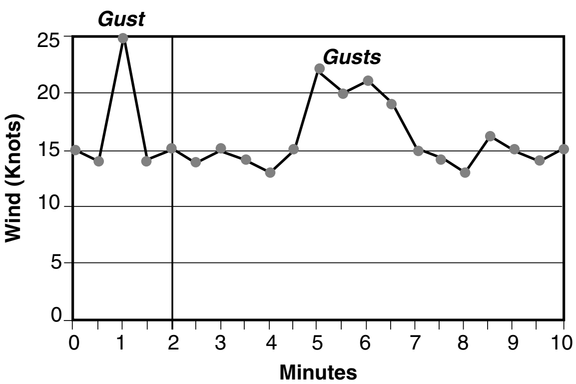


ATC = Air traffic control
ATIS = Automatic terminal information service

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 1

Wind Profile Resulting in ATC/ATIS Report of 20-Knot Wind Velocity With Gusts to 25 Knots



ATC = Air traffic control
ATIS = Automatic terminal information service

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

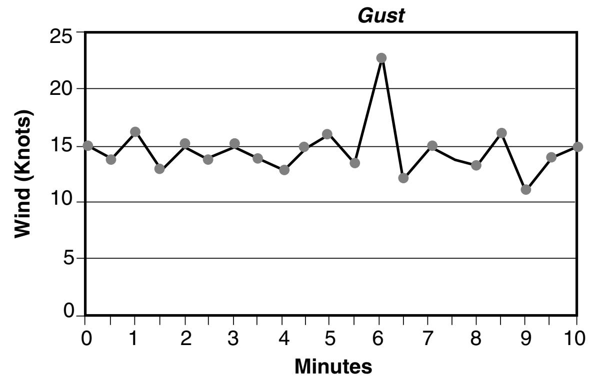
Figure 2

The two-minute average wind and the 10-minute peak gust are used by ATC for:

- ATIS broadcasts; and,
- Wind information on ground, tower, approach and information frequencies.

METARs include a 10-minute average-wind velocity and the 10-minute peak gust (Figure 3).

Wind Profile Resulting in METAR Report of 15-Knot Wind Velocity And Gusts to 23 Knots



METAR = Aviation routine weather report

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3

Maximum Demonstrated Crosswind

The *maximum demonstrated crosswind* published in the approved airplane flight manual (AFM), aircraft operating manual (AOM) and/or quick reference handbook (QRH) is the maximum crosswind component that was encountered and documented during certification flight tests or subsequent tests by the manufacturer.

The wind value is recorded during a time period bracketing the touchdown (typically from 100 feet above airport elevation to when the airplane reaches taxi speed).

For some aircraft models, if a significant gust is recorded during this period, a demonstrated gust value also is published.

The maximum demonstrated crosswind;

- Is not an operating limitation (unless otherwise stated);
- Is not necessarily the maximum aircraft crosswind capability; and,
- Generally applies to a steady wind.

Maximum Computed Crosswind

The *maximum computed crosswind* reflects the design capability of the aircraft in terms of:

- Rudder authority;
- Roll-control authority; and,
- Wheel-cornering capability.

Crosswind Capability

Crosswind capability is affected adversely by the following factors:

- Runway condition (e.g., contaminated by standing water, snow, slush or ice);
- Systems malfunctions (e.g., rudder jam); or,
- Minimum equipment list (MEL)/dispatch deviation guide (DDG) conditions (e.g., inoperative nosewheel steering).

Wind Information on Navigation Display

The wind information on the navigation display (ND) consists of two elements (Figure 4):

- A wind arrow:
  - The direction of the wind arrow is referenced to magnetic north and indicates the wind direction;
  - The length of the wind arrow may be fixed (velocity information is displayed separately), or the length of the wind arrow may be varied to indicate the wind velocity (depending on aircraft models and standards); and,
  - The wind arrow is the primary visual wind reference during the final approach (together with the groundspeed display); and,
- Digital wind information showing wind direction (typically referenced to true north) and wind velocity:
  - Digital wind information is used primarily to compare the current wind to the predicted wind, as provided on the computerized flight plan.

Depending on aircraft models and standards, the wind information may be computed either by the inertial reference system (IRS) or by the flight management system (FMS).

Lower-left Corner of Navigation Display Shows Winds From 212 Degrees At 20 Knots

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4

Depending on the equipment, different time delays for "smoothing" (i.e., averaging) the wind value are applied, as discussed below.

The wind information on the ND is updated typically 10 times per second.

IRS Wind

IRS wind is assessed geometrically using the triangle of true airspeed (TAS), groundspeed and wind vectors.

The TAS vector and groundspeed vector are defined, in terms of velocity and direction, as follows:

- TAS vector:
  - Velocity: TAS from the air data computer (ADC); and,
  - Direction: magnetic heading from the IRS; and,
- Groundspeed vector:
  - Velocity: groundspeed from the IRS; and,
  - Direction: magnetic track from the IRS.

The IRS wind is computed and is transmitted typically 10 times per second to the electronic flight instrument system (EFIS) for display on the ND.

The IRS wind display provides, for practical purposes, *near-real-time* wind information.

FMS Wind

FMS wind is computed similarly to IRS wind, but FMS wind is averaged over a 30-second period.

FMS wind is more accurate than IRS wind because distance-measuring equipment (DME) position or global positioning system (GPS) position, when available, are included in the computation.

FMS wind is less accurate (i.e., delayed) under the following conditions:

- Shifting wind;
- Sideslip; or,
- Climbing or descending turn.

FMS wind cannot be considered instantaneous wind, but the FMS wind shows:

- More current wind information than the ATIS or tower average wind; and,
- The wind conditions prevailing on the aircraft flight path (aft of the aircraft).

Summary

METAR wind is a 10-minute average wind.

ATIS wind or tower average wind is a two-minute average wind.

ATIS gust or tower gust is the wind peak value during the past 10-minute period.

The ATIS broadcast is updated only if the wind direction changes by more than 30 degrees or if the wind velocity changes by more than five knots over a five-minute time period.

If an instantaneous wind reading is desired and is requested from ATC, the phraseology "instant wind" should be used in the request. (ATC may provide instant-wind information without request under shifting/gusting wind conditions.)

IRS wind is near-real-time wind.

FMS wind is a 30-second-average wind.

Maximum demonstrated crosswind generally applies to a steady wind and is not a limitation (unless otherwise stated).

The most appropriate source of wind information should be selected for the flight phase.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *8.5 — Wet or Contaminated Runways*; and,
- *8.7 — Crosswind Landings*.♦

References

1. Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.
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World Meteorological Organization. *Guide to Meteorological Instruments and Methods of Observation*. Sixth edition – 1996.

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- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
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FSF ALAR Briefing Note 8.7 — Crosswind Landings

Operations in crosswind conditions require adherence to applicable limitations or recommended maximum crosswinds, and recommended operational and handling techniques, particularly when operating on wet runways or runways contaminated by standing water, snow, slush or ice.

Statistical Data

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force found that adverse wind conditions (i.e., strong crosswinds, tail winds or wind shear) were involved in about 33 percent of 76 approach-and-landing accidents and serious incidents worldwide in 1984 through 1997.[1]

The task force also found that adverse wind conditions and wet runways were involved in the majority of the runway excursions that comprised 8 percent of the accidents and serious incidents.

Runway Condition and Maximum Recommended Crosswind

The maximum demonstrated crosswind and maximum computed crosswind are applicable only on a runway that is dry, damp or wet.

On a runway contaminated with standing water, slush, snow or ice, a recommended maximum crosswind (Table 1, page 190) usually is defined as a function of:

- Reported braking action (if available);
- Reported runway friction coefficient (if available); or,
- Equivalent runway condition (if braking action and runway friction coefficient are not reported).

Equivalent runway condition, as defined by the notes in Table 1, is used only for the determination of the maximum recommended crosswind.

Table 1 cannot be used for the computation of takeoff performance or landing performance, because it does not account for the effects of displacement drag (i.e., drag created as the tires make a path through slush) and impingement drag (i.e., drag caused by water or slush sprayed by tires onto the aircraft).

Recommended maximum crosswinds for contaminated runways usually are based on computations rather than flight tests, but the calculated values are adjusted in a conservative manner based on operational experience.

The recommended maximum crosswind should be reduced for a landing with one engine inoperative or with one thrust reverser inoperative (as required by the aircraft operating manual [AOM] and/or quick reference handbook [QRH]).

Some companies also reduce the recommended maximum crosswind when the first officer is the pilot flying (PF) during line training and initial line operation.

AOMs/QRHs prescribe a maximum crosswind for conducting an autoland operation.

The pilot-in-command should request assignment of a more favorable runway if the prevailing runway conditions and crosswind are unfavorable for a safe landing.

Table 1
Factors Included in Typical Recommended Maximum Crosswind

Reported Braking Action (Index)	Reported Runway Friction Coefficient	Equivalent Runway Condition	Recommended Maximum Crosswind
Good (5)	0.40 and above	(See Note 1)	35 knots
Good / Medium (4)	0.36 to 0.39	(See Note 1)	30 knots
Medium (3)	0.30 to 0.35	(See Notes 2 and 3)	25 knots
Medium / Poor (2)	0.26 to 0.29	(See Note 3)	20 knots
Poor (1)	0.25 and below	(See Notes 3 and 4)	15 knots
Unreliable (9)	Unreliable	(See Notes 4 and 5)	5 knots

Note 1: Dry, damp or wet runway (less than three millimeters [0.1 inch] of water) without risk of hydroplaning.

Note 2: Runway covered with dry snow.

Note 3: Runway covered with slush.

Note 4: Runway covered with standing water, with risk of hydroplaning, or with slush.

Note 5: Runway with high risk of hydroplaning.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Approach Techniques

Figure 1 (page 191) shows that, depending on the recommendations published in the AOM/QRH, a final approach in crosswind conditions may be conducted:

- With wings level (i.e., applying a drift correction to track the runway centerline); this type of approach usually is referred to as a *crabbed approach*; or,
- With a steady sideslip (i.e., with the fuselage aligned with the runway centerline, using a combination of into-wind aileron and opposite rudder [cross-controls] to correct the drift).

The following factors should be considered when deciding between a wings-level approach and a steady-sideslip approach:

- Aircraft geometry (pitch-attitude limits and bank-angle limits, for preventing tail strike, engine contact or wing-tip contact);
- Aileron (roll) and rudder (yaw) authority; and,
- The magnitude of the crosswind component.

The recommended maximum crosswind and the recommended crosswind landing technique depend on the aircraft type and model; limitations and recommendations usually are published in the AOM/QRH.

Flare Techniques

When approaching the flare point with wings level and with a crab angle, as required for drift correction, one of three techniques can be used:

- Align the aircraft with the runway centerline, while preventing drift, by applying into-wind aileron and opposite rudder;
- Maintain the crab angle for drift correction until the main landing gear touch down; or,
- Perform a partial decrab, using the cross-controls technique to track the runway centerline.

Some AOMs and autopilot control requirements for autoland recommend beginning the alignment phase well before the flare point (typically between 200 feet and 150 feet), which results in a steady-sideslip approach down to the flare.

Landing Limitations

Knowledge of flight dynamics can provide increased understanding of the various crosswind techniques.

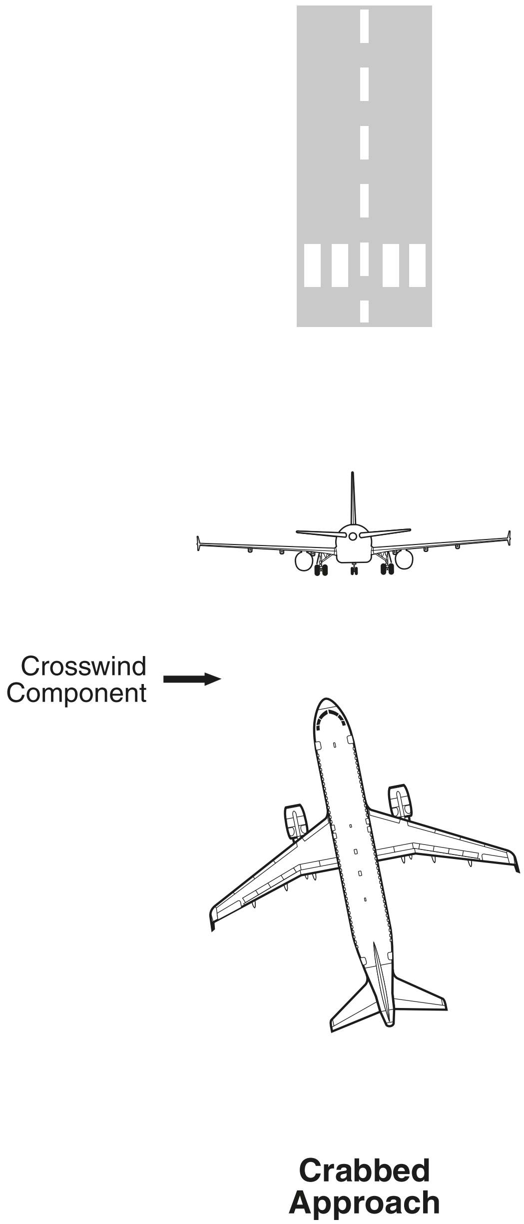
Landing Capabilities

Figure 2 (page 192) and Figure 3 (page 193) show the limitations involved in crosswind landings (for a given steady crosswind component):

- Bank angle at a given crab angle or crab angle at a given bank angle:
  - The graphs show the bank-angle/crab-angle relationship required to correct drift and to track the runway centerline at the target final approach speed.

    Positive crab angles result from normal drift correction and sideslip conditions (i.e., with the aircraft pointing into the wind).

Crabbed Approach and Sideslip Approach



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

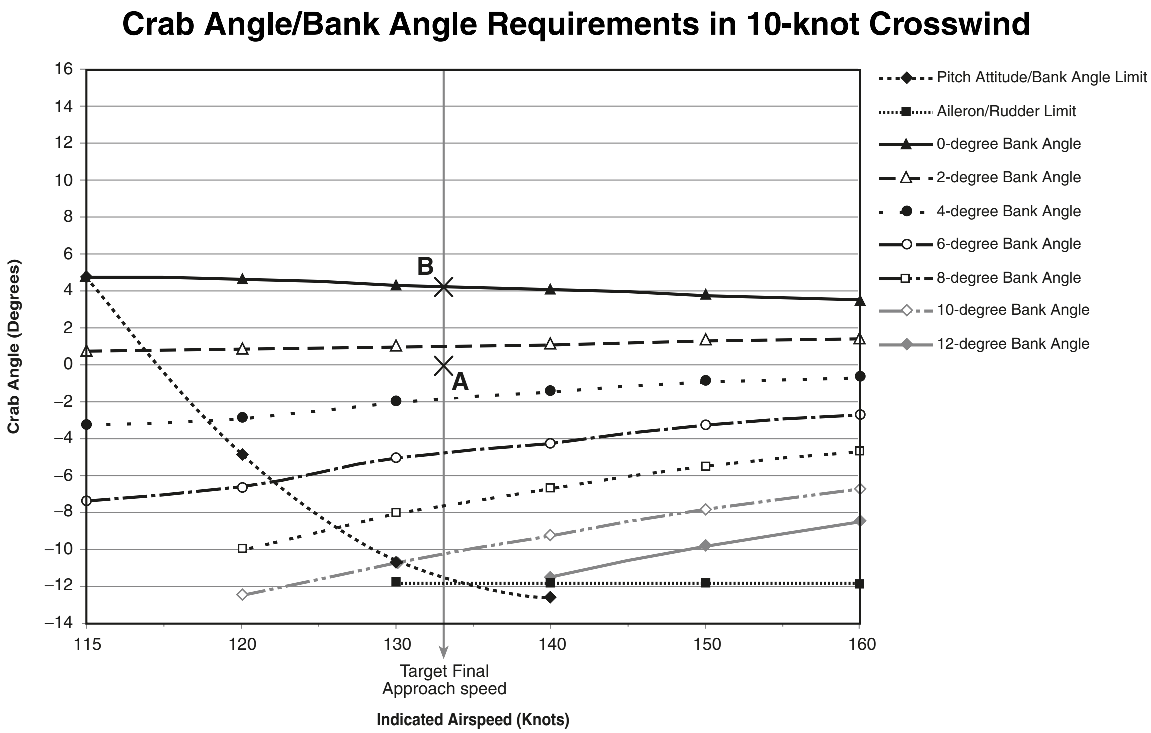
Figure 1

Negative crab angles are shown but would require an excessive sideslip rudder input, resulting in a more-than-desired bank angle;

- Aircraft geometry limits:
  - Limits result from the maximum pitch attitude/bank angle that can be achieved without striking the runway with the tail or with the engine pod (for underwing-mounted engines), the flaps or the wing tip; and,
- Aileron/rudder authority:
  - This limitation results from the aircraft's maximum capability to maintain a steady sideslip under crosswind conditions.

Figure 2 and Figure 3 assume that the approach is stabilized and that the flare is conducted at a normal height and rate.

The data in these figures may not apply to all aircraft types and models, but all aircraft are subject to the basic laws of flight dynamics that the data reflect.



Examples: A sideslip landing (zero crab angle) requires about a three-degree bank angle at touchdown (point A). A wings-level landing (no decrab) requires a crab angle between four degrees and five degrees at touchdown (point B).

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 2

Figure 2 shows that with a 10-knot steady crosswind component:

- Achieving a steady-sideslip landing (zero crab angle) requires only a three-degree into-wind bank angle (point A on the graph); or,
- Achieving a wings-level landing (no decrab) requires only a four-degree to five-degree crab angle at touchdown (point B).

A sideslip landing can be conducted while retaining significant safety margins relative to geometry limits or to aileron/rudder authority limits.

Figure 3 shows that with a 30-knot steady crosswind component:

- Achieving a steady-sideslip landing (zero crab angle) requires nearly a nine-degree into-wind bank angle, placing the aircraft closer to its geometry limits and aileron/rudder authority limits (point A on the graph); or,
- Achieving a wings-level landing (no decrab) would result in a 13-degree crab angle at touchdown, potentially resulting in landing gear damage (point B).

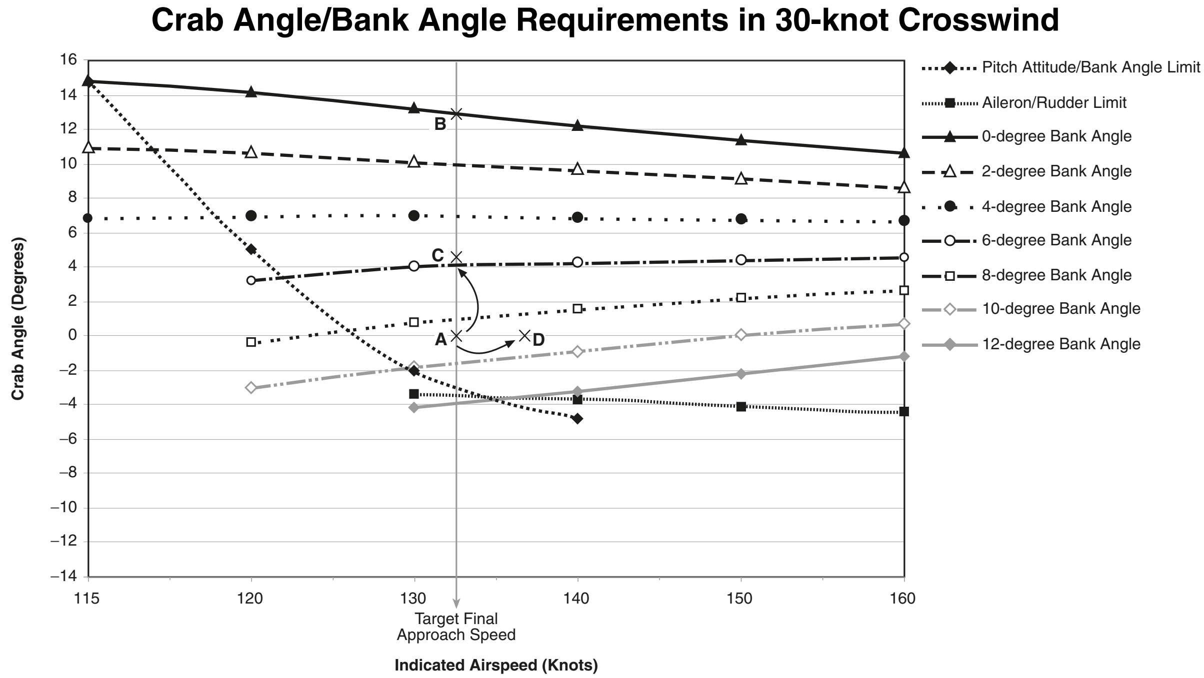
With a 30-knot crosswind component, adopting a combination of sideslip and crab angle with five degrees of crab angle and five degrees of bank angle restores significant safety margins relative to geometry limits and aileron/rudder authority limits while eliminating the risk of landing-gear damage (i.e., moving from point A to point C).

On aircraft models limited by their geometry, increasing the final approach speed (e.g., by applying a wind correction to the final approach speed, even under full crosswind) would increase the safety margin with respect to this limitation (i.e., moving from point A to point D).

Operational Recommendations and Handling Techniques

Figure 2 and Figure 3 show that:

- With a relatively light crosswind (typically up to a 15-knot to 20-knot crosswind component), a safe crosswind landing can be conducted with either:
  - A steady sideslip (no crab); or,
  - Wings level, with no decrab prior to touchdown; and,
- With a strong crosswind (typically above a 15-knot to 20-knot crosswind component), a safe crosswind landing requires a crabbed approach and a partial decrab prior to touchdown.



Examples: A sideslip landing (zero crab angle) requires about a nine-degree bank angle at touchdown (point A). A wings-level landing (no decrab) requires about a 13-degree crab angle at touchdown (point B). Point C represents a touchdown using a combination of sideslip and crab angle (about five degrees of bank angle and about five degrees of crab angle). Point D represents a steady-sideslip landing conducted about four knots above V_{REF}.

Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 3

For most transport category airplanes, touching down with a five-degree crab angle (with an associated five-degree bank angle) is a typical technique in strong crosswinds.

The choice of handling technique should be based on the prevailing crosswind component and on the following factors:

- Wind gusts;
- Runway length;
- Runway surface condition;
- Type of aircraft; and,
- Pilot experience in type.

Touchdown — Friction Forces

Upon touchdown following a crabbed approach down to flare with a partial decrab during flare, the flight deck should be on the upwind side of the runway centerline to ensure that the main landing gear is close to the runway centerline.

After the main landing gear touches down, the aircraft is influenced by the laws of ground dynamics.

The following are among the events that occur upon touchdown:

- Wheel rotation, unless hydroplaning is experienced. Wheel rotation is the trigger for:
  – Automatic-ground-spoiler extension (as applicable);
  – Autobrake system operation; and,
  – Anti-skid system operation.

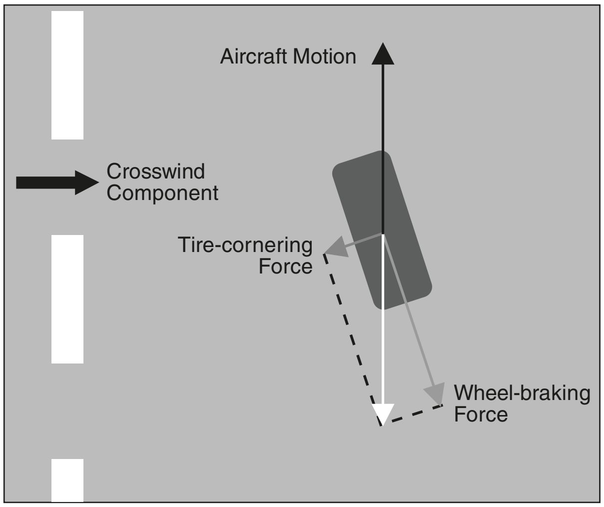
To minimize the risk of hydroplaning and to ensure rotation of the wheels, a firm touchdown should be made when landing on a contaminated runway.

- Buildup of friction forces begins between the tires and the runway surface because of the combined effect of:
  – Wheel-braking forces; and,
  – Tire-cornering forces (Figure 4, page 194).

Wheel-braking forces and tire-cornering forces are based on tire conditions and runway conditions, and also on each other — the higher the braking force, the lower the cornering force, as shown by Figure 5 (page 194).

Transient effects, such as distortion of tire tread (caused by a yawing movement of the wheel) or the activation of the anti-skid system, affect the tire-cornering forces and wheel-braking forces (in both magnitude and direction), and therefore affect the overall balance of friction forces.

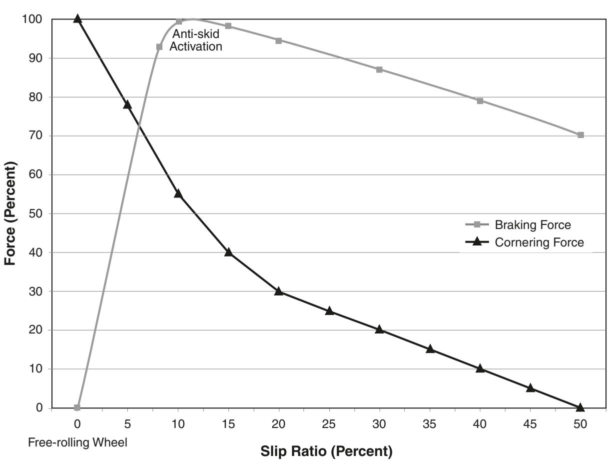
Tire-cornering and Wheel-braking Forces



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 4

Interaction of Tire-cornering and Wheel-braking Forces



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 5

Thus, the ideal balance of forces shown in Figure 3 is maintained rarely during the initial landing roll.

Effect of Touchdown on Alignment

When touching down with some crab angle on a dry runway, the aircraft tends to realign itself with the direction of travel down the runway.

When touching down with some crab angle on a contaminated runway, the aircraft tends to continue traveling with a crab angle along the runway centerline.

Effect of Wind on the Fuselage and Control Surfaces

As the aircraft touches down, the side force created by the crosswind striking the fuselage and control surfaces tends to make the aircraft skid sideways off the centerline (Figure 6, page 195).

Thrust Reverser Effect

When selecting reverse thrust with some crab angle, the reverse thrust results in two force components (Figure 6):

- A stopping force aligned with the aircraft's direction of travel (runway centerline); and,
- A side force, perpendicular to the runway centerline, which further increases the aircraft's tendency to skid sideways.

The thrust-reverser effect decreases with decreasing airspeed.

Rudder authority also decreases with decreasing airspeed and is reduced further by airflow disturbances created by the thrust reversers. Reduced rudder authority can cause directional-control problems.

Effect of Braking

In a strong crosswind, cross-control usually is maintained after touchdown to prevent the into-wind wing from lifting and to counteract the weather-vane effect (i.e., the aircraft's tendency to turn into the wind). (Some flight crew training manuals say that the pilot should continue to "fly the aircraft" during the landing roll.)

However, into-wind aileron decreases the lift on the into-wind wing, thus resulting in an increased load on the into-wind landing gear.

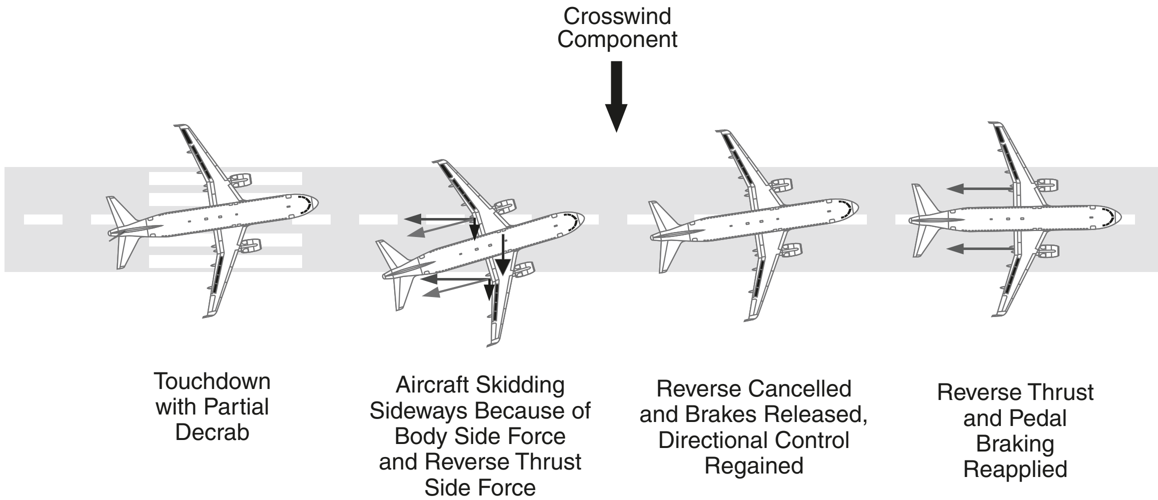
Because braking force increases as higher loads are applied on the wheels and tires, the braking force increases on the into-wind landing gear, creating an additional tendency to turn into the wind (Figure 7, page 195).

When runway contamination is not evenly distributed, the anti-skid system may release only the brakes on one side.

Maintaining Directional Control

The higher the wheel-braking force, the lower the tire-cornering force. Therefore, if the aircraft tends to skid sideways, releasing the brakes (i.e., by taking over from the

Recovery From a Skid Caused by Crosswind and Reverse Thrust Side Forces



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 6

autobrakes) will increase the tire-cornering force and help maintain directional control.

Selecting reverse idle thrust will cancel the side-force component caused by the reverse thrust, will increase rudder authority and will further assist in returning to the runway centerline.

After the runway centerline and directional control have been regained:

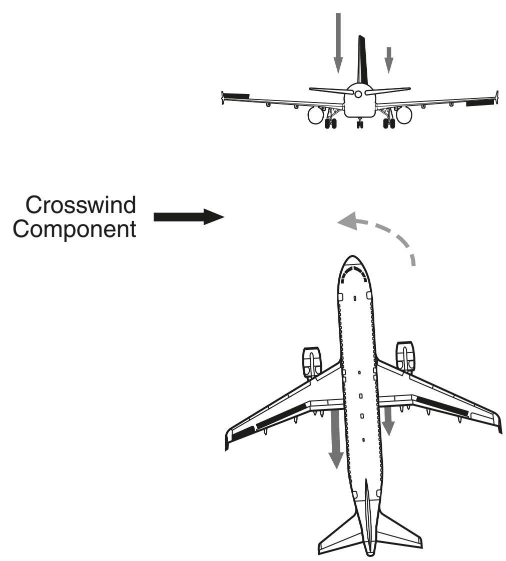
- Pedal braking can be applied (autobrakes were previously disarmed) in a symmetrical or asymmetrical manner, as required; and,
- Reverse thrust can be reselected.

Factors Involved in Crosswind Incidents and Accidents

The following factors often are involved in crosswind-landing incidents and accidents:

- Reluctance to recognize changes in landing data over time (e.g., wind shift, wind velocity/gust increase);
- Failure to seek additional evidence to confirm initial information and initial options (i.e., reluctance to change plans);
- Reluctance to divert to an airport with more favorable wind conditions;
- Insufficient time to observe, evaluate and control aircraft attitude and flight path in a highly dynamic situation; and/or,
- Pitch effect on aircraft with underwing-mounted engines caused by the power changes required in gusty conditions.

Effect of Uneven Braking Forces On Main Landing Gear



Source: Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force

Figure 7

Summary

To increase safety during a crosswind landing, flight crews should:

- Understand all applicable operating factors, recommended maximum values and limitations;
- Use flying techniques and skills designed for crosswind landings;

– A wings-level touchdown (i.e., without any decrab) usually is safer than a steady-sideslip touchdown with an excessive bank angle;

- Request assignment of a more favorable runway if the prevailing runway conditions and crosswind are unfavorable for a safe landing;
- Adjust the autopilot-disconnect altitude for prevailing conditions to provide time to establish manual control and trimming of the aircraft before the align/decrab and flare;
- Detect changes in automatic terminal information service (ATIS) broadcasts and tower messages (e.g., wind shift, wind velocity/gust increase); and,
- Understand small-scale local effects associated with strong winds:
  – Updrafts and downdrafts; and,
  – Vortices created by buildings, trees or terrain.

The following FSF ALAR Briefing Notes provide information to supplement this discussion:

- *8.1 — Runway Excursions and Runway Overruns*;
- *8.2 — The Final Approach Speed*;
- *8.3 — Landing Distances*;
- *8.4 — Braking Devices*;
- *8.5 — Wet or Contaminated Runways*; and,
- *8.6 — Wind Information*.♦

Reference

1 Flight Safety Foundation. "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents." *Flight Safety Digest* Volume 17 (November–December 1998) and Volume 18 (January–February 1999): 1–121. The facts presented by the FSF ALAR Task Force were based on analyses of 287 fatal approach-and-landing accidents (ALAs) that occurred in 1980 through 1996 involving turbine aircraft weighing more than 12,500 pounds/5,700 kilograms, detailed studies of 76 ALAs and serious incidents in 1984 through 1997 and audits of about 3,300 flights.

Related Reading from FSF Publications

Flight Safety Foundation (FSF) Editorial Staff. "Crew Fails to Compute Crosswind Component, Boeing 757 Nosewheel Collapses on Landing." *Accident Prevention* Volume 57 (March 2000).

FSF Editorial Staff. "Unaware of Strong Crosswind, Fokker Crew Loses Control of Aircraft on Landing." *Accident Prevention* Volume 56 (November 1999).

Regulatory Resources

International Civil Aviation Organization. *Preparation of an Operations Manual*. Second edition – 1997.

Joint Aviation Authorities. *Joint Aviation Requirements – Operations 1*, *Commercial Air Transportation (Aeroplanes)*. 1.1045 "Operations Manual – structure and contents." March 1, 1998.

Notice

The Flight Safety Foundation (FSF) Approach-and-landing Accident Reduction (ALAR) Task Force has produced this briefing note to help prevent ALAs, including those involving controlled flight into terrain. The briefing note is based on the task force's data-driven conclusions and recommendations, as well as data from the U.S. Commercial Aviation Safety Team (CAST) Joint Safety Analysis Team (JSAT) and the European Joint Aviation Authorities Safety Strategy Initiative (JSSI).

The briefing note has been prepared primarily for operators and pilots of turbine-powered airplanes with underwing-mounted engines (but can be adapted for fuselage-mounted turbine engines, turboprop-powered aircraft and piston-powered aircraft) and with the following:

- Glass flight deck (i.e., an electronic flight instrument system with a primary flight display and a navigation display);
- Integrated autopilot, flight director and autothrottle systems;
- Flight management system;
- Automatic ground spoilers;
- Autobrakes;
- Thrust reversers;
- Manufacturers'/operators' standard operating procedures; and,
- Two-person flight crew.

This briefing note is one of 34 briefing notes that comprise a fundamental part of the FSF *ALAR Tool Kit,* which includes a variety of other safety products that have been developed to help prevent ALAs.

This information is not intended to supersede operators' or manufacturers' policies, practices or requirements, and is not intended to supersede government regulations.

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Preliminary Data Show Downward Trend In Controlled-flight-into-terrain Accidents Among Large Western-built Commercial Jets

These data also show that approach-and-landing accidents remain a significant safety problem.

FSF Editorial Staff

Preliminary data from The Boeing Co., Airclaims and Don Bateman, chief engineer, flight safety systems, Honeywell International, show that three accidents involving controlled flight into terrain (CFIT) and nine approach-and-landing accidents (ALAs) have occurred from Jan. 1, 2000, to Oct. 15, 2000, to Western-built large commercial jets, those heavier than 60,000 pounds (27,216 kilograms).

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

Boeing's definition differs slightly, describing a CFIT accident as "an event where a mechanically normally functioning airplane is inadvertently flown into the ground, water or obstacle (not on airport property while attempting to land)." The Boeing data include worldwide Western-built large commercial jet airplanes that are heavier than 60,000 pounds maximum gross weight; the data exclude airplanes manufactured in the Commonwealth of Independent States.

Boeing defines a hull loss as damage to an airplane that is substantial and beyond economic repair. Boeing also classifies an airplane as a hull loss if the aircraft is missing, if the wreckage has not been found and the search has been terminated, or if the airplane is substantially damaged and is inaccessible.

Boeing data (Figure 1, page 202) show that in 1990 through 1999, 227 accidents occurred worldwide in the CFIT category or in categories often related to ALAs (aircraft off end of runway on landing, aircraft off side of runway on landing, hard landing, landed short, gear collapse/gear failure/gear up and windshear). Thirty accidents in these categories (7.8 percent of total accidents in all categories) occurred among first-generation airplanes,[1] which had 22.5 accidents per million departures. Eighty-seven accidents in these categories (22.6 percent of total accidents in all categories) occurred among second-generation airplanes,[2] which had 2.2 accidents per million departures. Eighteen accidents in these categories (4.7 percent of total accidents in all categories) occurred among early wide-body airplanes,[3] which had 4.1 accidents per million departures. Ninety-two accidents in these categories (23.9 percent of total accidents in all categories) occurred among current-generation airplanes,[4] which had 1.8 accidents per million departures.

Figure 2 (page 203) shows that 6,655 fatalities occurred worldwide in large Western-built commercial jet accidents in 1990 through 1999 (including 6,464 fatalities aboard airplanes), and 379 of these fatalities occurred aboard airplanes in 1999. CFIT accidents resulted in the largest number of fatalities by category — 2,111, with five in 1999 — and 204 fatalities, 37 in 1999, occurred in the landing category.

Figure 3 (page 204) shows hull-loss accidents, fatal accidents and fatalities on board Western-built large commercial jets during the last four phases of flight (descent, initial approach, final approach and landing). Fifty-nine percent of the accidents and 56 percent of the fatalities occurred during these phases of flight.

Figure 4 (page 205) shows the distribution of 18 events involved in 199 landing accidents among Western-built large commercial jets in 1990 through 1999. The five events reported most often in these accidents were hard landing, aircraft off the side of the runway, aircraft off the end of the runway, wet/icy runway and loss of directional control.

Table 1 (page 199) shows the hull-loss accidents that involved Western-built large commercial jets from Jan. 1, 2000, through Oct. 15, 2000. Fifteen hull-loss accidents occurred worldwide during this period. Seven accidents were survivable accidents with no fatalities.

Table 2 (page 199) shows that seven hull-loss accidents occurred worldwide during the same period to Western-built commercial jets less than 60,000 pounds. Six accidents resulted in one or more fatalities.

Table 3 (page 200) shows that 18 hull-loss accidents occurred worldwide during the same period to Western-built commercial turboprop airplanes with more than 15 seats. Seven of the accidents occurred during approach and landing. Five accidents involved no fatalities; 120 fatalities were reported in the other 13 accidents, an average of nine fatalities per accident.

Table 4 (page 200) shows that three hull-loss accidents, which occurred during this period among Western-built large commercial jets, have been categorized — on a preliminary basis — as involving CFIT during approach. No fatalities occurred in nine of the accidents; 274 fatalities occurred in two accidents.

Figure 5 (page 206) shows that during an approximate 11-year period, the number of CFIT accidents among Western-built large commercial jets has ranged from a low of one in 1999 to a high of seven in 1992 and in 1998, an average of about 3.8 CFIT accidents per year.

Table 5 (page 201) shows that nine hull-loss accidents that occurred worldwide during this period among Western-built large commercial jets were ALAs (based on preliminary categorization). No fatalities occurred in five of the accidents; 335 fatalities occurred in the other four accidents.

Figure 6 (page 206) shows that during an approximate 11-year period, the number of ALAs among Western-built large commercial jets has ranged from a low of seven in 1998 to a high of 18 in 1992, an average of about 12.5 ALAs per year.

Figure 7 (page 207) shows that CFIT accident rates and ALA rates for Western-built large commercial jets have followed a cyclical pattern and that a downward trend in ALAs currently exists based on the three-year moving-average lines.♦

Notes

1. In its definition of first-generation commercial jets, Boeing Commercial Airplanes Group includes the British Aerospace Comet, Boeing 707/720, McDonnell Douglas DC-8, CV-880/-990 and Caravelle.
2. In its definition of second-generation commercial jets, Boeing Commercial Airplanes Group includes the Boeing 727, British Aerospace Trident, British Aerospace VC-10, BAC-111, McDonnell Douglas DC-9, Boeing 737-100/-200 and Fokker F28.
3. In its definition of early wide-body commercial jets, Boeing Commercial Airplanes Group includes the Boeing 747-100/-200/-300/SP, McDonnell Douglas DC-10, Lockheed L-1011 and Airbus A300.
4. In its definition of current-generation commercial jets, Boeing Commercial Airplanes Group includes the McDonnell Douglas MD-80, Boeing 767, Boeing 757, Airbus A310, British Aerospace BAe146, Airbus A300-600, Boeing 737-300/-400/-500, Fokker F100, Airbus A320/319/321, Boeing 747-400, McDonnell Douglas MD-11, Airbus A340, Airbus A330, McDonnell Douglas MD-90, Boeing 777, Boeing 737-NG and Boeing 717.

Table 1
Hull-loss Accidents

Worldwide Large Commercial Jet Airplanes[1]
Jan. 1, 2000–Oct. 15, 2000

Date	Operator	Aircraft	Location	Phase of Flight	Total Fatal
Jan. 30, 2000	Kenya Airways	Airbus A310	Abidjan, Côte d'Ivoire	Climb	169
Jan. 31, 2000	Alaska Airlines	McDonnell Douglas MD-83	Near Oxnard, California, U.S.	Descent	88
Feb. 3, 2000	Trans Arabian Air Transport	Boeing 707-320	Mwanza, Tanzania	Approach	0
Feb. 11, 2000	Air Afrique	Airbus A300B4	Dakar, Senegal	Taxi Out	0
Feb. 12, 2000	TransAfrik	Boeing 727	Luanda, Angola	Approach	0
Feb. 16, 2000	Emery Worldwide	McDonnell Douglas DC-8-71F	Sacramento, California, U.S.	Climb	3
March 5, 2000	Southwest Airlines	Boeing 737-300	Burbank, California, U.S.	Landing	0
April 19, 2000	Air Philippines	Boeing 737-200	Davao, Philippines	Approach	131
April 22, 2000	Turkish Airlines	RJ Avroliner	Siirt, Turkey	Landing	0
April 30, 2000	Das Air Cargo	McDonnell Douglas DC-10-30F	Entebbe, Uganda	Landing	0
July 12, 2000	Hapag-Lloyd	Airbus A310	Vienna, Austria	Descent	0
July 17, 2000	Alliance Air	Boeing 737-200	Patna, India	Landing	57
July 25, 2000	Air France	British Aerospace/ Aerospatiale Concorde	Paris, France	Takeoff	113
Aug. 23, 2000	Gulf Air	Airbus A320	Manama, Bahrain	Approach	143
Oct. 6, 2000	Aeroméxico	McDonnell Douglas DC-9	Reynosa, Mexico	Landing	4
				Total	**708**

Note:

1. Heavier than 60,000 pounds (27,216 kilograms) maximum gross weight; excluding the Commonwealth of Independent States.

Source: The Boeing Co.

Table 2
Hull-loss Accidents

Worldwide Business Jet Airplanes[1]
Jan. 1, 2000–Oct. 15, 2000

Date	Operator	Aircraft	Location	Phase of Flight	Total Fatal
March 26, 2000	Private	CitationJet	Buda, Texas, U.S.	Approach	1
April 5, 2000	Bankair	Learjet 35	Marianna, Florida, U.S.	Landing	3
May 2, 2000	Northern Executive Aviation	Learjet 35	Lyon, France	Landing	2
May 10, 2000	Price Aircraft	Sabreliner	Kaunakaki, Hawaii, U.S.	Approach	6
June 13, 2000	Grand Aire Express	Falcon 20	Peterborough, Ontario, Canada	Landing	0
June 23, 2000	Universal Jet Aviation	Learjet 55	Boca Raton, Florida, U.S.	Climb	3
Aug. 14, 2000	The Colonel's	Sabreliner	Ironwood, Michigan, U.S.	Cruise	2
				Total	**17**

Note:

1. Business, corporate or executive jet operations; less than 60,000 pounds (27,216 kilograms) maximum gross weight; excluding the Commonwealth of Independent States.

Source: Airclaims

Table 3
Hull-loss Accidents

Worldwide Commercial Turboprop Airplanes[1]
Jan. 1, 2000–Oct. 15, 2000

Date	Operator	Aircraft	Location	Phase	Fatal
Jan. 5, 2000	Skypower Express Airways	Embraer EMB-110	Abuja, Nigeria	Landing	2
Jan. 10, 2000	Crossair	Saab 340	Niederhasli, Switzerland	Climb	10
Jan. 13, 2000	Avisto	Shorts Brothers 360	Marsá al Burayqah, Libya	Approach	23
Jan. 15, 2000	Aviones Taxi Aéreo	Let L-410	San Jose, Costa Rica	Climb	4
Feb. 8, 2000	Sabin Air	Embraer EMB-110	Maputo, Mozambique	Initial Climb	1
Feb. 10, 2000	Alp'Azur	DHC-6 Twin Otter	Courchevel, France	Takeoff	0
March 17, 2000	Aeroperlas	DHC-6 Twin Otter	Pico Carreto, Panama	Descent	10
March 17, 2000	Skypower Express Airways	Embraer EMB-110	Kaduna, Nigeria	Landing	0
May 17, 2000	Avirex	Beech 1900	Moanda, Gabon	Approach	3
May 21, 2000	Executive Airlines	Jetstream 31	Wilkes-Barre, Pennsylvania, U.S.	Approach	19
May 25, 2000	Streamline Aviation	Shorts Brothers 330	Paris, France	Taxi	1
June 2, 2000	Paraclub Moorsele	ASTA Nomad	Leopoldsburg, Belgium	Cruise	0
July 1, 2000	Channel Express	Fokker F27	Coventry, England	Landing	0
July 8, 2000	Aerocaribe	Jetstream 31	Villahermosa, Mexico	Descent	19
July 19, 2000	Airwave Transport	Gulfstream I	Linneus, Missouri, U.S.	Climb	2
July 27, 2000	Royal Nepal Airlines	DHC-6 Twin Otter	Dhangarhi, Nepal	Descent	25
July 31, 2000	Win-Win Aviation	DHC-6 Twin Otter	Raleigh, North Carolina, U.S.	Approach	1
Sept. 6, 2000	Aeroperlas	DHC-6 Twin Otter	Río Sidra, Panama	Landing	0
					Total 120

Note:

1. Greater than 15 seats; excluding the Commonwealth of Independent States.

Source: Airclaims

Table 4
Controlled Flight Into Terrain[1] Hull-loss Accidents

Worldwide Large Commercial Jet Airplanes[2]
Jan. 1, 2000–Oct. 15, 2000

Date	Operator	Aircraft	Location	Phase of Flight	Total Fatal
Feb. 3, 2000	Trans Arabian Air Transport	Boeing 707-320	Mwanza, Tanzania	Approach	0
April 19, 2000	Air Philippines	Boeing 737-200	Davao, Philippines	Approach	131
Aug. 23, 2000	Gulf Air	Airbus A320	Manama, Bahrain	Approach	143
					Total 274

Notes:

1. Categorization of accidents for 2000 is preliminary.
2. Heavier than 60,000 pounds (27,216 kilograms) maximum gross weight; excluding the Commonwealth of Independent States.

Source: Don Bateman, Honeywell International

Table 5
Approach and Landing[1] Hull-loss Accidents

Worldwide Large Commercial Jet Airplanes[2]
Jan. 1, 2000–Oct. 15, 2000

Date	Operator	Aircraft	Location	Phase of Flight	Total Fatal
Feb. 3, 2000	Trans Arabian Air Transport	Boeing 707-320	Mwanza, Tanzania	Approach	0
Feb. 12, 2000	TransAfrik	Boeing 727	Luanda, Angola	Approach	0
March 5, 2000	Southwest Airlines	Boeing 737-300	Burbank, California, U.S.	Landing	0
April 19, 2000	Air Philippines	Boeing 737-200	Davao, Philippines	Approach	131
April 22, 2000	Turkish Airlines	RJ Avroliner	Siirt, Turkey	Landing	0
April 30, 2000	Das Air Cargo	McDonnell Douglas DC-10-30F	Entebbe, Uganda	Landing	0
July 17, 2000	Alliance Air	Boeing 737-200	Patna, India	Landing	57
Aug. 23, 2000	Gulf Air	Airbus A320	Manama, Bahrain	Approach	143
Oct. 6, 2000	Aeroméxico	McDonnell Douglas DC-9	Reynosa, Mexico	Landing	4
				Total	**335**

Notes:

1. Categorization of accidents for 2000 is preliminary.
2. Heavier than 60,000 pounds (27,216 kilograms) maximum gross weight; excluding the Commonwealth of Independent States.

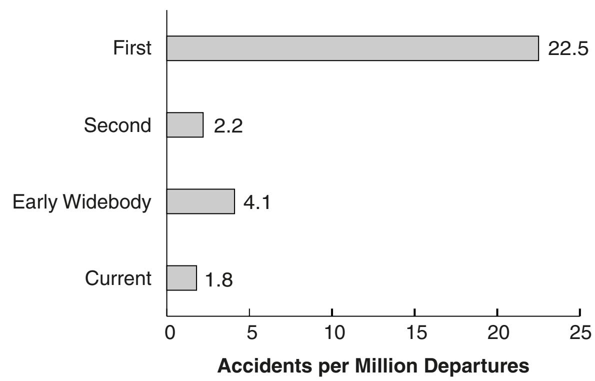
Source: The Boeing Co.

Accident Categories by Airplane Generation

Selected Accidents[1] — Worldwide Large Commercial Jet Operations[2]
1990–1999

Airplane Generation	Controlled Flight Into Terrain	Off End on Landing	Off Side on Landing	Hard Landing	Landed Short	Gear Collapse/Fail/Up	Windshear	Total
First	5	7	3	3	4	8	0	30
Second	17	17	20	15	9	8	1	87
Early Widebody	3	3	3	5	1	2	1	18
Current	11	22	11	32	2	13	1	92
Total	36	49	37	55	16	31	3	227

10-Year Accident Rate by Airplane Generation



Airplane Generation

First	British Aerospace Comet, Boeing 707/720, McDonnell Douglas DC-8, CV-880/-990, Caravelle
Second	Boeing 727, British Aerospace Trident, British Aerospace VC-10, BAC-111, McDonnell Douglas DC-9, Boeing 737-100/-200, Fokker F28
Early Widebody	Boeing 747-100/-200/-300/SP, McDonnell Douglas DC-10, Lockheed L-1011, Airbus A300
Current	McDonnell Douglas MD-80, Boeing 767, Boeing 757, Airbus A310, British Aerospace BAe146, Airbus A300-600, Boeing 737-300/-400/-500, Fokker F100, Airbus A320/319/321, Boeing 747-400, McDonnell Douglas MD-11, Airbus A340, Airbus A330, McDonnell Douglas MD-90, Boeing 777, Boeing 737-NG, Boeing 717

Note:

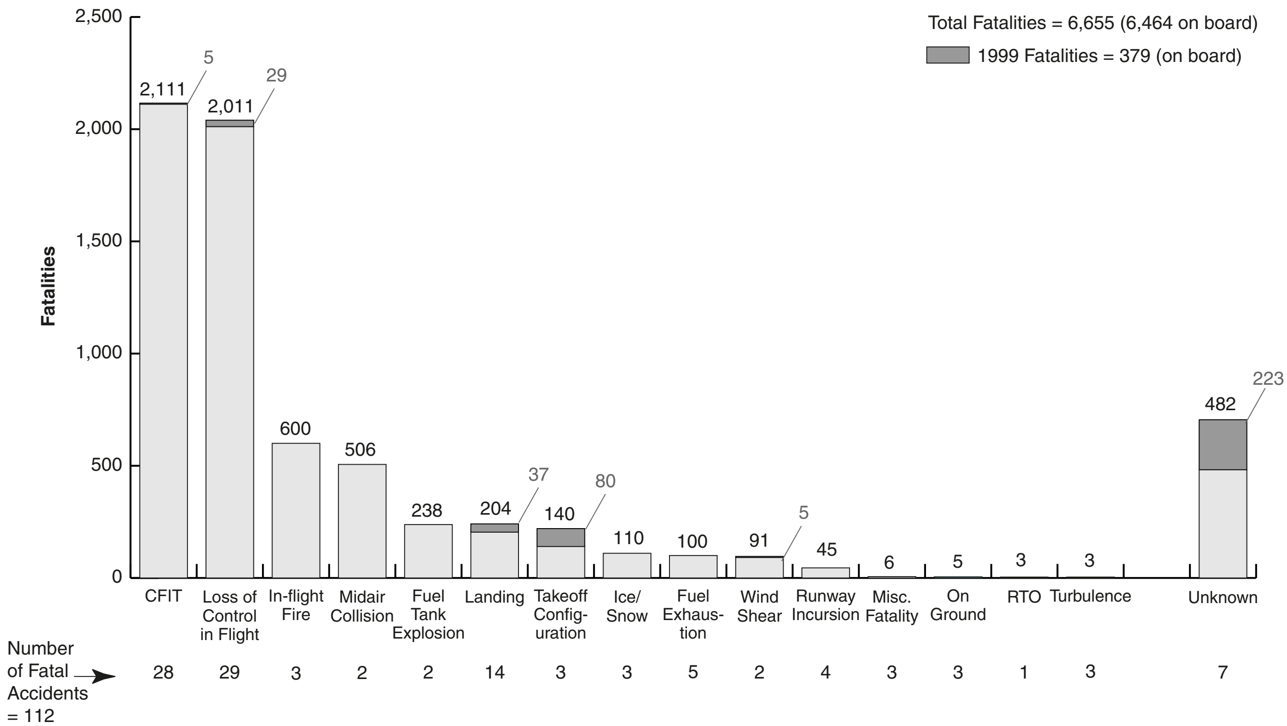
1. Boeing source data show 385 accidents in 27 categories for this time period.
2. Heavier than 60,000 pounds (27,216 kilograms) maximum gross weight; excluding the Commonwealth of Independent States.

Source: Boeing Commercial Airplanes Group

Figure 1

Fatalities by Accident Categories

Fatal Accidents[1] — Worldwide Large Commercial Jet Fleet[2]
1990–1999



CFIT = Controlled flight into terrain
RTO = Refused takeoff

Notes:
1. Accidents involving multiple, non-onboard fatalities are included. Accidents involving single, non-onboard fatalities are excluded.
2. Heavier than 60,000 pounds (27,216 kilograms) maximum gross weight; excluding the Commonwealth of Independent States.

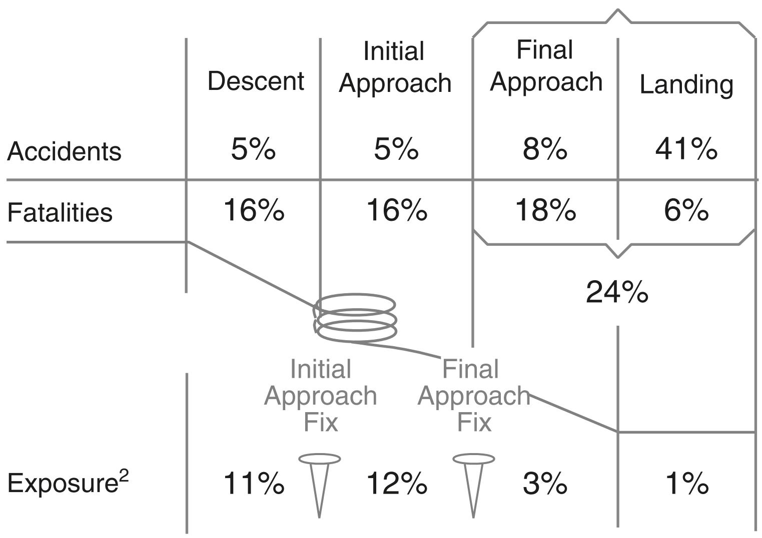
Source: Boeing Commercial Airplanes Group

Figure 2

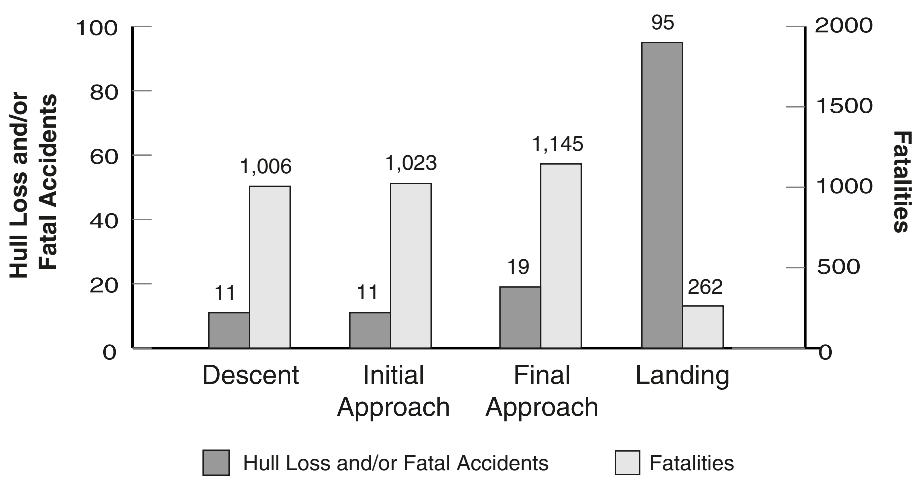
Accidents and On-board Fatalities by Phase of Flight

Hull Loss and/or Fatal Accidents
Worldwide Large Commercial Jet Fleet[1]
1990–1999

Percentage of Accidents/Fatalities



Distribution of Accidents and Fatalities



Note:

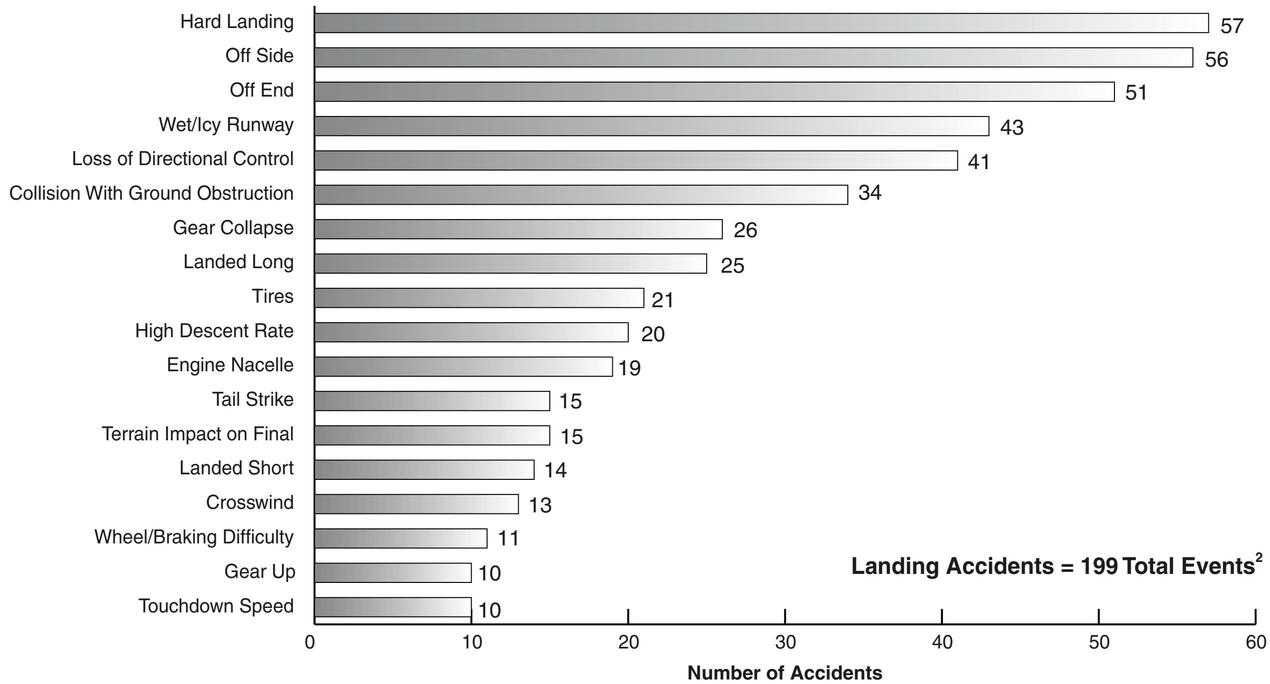
1. Heavier than 60,000 pounds (27,216 kilograms) maximum gross weight; excluding the Commonwealth of Independent States.
2. Exposure = Percentage of flight time based on flight duration of 1.5 hours.

Source: Boeing Commercial Airplanes Group

Figure 3

Landing Accidents by Event Descriptor

Worldwide Large Commercial Jet Operations[1]
1990–1999



Notes:

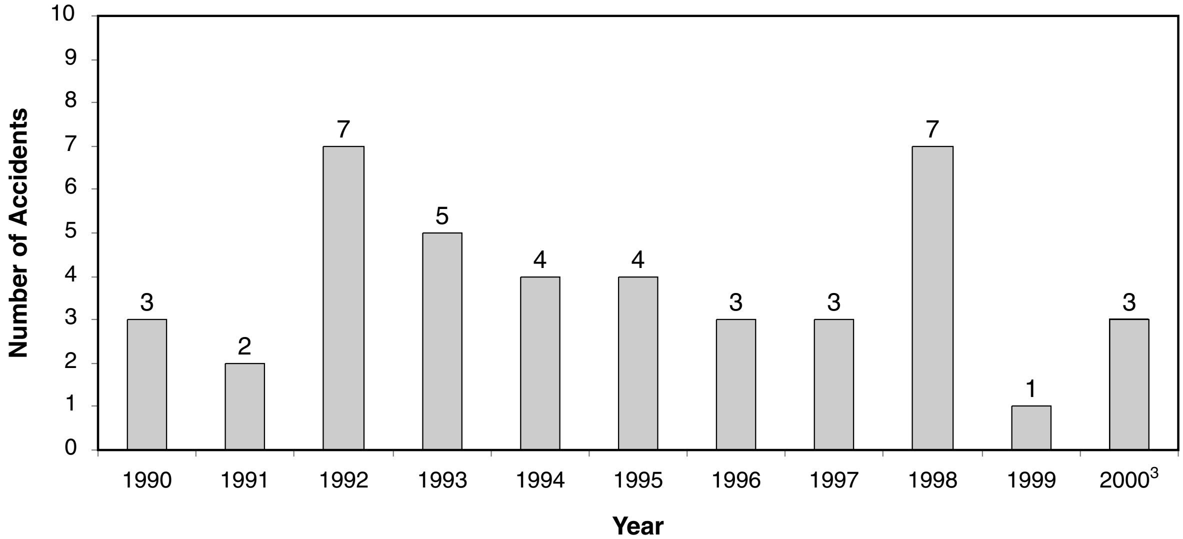
1. Heavier than 60,000 pounds (27,216 kilograms) maximum gross weight; excluding the Commonwealth of Independent States.
2. Each event may involve more than one event descriptor; therefore, the sum of the items may be more than the total accidents of this type.

Source: Boeing Commercial Airplanes Group

Figure 4

Controlled-flight-into-terrain[1] Hull-loss Accidents

Worldwide Large Commercial Jet Airplanes[2]
1990–2000[3]



Notes:

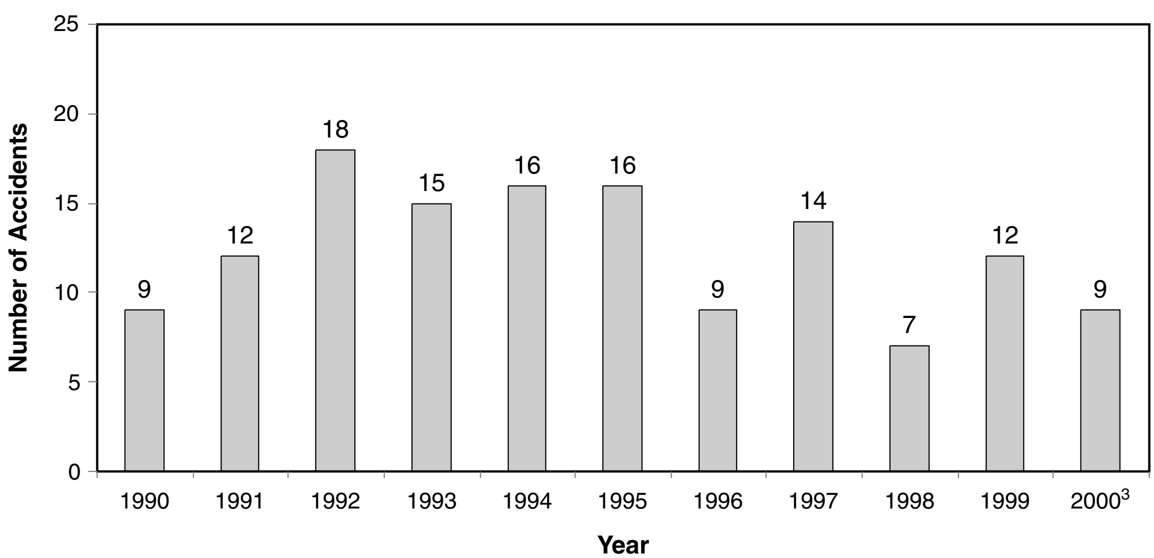
1. Categorization of accidents for 2000 is preliminary.
2. Heavier than 60,000 pounds (27,216 kilograms) maximum gross weight; excluding the Commonwealth of Independent States.
3. Accidents through Oct. 15, 2000.

Source: Don Bateman, Honeywell International

Figure 5

Approach-and-landing[1] Hull-loss Accidents

Worldwide Large Commercial Jet Airplanes[2]
1990–2000[3]



Notes:

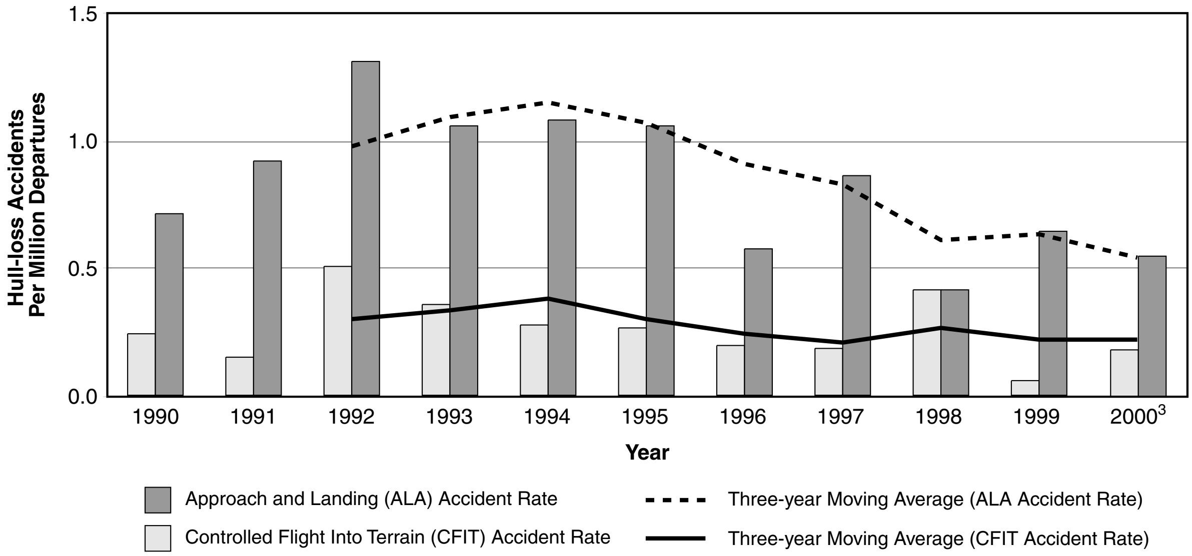
1. Categorization of accidents for 2000 is preliminary.
2. Heavier than 60,000 pounds (27,216 kilograms) maximum gross weight; excluding the Commonwealth of Independent States.
3. Accidents through Oct. 15, 2000.

Source: The Boeing Co.

Figure 6

Controlled-flight-into-terrain and Approach-and-landing[1] Hull-loss Accidents

Worldwide Large Commercial Jet Airplanes[2]
1990–2000[3]



Notes:

1. Categorization of accidents for 2000 is preliminary.
2. Heavier than 60,000 pounds (27,216 kilograms) maximum gross weight; excluding the Commonwealth of Independent States.
3. Accidents through Oct. 15, 2000.

Source: The Boeing Co.

Figure 7

Publications Received at FSF Jerry Lederer Aviation Safety Library

FAA Publishes Specifications for Portable Boarding Devices

The publication includes recommendations for the design of equipment used to help airline passengers whose mobility is impaired.

Advisory Circulars

Guide Specification for Devices Used to Board Airline Passengers With Mobility Impairments. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5220-21B. March 17, 2000. 9 pp. Available through GPO* and DOT.**

This AC contains performance standards, specifications and recommendations for the design, construction and testing of portable devices used to help passengers with mobility impairments to board airliners. Design criteria in the guide discuss two classes of devices: those that are self-propelled and those that are manually transported or towed. The document does not address passenger-loading bridges. The portion of the AC that pertains to lifts was developed in coordination with the Canadian General Standards Board CAN/CGSB-189.1-95, *Lifting Systems for Aircraft Boarding of Passengers With Mobility Impairments*. Equipment specifications meet boarding-device requirements contained in U.S. Department of Transportation regulations Part 27 and U.S. Federal Aviation Regulations Part 382. This AC cancels AC 150/5220-21A, *Guide Specification for Lifts Used to Board Airline Passengers With Mobility Impairments*, dated July 26, 1996. [Adapted from AC.]

Reports

Aviation Safety: Safer Skies Initiative Has Taken Initial Steps to Reduce Accident Rates by 2007. Report to the Subcommittee on Aviation, Committee on Transportation and Infrastructure, U.S. House of Representatives. June 2000. Report GAO/RCED-00-111. 101 pp. Figures, tables, appendix. Available through GAO.***

The U.S. General Accounting Office (GAO) reviewed the implementation of the U.S. Federal Aviation Administration Safer Skies initiative to reduce the fatal aviation accident rate by 2007. Safer Skies, developed in 1998 to unify government and industry efforts, addresses six major safety problems in commercial aviation: loss of control, approach-and-landing accidents, controlled flight into terrain, runway incursions, weather and uncontained engine failures.

The GAO report recommended that the Safer Skies program develop quantifiable performance measures to evaluate the effectiveness of the accident-reduction efforts and that the program study growth and technical changes within the industry to anticipate change-related problems. The report also said that data from past accidents and incidents alone may not be an adequate predictor of the future. [Adapted from report.]

National Airspace System: Persistent Problems in FAA's New Navigation System Highlight Need for Periodic Reevaluation. Report to the Chairman, Subcommittee on Transportation, Committee on Appropriations, U.S. Senate. June 2000. Report GAO/RCED/AIMD-00-130. 38 pp. Figures, tables, appendixes. Available through GAO.***

Plans are underway for the U.S. Federal Aviation Administration (FAA) to transition from an aging, ground-based navigation system to the satellite-based Global Positioning System (GPS). FAA officials believe that, even with planned improvements, GPS will not satisfy all requirements for safe aircraft operations. The report by the U.S. General Accounting Office discusses concerns about costs of improving the GPS program, scheduling, performance goals and technologies. [Adapted from report.]

Refractive Surgery in Aircrew Members Who Fly for Scheduled and Nonscheduled Civilian Airlines. Nakagawara, Van B.; Wood, Kathryn J.; Montgomery, Ronald W. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine. Report DOT/FAA/AM-00/19. May 2000. 8 pp. Figures, tables. Available through NTIS.****

Keywords
1. Aviation
2. Vision
3. Refractive Surgery
4. Aeromedical Certification
5. Occupational Health

The authors reviewed aeromedical certification and medical records of U.S. civil aircrew members who had undergone refractive surgery. Of 114 airline pilots and flight engineers who had undergone refractive surgery, 97 had incisional procedures, 15 had laser procedures and two had complex surgical procedures. Three airmen experienced serious complications, including problems with depth perception, a perforated cornea and a condition that resulted in a cataract. Nevertheless, the report said that, although some serious complications have resulted, the complications have not affected the ability of most pilots or flight engineers to receive medical certificates. [Adapted from abstract and report.]

Prevalence of Drugs and Alcohol in Fatal Civil Aviation Accidents Between 1994 and 1998. Canfield, Dennis V.; Hordinsky, Jerry; Millett, David P.; Endecott, Boyd; Smith, Dudley. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine. Report DOT/FAA/AM-00/21. June 2000. 6 pp. Tables. Available through NTIS.****

Keywords
1. Forensic Science
2. Toxicology
3. Drugs
4. Prevalence
5. Aviation

As required by law, the FAA Civil Aeromedical Institute (CAMI) monitors the use of alcohol and drugs in aviation. CAMI collects toxicology data by analyzing specimens from pilots who died in aviation accidents and stores the data in computer databases for future use. This report uses the data to compare the prevalence of drugs and alcohol in fatal accidents in five-year and 10-year periods. Tables show alcohol, drug and medication use by pilot class, drug class and substance schedule.

Priorities, Organization, and Sources of Information Accessed by Pilots in Various Phases of Flight. Schvaneveldt, Roger; Beringer, Dennis B.; Lamonica, John; Tucker, Richard; Nance, Christopher. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine. Report DOT/FAA/AM-00/26. 31 pp. Figures, tables, appendixes. Available through NTIS.****

Keywords
1. Flight Information
2. Pathfinder Analysis
3. Clustering of Flight Information
4. Priorities of Flight Information

The authors discussed two projects involving a study of information sources used by pilots during flight, with the objective of specifying what information pilots need, during which phase of flight the information is needed and how pilots organize the information. In the first project, 27 pilots were asked to rate 29 information elements during seven phases of flight. The results revealed the pilots' shifting priorities during flight. In the second project, 34 pilots participated in collecting data for 231 pairs of information elements. The authors discussed the data's potential for use in several areas, including instrumentation layout, integration of cockpit information systems and development of curriculum for flight instructors. [Adapted from abstract and report.]♦

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*Superintendent of Documents
U.S. Government Printing Office (GPO)
Washington, DC 20402 U.S.
Internet: www.access.gpo.gov

**U.S. Department of Transportation (DOT)
Subsequent Business Office
Annmore East Business Center
3341 Q 75th Ave.
Landover, MD 20785 U.S.
Internet: www.faa.gov

***U.S. General Accounting Office (GAO)
P.O. Box 37050
Washington, DC 20013 U.S.
Internet: www.gao.gov

****National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161 U.S.
Internet: www.ntis.org

Updated U.S. Federal Aviation Administration (FAA) Regulations and Reference Materials

Advisory Circulars

AC No.	Date	Title
147-2FF	Sept. 20, 2000	*FAA Certificated Aviation Maintenance Technician Schools Directory*. [Cancels AC 147-2EE, *Directory of FAA Certificated Aviation Maintenance Technician Schools*, dated March 12, 1999.]
120-71	Aug. 10, 2000	*Standard Operating Procedures for Flight Deck Crewmembers.*
61-89E	Aug. 4, 2000	*Pilot Certificates: Aircraft Type Ratings*. [Cancels AC 61-89D, *Pilot Certificates: Aircraft Type Ratings*, dated Feb. 21,1991.]
25-24	Aug. 2, 2000	*Sustained Engine Imbalance.*
121-29B	July 24, 2000	*Carry-on Baggage.* [Cancels AC 121-24A, *Carry-on Baggage*, dated June 25, 1998.]
00-61	July 24, 2000	*Event Planning Guide.*
21-2J	June 27, 2000	*Export Airworthiness Approval Procedures*. [Cancels AC 21-2H, *Export Airworthiness Approval Procedures*, dated Sept. 6, 1995.]
65-30	June 27, 2000	*Overview of the Aviation Maintenance Profession*.
23-18	June 14, 2000	*Installation of Terrain Awareness and Warning System (TAWS) Approved for Part 23 Airplanes.*
60-25D	June 9, 2000	*Reference Materials and Subject Matter Knowledge Codes for Airman Knowledge Testing*. (Cancels AC 60-25C, *Reference Materials and Subject Matter Knowledge Codes for Airman Knowledge Testing,* dated Aug. 23, 1999.)
60-26B	June 8, 2000	*Announcement of Availability: Flight Standards Service Airman Training and Testing Information*. (Cancels AC 60-26A, *Announcement of Availability: Flight Standards Service Airman Training and Testing Information*, dated Feb. 26, 1997, and AC 60-27, *Announcement of Availability: Changes to Practical Test Standards*, dated Nov. 18, 1996.)
20-143	June 6, 2000	*Installation, Inspection, and Maintenance of Controls for General Aviation Reciprocating Aircraft Engines.*
25-23	May 22, 2000	*Airworthiness Criteria for the Installation Approval of a Terrain Awareness and Warning System (TAWS) for Part 25 Airplanes.*
150/5345-26C	April 17, 2000	*FAA Specification for L-823, Plug and Receptacle, Cable Connectors*. (Cancels AC 150/5345-26B, *Specification for L-823 Plug and Receptacle, Cable Connectors*, dated Jan. 28, 1981.)
25-22	March 14, 2000	*Certification of Transport Airplane Mechanical Systems*. (Cancels AC 25-14, *High Lift and Drag Devices*, dated May 4, 1988.)
21-29B	March 13, 2000	*Detecting and Reporting Suspected Unapproved Parts.*

International Reference Updates

Airclaims

Supplement No.	Date	
122	Sept. 18, 2000	Updates *Major Loss Record.*
121	Sept. 21, 2000	Updates *World Aircraft Accident Summary.*
120	June 8, 2000	Updates *Major Loss Record.*
119	June 2000	Updates *World Aircraft Accident Summary.*

Accident/Incident Briefs

Uncommanded Engine Shutdowns Prompt Emergency Landing

Two of the DC-8's engines flamed out as the airplane was being flown over the Atlantic Ocean after departure from an airport in the Caribbean.

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

Engines Restarted During Return to Departure Airport

Douglas DC-8. No damage. No injuries.

Visual meteorological conditions prevailed and an instrument flight rules flight plan had been filed for the pre-dawn flight from an airport in the Caribbean. The airplane was in cruise flight at Flight Level (FL) 390 over the Atlantic Ocean, about 170 nautical miles (315 kilometers) from the departure airport, with climb thrust set to about 95 percent N_1 (low-pressure compressor speed) when the flight crew disengaged the ignition override. About two minutes later, the no. 3 engine had an uncommanded shutdown.

The captain said that he executed the "phase one" items and re-engaged the ignition override to "all engines." During descent to FL 350, the no. 4 engine had an uncommanded shutdown. The flight crew performed the second engine-failure "phase one" items, declared an emergency and received vectors to fly the airplane to the departure airport. As the airplane descended through FL 220, both engines were restarted. They operated normally for the remainder of the flight, and the landing was normal.

Landing Gear Collapses During Takeoff Roll

Boeing 747. Substantial damage. No injuries.

The airplane was beginning a takeoff roll on a runway at an airport in Italy when the right-main landing gear collapsed. The airplane veered to the right and came to a stop with one engine touching the runway.

An airline official said that the collapse probably was caused by torsional failure "at the upper end of one of the landing-gear cylinders." He said that the torsional failure might have been a result of corrosion or a stone chip.

Pitch Oscillations Prompt Aircraft's Removal From Service

Boeing 747. No damage. No injuries.

The airplane was in cruise flight at Flight Level 370 during an early-morning flight from the United States to England when the flight crew observed that vertical-speed indications on each pilot's primary flight display were fluctuating about plus or minus 200 feet per minute. (Actual altitude deviation during the fluctuations was less than 100 feet.) Because the pilots of other aircraft in the area had reported clear air turbulence, the flight crew initially regarded the altitude fluctuations as weather-related.

Later, the captain observed that “the motion at the rear of the flight deck felt different [than] normal,” the report said. The crew disengaged the autopilot and engaged a different autopilot, but the vertical speed fluctuations continued, now at about plus or minus 300 feet per minute. The pitch oscillations persisted at irregular intervals during the crew’s use of a third autopilot and during a period of hand-flying.

“The [captain] reported that, during manual handling, the control column felt very stiff to move in the required direction and, after the exertion of considerable pressure, would become free and the aircraft would respond immediately, then requiring opposite control input,” the report said.

Because the captain was concerned about the possible effects of the pitch-control problem during the landing flare, he declared “pan, pan” (urgency) status with air traffic control and was given a priority approach. As a precaution, passengers were told to adopt the “brace” position for landing.

The first officer assisted with flight control pitch inputs during the landing, and the touchdown was described as “smooth and accurate.” Shortly after the airplane was taxied clear of the runway, a flight attendant reported smoke and a burning odor in the cabin. An external inspection revealed no abnormal indications, but as the airplane continued to taxi, smoke was reported coming from the no. 4 engine. Subsequent inspection revealed that the burning odor in the cabin was tire smoke that resulted from the full autobrake landing and that smoke from the no. 4 engine came from the oil breather and was not an unusual event.

Information from the flight data recorders (FDRs) confirmed that the aircraft had experienced periods of pitch oscillations, but an examination of the aircraft’s pitch control and trim system revealed no defects. The problem did not recur during a test flight, but a lack of synchronization of elevator positions was observed and was repaired.

The airplane was returned to service and was operated with no apparent problems for five days. Then, an analysis of recorded data confirmed that pitch oscillations similar to those of the incident flight were continuing during autopilot operations. The airplane was withdrawn from service for further inspection, which determined that ball bearings in one inboard-elevator power-control unit (PCU) were corroded. The corrosion was attributed to condensation that penetrated the PCU dust seals and washed lubricant from the top bearing onto the lower bearing, leading to corrosion of both bearings. The report said that the corrosion probably resulted in reduced movement of the entire pitch-control mechanism for each correction signal from the autopilot. The reduced rate at which the aircraft returned to the correct pitch attitude would have initiated a series of responses that resulted in pitch oscillations, the report said.

The report said that analysis of the FDR data was the only means of identifying the defect before it was experienced by a flight crew. The manufacturer of the PCUs had addressed the bearing corrosion by changing to stainless steel bearings with better drainage, and issued a product improvement document to inform aircraft operators of the change. The report said, however, that because PCUs are dismantled infrequently, operators have few opportunities to assess their condition. The aircraft manufacturer issued a service letter Aug. 31, 2000, recommending that operators install the stainless steel bearings at their next opportunity.

Air Taxi Commuter

Bird Strike Damages Wing Leading Edge

De Havilland DHC-6-300. Substantial damage. No injuries.

The airplane was being flown on the downwind portion of the landing approach to an airport in the United States. Night visual meteorological conditions prevailed.

The airplane was about 1,800 feet above sea level when the flight crew observed several birds, then felt an impact. After landing, they observed damage to the left wing leading edge and found small portions of a bird on the leading edge.

Examination of the wing revealed that the leading edge was dented, the upper wing surface was wrinkled and two nose ribs had been broken.

Crew Fails in Efforts to Extend Landing Gear

Lockheed L382-G. Substantial damage. No injuries.

When the flight crew moved the landing gear switch to the down position in preparation for landing at an airport in Australia, the left-main landing-gear position indicator indicated that the landing-gear position was unsafe. The crew recycled the landing-gear switch, but the left-main landing-gear position indicator continued to indicate that the landing-gear position was unsafe. The flight crew conducted checks that confirmed that the left-main landing gear had failed to extend.

The crew used emergency gear-extension procedures and attempted to lower the landing gear hydraulically by overriding the landing-gear-selector valve, but those attempts were unsuccessful.

"The crew then attempted to extend the landing gear manually, but the emergency engaging handle could not be moved," the report said. "The manual-selection system appeared jammed, and consequently, the selection could not be made. They then attempted to lower the landing gear by disconnecting the universal joints on the vertical-torque shafts of the left-main landing gear. However, the castellated nuts on the rear-wheel vertical-torque shaft universal joint could not be unwound without the use of spanners, and after about 30 [minutes], only two of the four bolts had been undone."

By that time, the airplane's fuel supply was low, and the captain decided that there was insufficient time to remove the remaining bolts before a landing would be required. The crew then retracted the nose landing gear and the right-main landing gear and landed the airplane.

Corporate Business

Loss of Power Prompts Fatal Forced Landing on Basketball Court

Piper PA-32-260. Airplane destroyed. Five fatalities.

Visual meteorological conditions prevailed for the mid-morning departure from an airport in Ecuador. Witnesses said that, during the initial climb, they heard engine power fluctuate and saw the airplane gliding with its propeller stopped as the pilot maneuvered to avoid buildings in a downtown business district.

The airplane struck a telephone post before impacting an outdoor basketball court. A postaccident fire destroyed the airplane. The accident killed the pilot and all four passengers.

Leaking Hydraulic Fluid Found After Airplane Rolls off Runway

Learjet 60. Substantial damage. No injuries.

Night visual meteorological conditions prevailed for the second segment of a flight that followed maintenance on the airplane. Two miles from the destination airport in the United States, the crew told air traffic control that the airplane had a hydraulic problem.

They landed the airplane at the destination airport. After touchdown, the airplane rolled off the departure end of the runway and struck a localizer antenna array.

Examination of the airplane revealed that the actuator-extend hose-line connector for the left-main landing gear and the right-main landing gear were not torqued to specifications and that the left-main landing-gear actuator-extend hose-line connector was leaking hydraulic fluid.

Controller's Action Stops Crew From Landing at Wrong Airport

Cessna Citation 550. No damage. No injuries.

The flight crew was flying a very-high-frequency omnidirectional radio (VOR) approach to an airport in Northern Ireland in early afternoon and had received clearance to land on Runway 7. An air traffic controller observed that the air traffic monitor showed that the airplane was south of the typical approach track at a lower altitude than typical.

"The controller asked if the crew had the approach lights in sight," the report said. "[T]he crew responded that they had the runway in sight but no approach lights. The controller then advised the crew that there was a similar airfield three [nautical] miles [5.6 meters] to the west … and to advise her when they could see the approach lights."

The crew said that they could see no lights but that they were on short final approach. The controller then instructed the crew to go around and to climb to 3,000 feet. After the climb, the crew told the controller that they could see approach lights on their left, and they received clearance for a visual approach to Runway 7.

On several previous occasions, pilots had mistaken the other, private airport (with Runway 8/26 and Runway 3/21) for the larger airport.

"Because of this, the ATIS [automatic terminal information system] … was advising pilots of the existence of [the private airport] and that Runway 7 … would have its approach lights illuminated," the report said. "On this occasion, close monitoring and effective action by the controller stopped the crew … from landing at [the wrong airport]."

Other General Aviation

Parked Aircraft Struck By Airplane Being Prepared for Instructional Flight

Piper PA-34-200T. Minor damage. No injuries.

A student pilot applied the parking brakes before starting the engines for a night training flight from an airport in England. An instructor occupied the other front seat; another student pilot sat in back.

When the engines were started, both the student pilot and the instructor applied the foot brakes, and the instructor looked out the window to ensure that the airplane did not move. Then the instructor transferred his attention inside the cockpit as the student pilot conducted more pretaxi checks. When the instructor realized that the airplane was yawing to the left, he closed both throttles.

The instructor and the students observed that the airplane had collided with a parked Piper PA-28, with the left propeller damaging the PA-28 rudder and tail cone and the right propeller damaging the PA-28 right aileron. The left engine on the PA-34-200T had stopped, and the pilots shut down the right engine. The instructor said that the parking brake apparently had not been applied fully. Because of darkness, he had no sensation and no visual cues that the airplane was moving until he observed the abrupt yawing movement.

Airplane Strikes Terrain During Photo Flight

Cessna 172R. Airplane destroyed. Four fatalities.

Visual meteorological conditions prevailed for the afternoon flight from an airport in Australia. Photographs taken from the airplane during the flight indicated that the pilot had conducted a number of steep turns, and witnesses in several locations saw the airplane turning.

Radar information showed that the airplane was flown in a series of left turns between 550 feet and 950 feet above ground level. Witnesses said that, during the final turn, the airplane's angle of bank steepened before the airplane pitched nose-down. The airplane was destroyed when it struck the ground.

An investigation revealed that the engine was producing power at the time of the impact and that there were no pre-existing defects that could have affected the airplane's operation. The airplane flight manual said that a stall during a steep turn causes both the airplane's nose and a wing to drop. The maneuver described by witnesses was consistent with a stall during a steep left turn. Turbulence and wind gusts to 27 knots were reported at the time of the accident, when the temperature was 33 degrees Celsius (91 degrees Fahrenheit); the accident report said that those conditions would have reduced the airplane's performance and made stall recovery more difficult.

Airplane Veers off Runway After Landing; Brake Failure Blamed

Champion 7GCAA. Substantial damage. No injuries.

The airplane was flown on a morning flight in visual meteorological conditions to an airport in the United States. The pilot said that the landing at the destination airport was normal until he applied the brakes during the rollout, and the left brake did not engage.

The airplane veered off the runway to the right. The pilot took his foot off the right brake pedal in an attempt to keep the airplane traveling straight ahead, then applied the right brake again to steer around a hill in the airplane's path. The pilot said that he had not observed a ditch on the left side of the airplane and that, when the airplane's left wheel entered the ditch, the left wing was bent.

Faulty Brake Valve Blamed for Airplane's Departure From Runway

Beech 58. Minor damage. No injuries.

The airplane was being taxied to the departure end of the runway in preparation for takeoff. As the pilot applied the brakes to aid in a turn to align the airplane with the runway centerline, the airplane rolled toward the edge of the tarmac and onto the grass.

The pilot said that, when he applied the right brake, no braking occurred, and that he shut down both engines in an attempt to stop the airplane's movement. The left propeller was still turning as the left-main wheel left the tarmac and sank into the ground, and the left propeller struck the edge of the tarmac.

Tests by maintenance personnel revealed that, although the brakes worked properly when the left pedal and right pedal were pressed simultaneously, there was no braking action on the right-main landing wheel when only the right-brake pedal was applied. They said that the braking characteristics indicated that the right-brake shuttle valve was defective, although no wear or damage was found. The right-brake shuttle valve was replaced, and full braking was restored.

Rotorcraft

Helicopter Strikes Terrain During Ferry Flight

Bell 47J-2A. Helicopter destroyed. Two fatalities.

Visual meteorological conditions prevailed for the mid-morning flight from an airport in Australia. The flight was one of a series of ferry flights to be conducted over three days. The pilots planned at least four refueling stops, and the helicopter carried seven 20-liter (5.3-gallon) containers of fuel.

When the helicopter did not arrive at the destination, a search was begun. The burned wreckage was found in flat, open land about 150 nautical miles (278 kilometers) from the previous refueling stop.

The postimpact fire, fed by fuel from the fuel containers, destroyed the cockpit and the forward section of the tail boom. The engine also had received significant impact damage and external fire damage, but the internal components were capable of normal operation.

Examination of the wreckage revealed no pre-existing defects that might have contributed to the accident. The accident report said that main-rotor speed probably was too low for a controlled descent, that one fuel tank contained a "minute quantity" of fuel and that the other fuel tank was empty. The rest of the fuel system was damaged extensively by fire. Investigators could not determine whether there had been a fuel leak during the flight or how much fuel had been in the tanks after the previous refueling.

Fuel Starvation Prompts Landing; Auxiliary Tank Full

Aerospatiale SA-341G. Minor damage. No injuries.

The helicopter was flown from a private landing site in England with about 80 liters (21 gallons) of fuel in the main tank. The 90-liter (24-gallon) auxiliary tank was full. The standard procedure was to transfer fuel from the auxiliary tank to the main tank when there was less than 100 liters (26 gallons) of fuel in the main tank, but the pilot said that the transfer sometimes was delayed until the "fuel" warning light illuminated, indicating that 50 liters (13 gallons) of fuel remained in the main tank. (Main tank fuel capacity is 455 liters [120 gallons].)

About 25 minutes after departure, the helicopter's engine failed because of fuel starvation. The pilot prepared to land the helicopter in a field and conducted an autorotation. When he applied additional collective control to avoid a stone wall, the main-rotor speed decreased. The helicopter landed hard and bounced, and two main-rotor blades struck the three vertical stabilizer surfaces.

The pilot said that he had not transferred fuel from the auxiliary tank, which was full at the time of the accident.

Ground Worker Electrocuted During External-load Operation

Bell UH-1B. No damage. One fatality.

The helicopter was being flown in visual meteorological conditions to perform external-load operations in the United States.

The pilots hovered the helicopter near high-voltage wires with a 110-foot (34-meter) cable attached to the helicopter and to a load of steel beams on the ground.

The company's chief pilot occupied the right seat to provide guidance to the pilot flying, who was flying the helicopter from the left seat for the first time. Two members of a ground crew secured the lifting cable to the load of beams. Before the helicopter began to lift the load, a "slight amount of slack" was in the lifting cable, which touched an electrical wire about 50 feet (15 meters) above the ground. One of the ground crewmembers, who was holding the helicopter long-line cable and waiting to attach it to the load straps, was electrocuted.

The left-seat pilot — who had 15,000 flight hours in helicopters — said that he had begun work at the construction site two days before the accident flight, flying a McDonnell-Douglas 500. The day before the accident, he was the second pilot (right-seat pilot) of the accident helicopter for about one hour during external-load operations. On the day of the accident, he flew the accident helicopter from the left seat for about one hour and conducted about nine lifts before the accident. He said that he had not known that the electrical wires at the construction site were energized. The chief pilot said that he had known that the wires were energized.♦

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