CHAPTER 2. ALL-WEATHER TERMINAL AREA OPERATIONS

SECTION 3. FACTORS AFFECTING ALL-WEATHER TERMINAL AREA OPERATIONS

471. GENERAL FACTORS AFFECTING OPERATING MINIMUMS. The external visual references necessary for controlling an aircraft solely by visual means are not available throughout an instrument approach and landing operation in instrument conditions. Therefore, the pilot must control the aircraft along the desired flightpath by reference to instruments, or by reference to a combination of instrument and external visual information. In all-weather operations, the desired level of safety is achieved through the use of special equipment, special training, instrument flight procedures, and associated operating minimums. These factors ensure that the combination of information (available from external sources and airborne instruments and equipment) is sufficient to enable an aircraft to be safely operated along the desired flightpath, provided weather conditions are at or above the operating minimum. As external visual information decreases due to restricted seeing-conditions, the quality and quantity of information from instrument and other equipment sources and the proficiency of the flightcrew must increase. For approach and landing operations, the specific considerations involved when determining operating minimums are related to the following factors:

- Precision with which the aircraft can be controlled along the desired approach path using the guidance provided by navigational aids (NAVAID) through reference to aircraft instrumentation and use of airborne equipment
- Flight characteristics of the aircraft
- Physical characteristics of the aircraft
- Character of the ground environment and obstructions
- Flightcrew proficiency
- Extent to which external visual information must be used to control the aircraft
- Interaction of these factors to provide satisfactory total system performance

473. PRECISION OF FLIGHTPATH CONTROL.

The precision of flightpath control is dependent upon at least the following factors:

- Accuracy and integrity of the “signals-in-space” radiated by NAVAID’s (accuracy and integrity of NAVAID’s)
- Accuracy of airborne equipment in detecting the “signals-in-space” and in providing instrument information to the pilots or autopilot (accuracy of airborne equipment)
- Precision with which the pilot or autopilot maintains the selected flightpath in varying environmental conditions (flight technical error)

475. OBSTACLE CLEARANCE. Obstacle clearance is achieved by the pilot seeing and avoiding the obstacles, by the pilot’s use of instrument information, and/or through instrument procedure design. It is not always practical to design an instrument procedure that permits instrument information to be used for avoiding obstacles. In these situations, operating minimums are established which ensure that the flightcrew will have sufficient seeing-conditions to identify obstacles and safely maneuver to landing using external visual references. Accuracy of the guidance and control systems, and the pilot’s proficiency, determine the size of the area in which obstacle clearance must be considered. The more precise a total system is, the smaller the area in which obstacles must be considered (fewer obstacles) and usually lower operating minimums can be established. When obstacles are not limiting, the height to which an approach can be conducted without establishing external visual reference is limited by performance of the total system. Generally, lower operating minimums are achieved by increasing precision, reliability, and integrity of the total system (both airborne and ground based).

477. FUNCTION OF EXTERNAL VISUAL REFERENCES. Except for certain Category (CAT) III operations, external visual information is essential for a pilot to safely take off or to complete an instrument approach and landing. This external visual information (visual cues) is necessary for a pilot when assessing the three-dimensional position of the aircraft, its velocity, and its acceleration or deceleration in relation to the intended landing or takeoff surface. This information is essential for a pilot when manually maneuvering (or when evaluating the autopilot's performance in maneuvering) the aircraft into alignment with the centerline of a landing or takeoff surface. External visual references are essential for a pilot to safely touch down (decelerate to air-taxi/hover for rotorcraft) within the touchdown zone (TDZ) and for maintaining directional control so as to stop on the runway (maintain directional control and avoid obstacles while air taxiing for rotorcraft). In degraded seeing-conditions, the quality of external visual information can be significantly improved by use of visual aids, such as runway markings and lighting. Such visual aids are necessary to increase the conspicuousness of the landing or takeoff surface. These aids provide pilots with the necessary visual references during takeoff, the final stages of approach and landing, and ground movement. The importance of visual aids increases as seeing-conditions decrease.

A. Approach lighting, TDZ lighting, runway centerline lighting, runway edge lighting, and runway markings, provide visual references to pilots for assessing lateral position and crosstrack velocity or acceleration.

B. Approach lighting, threshold lighting, in-runway lighting, and runway markings, provide visual roll references during landing, takeoff, rotation, and initial climb.

C. TDZ lighting and runway markings indicate the plane of a landing surface and identify the touchdown area, thereby providing a vertical and longitudinal reference. These visual aids provide necessary visual information for a pilot to determine vertical position, sink rate, and vertical acceleration or deceleration.

D. The visual guidance information from in-runway lights and/or markings must be sufficient to ensure adequate alignment and directional control information during takeoff or during final stages of landing and deceleration.

E. Reference to external visual aids is a primary requirement for controlling the aircraft's flightpath when operating below the minimum altitude (height) published for instrument flight.

479. MAXIMUM SINK RATES.

A. Perceptual Limitations. Restricted seeing-conditions significantly affect a pilot's ability to visually detect or perceive vertical height, sink rate (vertical velocity), and vertical acceleration. As seeing-conditions decrease, the pilot's ability to perceive vertical height, sink rate, and vertical acceleration degrades faster than the ability to perceive lateral errors and lateral accelerations (see discussion of visual illusions in paragraph 509). Personnel establishing operating minimums must consider these human perceptual limitations.

B. Aircraft Structural Limitations. According to structural design criteria, the aircraft structure must tolerate touchdown sink rates (vertical velocity) of at least 10 feet per second (fps) (600 feet per minute (fpm)). Touchdown sink rates higher than the maximum rates evaluated during the certification of an aircraft can cause serious structural damage including catastrophic failure. Therefore, instrument procedure design must provide for sink rates that give a pilot the capability of detecting unacceptable situations and adjusting the flightpath to achieve a safe landing considering available visual aids and operating minimums. Visual aids and operating minimums must provide a high probability that a pilot will be able to adequately control the aircraft and adjust the vertical flightpath to achieve acceptable sink rates at touchdown and touchdown within the TDZ.

C. Maximum Acceptable Sink Rates. Operational experience and research has shown that a sink rate of greater than approximately 1,000 fpm (16.67 fps) is unacceptable during the final stages of an approach (below 1,000 feet above ground level (AGL)). This is due to a human perceptual limitation which is independent of the type of airplane operated and is equally applicable to helicopters. Therefore, the instrument approach procedures and the operational practices and techniques must ensure that sink rates greater than 1,000 fpm are not required or permitted in either the instrument or visual portions of an approach and landing operation. Operating minimums and available visual aids must provide reasonable assurance that a pilot will have adequate external visual references in the visual portions of all instrument flight procedures (certain CAT III operations excepted). To be considered adequate, these external visual references must permit a pilot to adequately perceive sink rates and manually maneuver the aircraft (or evaluate autopilot performance) to achieve an acceptable touchdown sink rate and touchdown point, considering the operating minimums and the available visual aids.

481. COCKPIT DESIGN. Physical design of an aircraft cockpit has a significant impact on seeing-conditions during takeoff and the final stages of an instrument approach and landing. Cockpit design has a direct effect on a pilot's ability to determine the three-dimensional position of an aircraft in relation to a landing or takeoff surface and, consequently, the ability to safely control the flightpath of the aircraft. Therefore, cockpit design is a significant factor in establishing operating minimums of a particular aircraft (see discussion in paragraph 503). Generally, aircraft with larger cockpit-cutoff-angles (better downward viewing angles over the nose) and shallower landing pitch attitudes provide for better seeing-conditions. Improved seeing-conditions derived from improved cockpit design can be used to justify lower operating minimums. For example, the entire portion of the fuselage forward of the Concorde cockpit is tilted downward for landing to compensate for the very high pitch attitude in the landing configuration. This Concorde design feature maintains seeing-conditions necessary for the lower operating minimums.

483. MINIMUM INSTRUMENT FLIGHT ALTITUDES. Except for certain CAT III operations, all instrument approach and landing operations have limitations related to obstacles, airborne instrumentation and equipment, ground-based navigation equipment, and/or visual aids. Because of these limitations, external visual information is required to safely complete instrument approaches and landings. Airborne instruments and equipment and the signals-in-space radiated by ground-based NAVAID's must provide pilots adequate guidance to safely control an aircraft by reference solely to instruments until the aircraft arrives at a pre-established minimum height or altitude (decision height (DH) or minimum descent altitude (MDA)) for instrument flight. The total system (airborne and ground-based) does not provide this capability below the minimum height or altitude for instrument flight. Therefore, descent below the specified minimum height or altitude for instrument flight can only be safely accomplished when adequate external visual references are available. If adequate external visual references are not established, a pilot must execute an instrument missed approach at or before passing a preestablished missed approach point (MAP).

NOTE: Descent below the specified minimum instrument flight rules (IFR) altitude without adequate visual reference to control and maneuver the aircraft to a landing is unsafe and prohibited. The minimum height or altitude for instrument flight for an instrument approach and landing is specified in various ways depending on the type and category of instrument approach conducted.

A. Nonprecision Approaches. The minimum heights or altitudes for nonprecision approaches can be specified as an MDA, height above touchdown (HAT), height above airport (HAA), minimum descent height (MDH), obstacle clearance altitude (OCA), obstacle clearance height (OCH), or obstacle clearance limit (OCL). MDA, HAT, and HAA are used by the United States (U.S.) and certain foreign countries who use U.S. Terminal Instrument Procedures (TERPS) criteria. OCA, OCH, and OCL are used in most foreign countries and are established in accordance with International Civil Aviation Organization (ICAO) Procedures for Air Navigation Services Aircraft Operations (PANS-OPS). Although the current version of ICAO PANS-OPS eliminated use of OCL, some countries still use OCL criteria from previous versions of PANS-OPS. Some countries, in addition to OCA and OCH, provide MDA and MDH. MDA and OCA are barometric flight altitudes referenced to mean sea level (MSL). HAT, HAA, MDH, OCH, and OCL are radio or radar altitudes referenced to either the elevation of the airport, the elevation of the TDZ, or the elevation of the landing threshold.

(1) MDA or OCA may be specified for any nonprecision approach procedure.

(2) HAT, MDH, OCH, or OCL may be specified for straight-in, nonprecision approach procedures.

(3) HAA, MDH, OCH, or OCL may be specified for circling maneuvers.

B. Precision Approaches. The minimum height or altitude for instrument flight for precision approaches can be specified as a decision altitude (DA), OCA, DH, OCH, or OCL. In the U.S. and certain foreign countries that use U.S. TERPS criteria, the minimum instrument flight altitude for precision approaches is DH. DH is specified as a decision altitude referenced to MSL for aircraft equipped with only barometric altimeters and as HAT for aircraft equipped with radio or radar altimeters. Within the U.S., both means of specifying this height or altitude are commonly referred to as DH. DA, DH, OCH, and OCL are used in most foreign countries and are established in accordance with various versions of ICAO PANS-OPS. DA and OCA are referenced to a barometric altitude (MSL). DH (in most countries), OCH, and OCL are referenced to a radio or radar height above either the elevation of the airport, the elevation of the TDZ, or the elevation of the landing threshold.

C. Lowest Permissible Height or Altitude for Instrument Flight. The lowest permissible height or altitude for instrument flight for any precision or nonprecision approach cannot be lower than any of the following:

- Minimum height specified by the Federal Aviation Administration (FAA)-approved airplane flight manual (AFM)
- Minimum height or altitude for which the signals from ground-based or space-based navigation equipment can be relied upon for instrument flight
- Minimum height or altitude that provides adequate obstacle clearance

- Minimum height or altitude authorized for the flightcrew
- Minimum height or altitude authorized for the operator for that aircraft and equipment combination
- Minimum height or altitude permitted by the operative airborne and ground-based or space-based equipment
- Minimum height or altitude published or otherwise established for the instrument approach
- Minimum height or altitude authorized in operations specifications for the operation being conducted

485. MINIMUM VISIBILITY, RUNWAY VISIBILITY VALUES, AND/OR RUNWAY VISUAL RANGE. Upon arrival at the minimum height or altitude for instrument flight and before passing a pre-established decision point, a pilot must establish adequate seeing-conditions to safely complete the approach and landing. Operating minimums are expressed as visibility (VIS), runway visibility values (RVV), or runway visual range (RVR). Criteria for establishing operating minimums must provide a reasonable assurance that a pilot can establish the required seeing-conditions before passing the decision point. This criteria provides this assurance if the weather conditions are reported to be at or above the landing minimum when the approach is initiated. To achieve this objective, the operating minimums specified for the procedure (VIS, RVV, RVR) must be compatible with the minimum height or altitude for instrument flight and the decision point specified for the procedure. Therefore, when the reported weather conditions are at the authorized minimums, a pilot should be able to establish external visual references upon arrival at the minimum height or altitude (DH or MDA), and before passing the decision point (DH, MAP, or visual descent point (VDP)). At this point a pilot must be able, by external visual reference, to maneuver to a landing without exceeding a descent rate of 1,000 fpm or exceeding aircraft limitations on touchdown. (See paragraph 497 for a discussion of factors affecting seeing-conditions.) For example, it would not be practical to specify a DH of 200 feet (HAT 200) with an operating minimum of RVR 700 since the first visual contact in a typical aircraft would not occur until approximately 130 feet above the elevation of the TDZ. The specified operating minimum must also permit adequate external visual references to be established early enough for a normal descent to landing (less than 1,000 fpm). For example, it would not be reasonable to specify an MDA equivalent to a HAT of 400 feet and an operating minimum of RVR 1600 for typical turbojet airplanes. In this situation, the pilot would not establish first visual contact until the airplane is within 4,000 feet of the landing threshold and would require a descent rate much higher than 1,000 fpm to land within the TDZ.

487. SAFETY DURING GO-AROUNDS. Most aircraft used in air transportation have the capability, in a normal approach and landing configuration, of safely executing a go-around from any point before touchdown, even when significant failures occur, such as engine, hydraulic, or autopilot failures. This aircraft performance capability for safety in go-arounds should be provided for, particularly for go-arounds caused by operational factors, such as airborne and ground-based equipment failures, air traffic control (ATC) contingencies, loss of external visual references, and misalignment with the landing surface. This capability is required in all CAT II and CAT III operations. When establishing operating minimums for aircraft that do not have this capability, the consequences of the failures that would preclude a safe go-around must be considered. Operating minimums for aircraft without the performance capability to safely go-around following engine failure must provide adequate seeing-conditions to successfully accomplish a forced landing in a pre-established location. The following factors must be considered when evaluating the safety of go-arounds from any point in the approach before touchdown:

A. The go-around capability is based on normal operating conditions at the lowest authorized operating minimum. Factors related to geometric limitations of the aircraft during the transition to a go-around (such as tail strike, or rotor strike) must be considered. Other factors such as the available visual cues, autopilot or flight director mode switching, altitude loss in transition to go-around, and altitude loss due to autopilot malfunction must also be considered.

B. If a go-around could result in an inadvertent touchdown, the safety of such an event must be considered. The aircraft design and/or procedures used must accommodate for relevant factors. Examples of relevant factors that must be considered include operation of engines, the operation of autothrottle, autobrakes, autospoilers, autopilot mode switching, and other systems that could be adversely affected by an inadvertent touchdown.

C. If the occurrence of any failure condition in the aircraft or its associated equipment could preclude a safe go-around from low altitude, then these failure conditions must be clearly identified. In these cases, a minimum height must be specified from which a safe go-around can be initiated if the failure occurs. If the failure occurs below the specified height, pilots must be made aware of the effects or consequences of any attempt to go-around.

D. Information must be provided to the flightcrew concerning appropriate procedures for low altitude go-arounds and the height loss expected. If the conduct of certain approach and landing operations is authorized with an engine-out, height loss information for engine-out operations must also be provided to the flightcrew.

489. CONCEPT OF DECISION HEIGHT. The DH concept is the foundation for current precision CAT I and CAT II approach and landing operations. It is also an essential concept in certain CAT III operations. This concept evolved after the introduction of turbojets in 1958. It was established to resolve problems created by use of a ceiling as an element of operating minimums, especially during rapidly changing weather conditions. The use of the DH concept also enhances safety of operations in degraded seeing-conditions. A DH is established to require that the pilot, before passing the specified height, decide whether adequate visual references are available for accomplishing the following actions:

- Verifying that the aircraft is in a position that will permit a safe landing in the TDZ
- Determining that sufficient external visual references are available to manually maneuver the aircraft (or assess autopilot maneuvering in CAT II and III operations) into alignment with the runway centerline
- Determining that the aircraft can be maneuvered to touchdown within the TDZ, that directional control can be maintained on the runway, and that the aircraft can be stopped within the available runway length
- For helicopter operations, determining that sufficient visual references are available to maneuver the helicopter to align with the landing area; decelerate to air taxi, or hover; and maintain directional control while air taxiing

A. From an operational viewpoint, DH is the limit to which a pilot can descend before having to decide to continue the approach by visual means. If the visual references required to safely continue the approach have not been established before passing DH, a missed approach must be executed at DH. This does not mean that a pilot waits until arriving at DH before deciding to go-around or to continue the approach based on visual references. The decision-making process begins when the approach is initiated and continues throughout the approach. A pilot must continually evaluate course and glidepath displacement information throughout the approach. Knowing that significant changes cannot occur instantaneously, a pilot begins to formulate a decision concerning the probable success of the approach long before reaching DH. Although DH is a specified point in space at which a pilot must make an operational decision, the pilot accumulates the information required to make that decision throughout the approach. It is incorrect to assume that all aspects of the decision-making process are delayed until the critical instant the aircraft arrives at DH. The visual cues that become available during the descent to DH enhance the pilot's formulation of the decision that must be made at DH. The operational decision to continue the approach by visual means, however, must be made before passing DH. At DH, if a pilot is satisfied that the total pattern of the visual cues provides sufficient guidance and the aircraft is in a position and tracking so as to remain within a position from which a safe landing can be made, a decision to continue the approach by reference to visual cues is appropriate. However, if a pilot is not satisfied that all of these conditions exist, a missed approach must be executed.

B. The decision that the pilot must make before passing DH is not a commitment to land. It is a decision to continue the approach based on visual cues. This distinction is important since the possibility exists that, after passing DH, visual cues may become inadequate to safely complete the landing, or the aircraft may deviate from the flightpath to a point where a safe landing cannot be assured. Since many variables are involved, the final decision to commit to a landing is the pilot-in-command's (PIC) and is primarily a judgment based on all the relevant operational factors. The PIC should usually delay the decision to commit to a landing until the final stages of flare and landing.

C. The following is a list of statements that describe what DH is:

(1) DH is a specified decision point.

(2) DH is the point at which a specific action must be initiated (either the approach is continued by reference to visual aids or the approach is terminated with a go-around).

(3) DH is the lowest permissible height to which a precision approach can be continued by reference to flight instruments alone.

(4) DH is the limit to which a pilot can descend before having to decide to continue the approach using external visual references.

D. The following is a list of statements which describe what DH is not:

(1) DH is not a point where a decision or commitment to land is made.

(2) DH is not a point where the decision-making process begins.

(3) DH is not the latest point at which a go-around could or should be made.

(4) DH is not a point where all aspects of the decision are instantaneously formulated.

491. CONCEPT OF MINIMUM DESCENT ALTITUDE AND MISSED APPROACH POINT (MDA/MAP). The MDA/MAP concept is the foundation for safe, CAT I nonprecision approach operations. Electronic glidepath information cannot be provided at certain locations because of obstacle or terrain problems, NAVAID sighting problems, and cost benefit factors. The MDA/MAP concept provides for safe nonprecision approach operations in instrument conditions without electronic glidepath information.

A. *Minimum Descent Altitude.* An MDA is the lowest permissible height (in a nonprecision approach) at which an aircraft can be controlled by reference only to instrument information. After passing the final approach fix (FAF) a pilot should descend to the MDA as rapidly as practical so that the pilot can acquire sufficient visual references while still in a position to safely complete the approach and landing by visual means. An MDA is established to require that the pilot, before descending below the specified height and before passing the MAP, determine that adequate visual references are available for accomplishing the following actions:

- Verifying that the aircraft is in a position that will permit a safe landing in the TDZ
- Determining that sufficient visual references are available to manually maneuver the aircraft to align it with the runway centerline, touch down within the TDZ, and maintain directional control on the runway
- For helicopter operations, determining that sufficient visual references are available to maneuver the helicopter to align with the landing area; decelerate to air taxi, or hover; and maintain directional control while air taxiing

(1) The following is a list of statements that describe what MDA is:

(a) MDA is the lowest permissible height at which a nonprecision approach can be continued by reference solely to flight instruments.

(b) MDA is the limit to which a pilot can descend before having to decide whether or not to continue the approach by using external visual references.

(c) MDA is the minimum height above the surface to which the aircraft can descend, unless the pilot determines that the aircraft is in a position from which it can be safely maneuvered using normal rates of descent (less than 1,000 fpm) to a touchdown within the TDZ (decelerate to air taxi or hover for helicopters).

(2) The following is a list of statements that describe what MDA is not:

(a) MDA is not a specified decision point.

(b) MDA is not a point at which a specific action is initiated.

(c) MDA is not a point where the decision process begins.

(d) MDA is not the latest point at which a go-around could or should be made.

(e) MDA is not a point where all aspects of the decision are instantaneously formulated.

B. Missed Approach Point. Since an electronic glidepath is not used in a nonprecision approach, it is necessary to define a point on or near the airport where a missed approach must be executed, if adequate external visual references for safely continuing the approach are not available. This point is specified as the MAP. An MAP is a three-dimensional airborne position where the MDA passes over a specified geographic fix (the MAP).

(1) The following is a list of statements that describe what MAP is:

(a) MAP is a specified decision point.

(b) MAP is the last point at which the approach can be continued by reference solely to flight instruments. After the MAP, the approach must be discontinued.

(c) MAP is the last point at which the published missed approach can be safely executed in instrument conditions.

(2) The following is a list of statements that describe what MAP is not:

(a) MAP is not the last point at which a pilot can decide to continue the approach by external visual references. Often, the MAP is located at a point where a pilot cannot safely descend and land if the MDA is maintained until arriving at the MAP (for example,

when the MAP is located over the very high frequency omnidirectional radio range (VOR) on the airport).

(b) MAP is not a point where a decision or commitment to land is made.

(c) MAP is not a point where the decision process is begun.

(d) MAP is not a point where all aspects of the decision are instantaneously formulated.

493. CONCEPT OF CIRCLING MANEUVERS. In many situations, instrument approach design criteria will not permit a "straight-in" approach to the landing runway. In these situations, a circling procedure is necessary to maneuver the aircraft to a landing on the intended runway. Circling maneuvers are usually necessary when there is an obstacle or terrain problem. Circling maneuvers are also required when a NAVAID is located in a position that precludes a straight-in approach to the intended landing runway. U.S. criteria require a circling maneuver if the inbound course is offset more than 30 degrees from the runway centerline. The circling maneuver can be initiated from either a precision or nonprecision instrument approach procedure and must be conducted entirely by external visual references. Electronic course or glidepath guidance cannot be used to perform a circling maneuver. A circling maneuver is not an instrument maneuver. Sufficient visual references for manually maneuvering the aircraft to a landing must be maintained throughout a circling maneuver. The pilot must keep the aircraft's position within the established maneuvering area while performing the circling maneuver. The circling MDA must be maintained until an aircraft (using normal maneuvers) is in a position from which a normal descent (less than 1,000 fpm) can be made to touchdown (decelerate to air taxi or hover for helicopters) within the TDZ. It is critical for pilots to understand that the published missed approach procedure may not provide adequate obstacle clearance, especially during the initial portion of a missed approach executed during a circling maneuver. The published missed approach is designed to provide obstacle clearance only when the missed approach is executed on the published final approach course at or above the MDA, and before passing the MAP. A published missed approach may not guarantee the necessary safety margin when a missed approach is executed past the MAP and/or below the MDA. The aircraft must remain within the established circling maneuvering area until the aircraft is at or above the MDA and established on the missed approach course. The following statements summarize the basic concepts of a circling maneuver:

A. A circling maneuver is a visual maneuver.

B. Sufficient visual references to manually maneuver the aircraft to a landing must be maintained throughout a circling maneuver.

C. The aircraft must be maintained at the MDA until it is at a position from which a safe landing can be made.

D. A missed approach must be executed when external visual references are lost or sufficient visual cues to manually maneuver the aircraft cannot be maintained.

E. The published missed approach procedure does not guarantee obstacle clearance during the initial phases of a missed approach, if initiated during a circling maneuver after descending below MDA or after MAP. Therefore, when a missed approach from a circling maneuver is executed, the direction of the initial turn must always be toward the airport to ensure obstacle clearance and to keep the aircraft within the maneuvering area until it is above MDA and can safely proceed on the missed approach course.

495. CONCEPT OF RUNWAY VISUAL RANGE. Operating minimums are specified in terms of ground visibility, tower visibility, RVV, and RVR. The RVR concept has evolved over a long period, and its use in the U.S. began in 1955. As operating minimums were reduced due to improvements in airborne and ground-based equipment, it became more likely that pilots would not see the full length of the runway upon arrival at the specified decision point. Positions established for taking visibility observations were often several miles from the approach end of many runways. This resulted in reported visibility values that frequently did not represent the seeing-conditions encountered during the final stages of approach and landing. This deficiency was particularly critical when rapidly changing weather conditions within the terminal area occurred. These factors generated a need for systems such as RVR which could rapidly and reliably provide reports of the seeing-conditions that a pilot could expect to encounter in the TDZ and along the runway.

A. RVR measurements are taken by a system of calibrated transmissometers and account for the effects of ambient background light and the runway light intensity. Transmissometer systems are strategically located to provide RVR measurement associated with one or more of the three basic portions of a runway: the TDZ portion, the mid runway (MID) portion, and the rollout (Rollout) portion.

(1) RVR is an instrumentally-derived value that reflects an artificially created seeing-condition on or near the portion of the runway associated with the RVR report. This artificially created seeing-condition

is achieved by using high intensity runway edge, TDZ, and centerline lights. These lights increase the conspicuousness of the landing surface and "reach out" to the pilot, thereby creating a seeing-condition that is significantly better than the reported ground visibility or tower visibility. For any particular fog density, RVR will be significantly greater than reported visibility because RVR is based on the use of high intensity lights. Since RVR is based on high intensity lights, an RVR report only has meaning when associated with the seeing-conditions on or near the portion of the runway where the report was obtained (TDZ, MID, or Rollout). An RVR report has no meaning unless a pilot is also seeing the high intensity lights on which the report is based.

(2) To properly apply operating minimums, it is important to understand RVR. The following is a list of statements that describe what RVR is:

(a) RVR is an instrumentally derived value.

(b) RVR is currently measured by transmissometers located approximately 400 feet from the runway centerline.

(c) RVR is related to the transmissivity (degree of opaqueness) of the atmosphere.

(d) RVR is an approximation of the distance a pilot should see when an aircraft is on, or slightly above, the portion of the runway associated with the report.

(e) RVR is calibrated by reference to runway lights and/or the contrast of objects.

(f) RVR is a value that varies with runway light setting.

(g) RVR is a value that only has meaning for the portions of the runway associated with the RVR report (TDZ, MID, or Rollout).

(3) The following is a list of statements that describe what RVR is not:

(a) RVR is not a measure of meteorological visibility.

(b) RVR is not a measure of surface visibility or tower visibility.

(c) RVR is not a measure of seeing-conditions on taxiways, ramps, or aprons.

(d) RVR is not a measure of seeing-conditions at or near MDA or DH.

(e) In the U.S., RVR is not measured or reported by a human observer.

(f) RVR is not "visibility."

FYI: RVR is a value that can be five to six times greater than ground or tower visibility at night and two to three times greater during daytime.

B. Concept of Controlling RVR. Controlling RVR means that RVR reports are used to determine operating minimums whenever operating minimums are specified in terms of RVR, and RVR reports are available for the runway being used. All CAT I operating minimums below 1/2 statute mile (RVR 2400) and all CAT II and III operating minimums are based on RVR. The use of visibility is prohibited because the reported visibility may not represent the seeing-conditions on the runway. All takeoff minimums below 1/4 statute mile visibility (RVR 1600 for airplanes and RVR 1200 for rotorcraft) are predicated on RVR, and use of visibility is prohibited. For example, if the takeoff minimum published for a particular operation is TDZ RVR 1200/Rollout RVR 1000, RVR reports are controlling and a takeoff is prohibited unless the TDZ RVR report is at or above RVR 1200 and the rollout RVR report is at or above RVR 1000. In this example, a takeoff cannot be based on visibility if the RVR system is operative, even if the reported visibility is greater than 1 statute mile.

497. GENERAL FACTORS AFFECTING SEEING CONDITIONS. Seeing conditions during all-weather terminal area operations are affected by numerous factors. These factors are related to aircraft design, weather conditions, ambient lighting level (day or night), airport environment, and available visual aids. Seeing conditions are also affected by operational factors, such as aircraft configuration, speed, and gross weight, the maneuver being conducted, use of aircraft lights, level of cockpit lighting selected, and the pilot's eye reference position (proper seat adjustment). Any of these factors can adversely affect seeing-conditions during any particular operation in instrument conditions. The effect of these factors significantly increases as visibility or RVR decreases. For example, a pilot's seat adjustment (eye reference position) used by many pilots for en route or CAT I operations in some aircraft may not provide adequate seeing-conditions for takeoff or landing operations in CAT II and CAT III weather conditions (see paragraph 505). The discussions in paragraphs 499 through 505 are intended to provide a basic understanding of some general factors affecting seeing-conditions.

499. WEATHER CONDITIONS/FOG STRUCTURE. Weather conditions have the most obvious effect on seeing-conditions. Visible moisture such as clouds, rain, snow, and fog, are the most common elements that obstruct pilot vision. Airborne particles such as smoke, dust, or haze can also significantly obstruct vision. During operations in CAT I weather conditions, the most frequently encountered obstructions to vision are related to cloud bases, visible precipitation, and airborne particles. In CAT II weather conditions and especially in CAT III conditions, various forms of fog are the primary obstructions to vision. The primary factors associated with these types of obstructions to pilot vision, and those which have the most significant effects on seeing-conditions, are as follows:

- Density of the obstruction (number of airborne particles per unit volume)
- Depth of the obstruction (thickness)
- Variation in density as a function of height above the surface (vertical structure)
- Variation in density as a function of distance from the runway (lateral structure)

A. Vertical/Lateral Structure. Cloud bases commonly encountered in CAT I weather conditions represent an extreme example of vertical structure. Cloud bases are created by an abrupt change in the density of water droplets suspended in the atmosphere as a function of height above the surface (abruptly increased density as height increases). Above the cloud base, vision is significantly restricted due to the higher density of suspended water droplets. As a cloud base is penetrated on descent, seeing-conditions rapidly improve because of a significant reduction in the density of the obscuring phenomena. Another example of vertical structure is a condition known as homogeneous fog. The density of water droplets in homogeneous fog is uniform with height and does not change as the aircraft descends. In classic homogeneous fog, the seeing-conditions gradually improve as the aircraft descends, primarily because the depth of the obstruction to vision decreases as the distance between the pilot's eyes and the runway decreases (see figures 4.2.3.1. and 4.2.3.2.). Shallow ground fog represents the opposite extreme of the cloud base example. When shallow ground fog exists, the density of the water droplets increases as the aircraft descends into the fog. In these situations, seeing-conditions can decrease dramatically and result in loss of adequate external visual references necessary to manually maneuver the aircraft in the final stages of landing. Shallow ground fog can be insidious. In some shallow ground fog conditions, the entire landing surface may be visible several miles out on final approach, but, just before touchdown, seeing-conditions may deteriorate to less than 500 feet. Although the variability in fog conditions is almost infinite, there are three general types of fog structures:

(1) Homogeneous Fog. Homogeneous fog is a condition in which the density is uniform with height (uniform vertical structure). Homogeneous fog conditions are fog conditions typically programmed into most flight simulators. In training scenarios using this fog condition, seeing-conditions steadily improve as the aircraft descends. Homogenous fog is usually encountered in very stable meteorological conditions and can exist for long periods of time.

(2) Mature Fog. Mature fog is a condition in which water droplet density increases with height. Seeing conditions rapidly deteriorate with height and conversely rapidly improve as an aircraft descends. Mature fog conditions are seldom programmed into flight simulators. Mature fog is usually encountered when fog begins to "lift" after an extended period of stable homogeneous fog. Often, mature fog will evolve into a cloud base before dissipating.

(3) Shallow Ground Fog. Shallow ground fog is a condition in which water droplet density decreases with height. Seeing conditions rapidly improve with height and conversely rapidly deteriorate as an aircraft descends. In extreme cases during the early formation of shallow ground fog, it is possible from the cockpit of a large aircraft (B-747) to see the control tower and tails of other airplanes but not to see the runway or taxiway at all. Shallow ground fog is usually encountered when radiation fog begins to form as the surface cools following sunset. If appropriate conditions exist for an extended period, shallow ground fog will usually evolve into homogeneous or mature fog.

B. Fog structures and other weather conditions have a major effect on seeing-conditions. The wide variation in weather conditions that routinely occur do not permit the use of "hard and fast" rules to determine the precise seeing-conditions that will be encountered during any particular operation. Variations in weather conditions are the primary reasons why the decision which must be made at DH or MDA/MAP is not a decision to land, but is a decision either to continue the approach using external visual references or to go-around. Instrument procedure design criteria and operational procedures allow for these limitations; therefore, safe alternatives are provided if adequate visual references cannot be established upon arrival at a decision point or maintained after descending below that point.

501. VISUAL AIDS AND RUNWAY ENVIRONMENT. A primary factor in the identification of objects, such as landing surfaces, depends on a pilot's ability to see contrasts between the object and the surrounding background. The ability to see and recognize contrasts in the brightness or color of an object is much greater than the ability to determine the actual level of illumination of an object. For example, a 100-watt light bulb seems to be much brighter at night than during daylight conditions even though the actual level of illumination is the same. The contrast between a 100-watt light and a dark night background is much greater than it is in a daylight background. The presence of airborne particles or water droplets causes the available light to diffuse or scatter. This scattering effect raises the overall illumination of the background which in turn reduces the level of contrast between an object and its background. This is the primary reason why seeing-conditions decrease when landing into the sun on a hazy or foggy day or when the landing lights of an aircraft are turned on in snow or fog conditions. Reduced levels of contrast increase the difficulty of identifying objects such as snow-covered runways or runways located in heavily lighted urban areas. As a result, contrast levels must be increased to provide the seeing-conditions necessary for the safe conduct of operations with reduced operating minimums. Seeing conditions can be improved by using visual aids and by enhancing the level of contrast within the runway environment. For example, the difference in the level of contrast between a landing or takeoff surface and the surrounding area can be improved through good airport maintenance practices. Such practices as planting and maintaining grass around a runway and between a runway and a taxiway, and plowing snow-covered runways, improves levels of contrast. The most effective way to improve the contrast of a landing or takeoff surface, however, is to use visual aids because they are effective in a variety of weather conditions. Visual aids such as approach lights, runway lights, and runway markings significantly improve the contrast between a landing or takeoff surface and the immediate surrounding area. The improved contrast provided by approach and runway lighting significantly improves seeing-conditions in both night and daylight operations. Approach lighting and runway lighting are essential elements of all landing operations conducted in weather conditions below RVR 4000 and all takeoff operations below RVR 1600.

503. EFFECTS OF AIRCRAFT/COCKPIT DESIGN ON SEEING CONDITIONS. The overall design of an aircraft and the design of a cockpit significantly affect seeing-conditions during the latter stage of an approach and landing and during the initial stage of a takeoff. Seeing conditions are affected by geometric factors related to the design of an aircraft's structure and by aerodynamic factors related to an aircraft's pitch axis. Figure 4.2.3.3. provides an illustration of these factors. Figure 4.2.3.1. provides an illustration of how the visual scene "opens up" as an aircraft descends. The visual segment used in these illustrations represents that portion of the approach light and landing surface visible to the pilot when looking over the nose of the aircraft from the proper sitting position (eye reference position). When analyzing these illustrations, it is important to note the following:

- That the radio (radar) altimeter is calibrated to read the height of the landing gear above the terrain (when in the landing configuration)
- That the glidepath antenna of an aircraft tracks down the centerline of the glideslope when the instruments in the cockpit indicate that the aircraft is on glidepath
- That the pilot's eyes are always higher than what is indicated on the radio (radar) altimeter
- That the pilot's eyes are above the electronic glideslope in most aircraft

B. Aircraft and Cockpit Physical Design. The significant factors related to the physical design of an aircraft and cockpit combination that affect seeing-conditions most are as follows (see figure 4.2.3.3., illustration A):

- Distance along the longitudinal axis from directly above the main landing gear to directly beneath the pilot's eyes
- Vertical distance from the pilot's eyes to a position abeam the main landing gear
- Distance along the longitudinal axis from directly beneath the glideslope antenna to directly beneath the pilot's eyes
- Vertical distance from the glideslope antenna to a position abeam the pilot's eyes
- Cockpit-cutoff-angle

B. The Cockpit-Cutoff-Angle. The cockpit-cutoff-angle (CCO) is the angle, measured downward, from the longitudinal axis of the aircraft (zero pitch reference) to the lowest (most depressed) angle that can be seen over the aircraft's nose from the proper sitting position (eye reference position) (see figure 4.2.3.3., illustration B). The CCO in most transport category aircraft is between 15 and 25 degrees. Although many visual flight rules (VFR) helicopters have an excellent CCO, most IFR helicopters have CCO's equivalent to transport category aircraft.

C. Aircraft Aerodynamic Design. The significant factors associated with the aerodynamic design of an aircraft that affect seeing-conditions are related to pitch attitudes. The pitch attitudes necessary for final approach, flare (deceleration for rotorcraft), and landing (air taxiing for rotorcraft), have a major effect on seeing-conditions. This is because a “nose-up” attitude reduces the downward viewing angle relative to the horizon, which reduces seeing-conditions (see figure 4.2.3.3., illustration B). For example, an aircraft with an excellent CCO of 21 degrees and a high final approach pitch attitude of 8 degrees would have a seeing-condition comparable to a similar size aircraft having a poor CCO of 13 degrees and a 0 degree pitch attitude. Since the pitch attitude on final approach varies with approach speed, aircraft configuration, and gross weight, the seeing-conditions change as these operational factors change. The aircraft’s flare characteristics (deceleration for rotorcraft) can also have a significant effect on the seeing-conditions during landing. The seeing-conditions during flare decrease if any positive pitch change is required. In helicopters, the most severe degradation to the seeing-conditions occurs during deceleration to air taxi or hover. Often, the deceleration rate in a helicopter must be limited to maintain adequate seeing-conditions. For example, when a typical IFR helicopter with an 18-degree CCO and a 0-degree final approach attitude approaches an 18-degree pitch attitude during a maximum effort deceleration, the pilot will lose sight of the landing surface. At an 18-degree pitch attitude with an 18-degree CCO, the lowest downward viewing angle would be parallel with the horizon. Therefore, a deceleration pitch attitude must be maintained significantly below 18 degrees to maintain adequate visual references with the landing surface. A similar situation is encountered in turbojet airplanes during takeoff rotation and initial climb when external visual references can be lost.

505. EYE REFERENCE POSITION. Eye reference position is a critical factor in achieving optimum seeing-conditions. A pilot’s seat must be individually adjusted so that the pilot’s eyes are located at an optimum eye reference position. When seated in this position, a pilot should be able to take advantage of the full CCO, maintain reference with the necessary flight instruments, and operate all necessary controls. Many aircraft have special devices that indicate proper seat adjustment. Improper seat adjustment, especially in CAT II and III operations, can prevent the pilot from acquiring adequate external visual reference upon arrival at DH or MDA/MAP. The seating position commonly used for en route operations in many aircraft is too low and too far aft for the pilot to achieve optimum seeing-conditions during approach and landing operations. This lower and farther aft seating position results in a reduction of the CCO, which degrades the seeing-conditions by reducing the segment of the approach and landing surface visible over the aircraft’s nose. A pilot maintaining this undesirable seating position during approach and landing may tend to compensate for the reduced CCO, and its effects, by leaning forward in an attempt to acquire the necessary external visual references. A consequence of this practice is a tendency to unintentionally reduce the pitch attitude. Since seeing conditions improve as the nose is lowered, this tendency to reduce pitch attitude can contribute to the tendency to “duck under,” which has resulted in landings short of the runway.

507. THRESHOLD CROSSING HEIGHT (TCH) CONCEPT. Many complex technical factors must be considered during the installation of instrument landing system (ILS) and microwave landing system (MLS) equipment to support approach and landing operations at any particular runway. The signals-in-space radiated by the facility must meet required flight inspection requirements (accuracy and course structure) for the particular category of operation to be supported. Design of ground support systems must be such that there is an extremely small probability of losing electronic guidance during actual operations (continuity of service). The design must also provide for an extremely high probability of providing continuously reliable electronic guidance (integrity). The ILS or MLS accuracy and course structure, continuity of service, and integrity must meet established standards for the category of operation authorized at that facility. Another critical factor in installing and siting these systems is the TCH. The following discussion addresses significant factors that must be considered when establishing acceptable TCH’s.

A. Aircraft Glideslope Antenna Location. The glide-slope receiver of the aircraft detects vertical movement (displacement) of the glideslope antenna in relation to the centerline of an electronic glideslope radiated from a ground facility. As a result, the location of the aircraft’s glideslope antenna on the aircraft directly relates to terrain and obstacle clearance during the final stages of an approach and landing. The physical dimensions and aerodynamic characteristics of the aircraft (especially pitch attitude) are important factors in the determination of the proper location of a glideslope reception antenna. In conventional aircraft, the glideslope antenna is located above the height of the main landing gear. Since an aircraft is maneuvered so that its glideslope antenna tracks the centerline of the electronic glidepath, the main landing gear will track below the glidepath (see figure 4.2.3.3., illustration A). For example, if the glideslope antenna of an aircraft is located 40 feet above the landing gear and the electronic glidepath crosses 30 feet above the runway threshold, the main landing gear will touch down short of the runway since the glideslope antenna, not the landing gear, flies the glidepath. This example illustrates the important relationship between the aircraft glideslope antenna location and the electronic glidepath TCH. This situation can be resolved by siting the ILS or MLS to achieve a specified TCH and by requiring proper location of the glideslope antenna on the aircraft. Similar problems are encountered when using visual vertical guidance systems such as visual approach slope indicator (VASI) or precision approach path indicator (PAPI), since the pilot's eyes track the visual glidepath and the gear follows a lower path. The need to maintain certain landing gear crossing heights at the threshold establishes the minimum safe TCH for a particular aircraft. The current (1989) minimum TCH requirements are based on the DC-10 which has, in landing configuration, the greatest vertical displacement between the antenna location and the landing gear.

B. Acceptable TCH's. Siting ILS or MLS equipment to achieve a particular TCH can be a complex task. Operational experience with siting these systems has shown a need to establish a range of acceptable TCH's. The types of aircraft likely to use a particular facility must be considered. Another consideration in establishing the range of acceptable TCH's is the pilot's ability to detect (by external visual references) deviations from the proper glidepath and to make the necessary flightpath adjustments for adequate landing gear clearance at the threshold. Proper TCH's in CAT II and especially CAT III operations are more critical because of the limited visual cues available and the use of automatic landing systems. The TCH siting criteria for facilities used in the U.S. National Airspace System are established in FAA Order 8260.34, "Glidescope Threshold Crossing Height Requirements."

(1) Minimum and Maximum Acceptable TCH's in the U.S. The minimum acceptable TCH at a particular runway is determined by the most "TCH critical" aircraft likely to be used at that facility. The maximum acceptable TCH also depends upon the types of aircraft likely to be used at the facility. The instrument approach and landing system must be sited so that all aircraft have a high probability of a safe touchdown (deceleration to air taxi or hover for rotorcraft) in the TDZ. Landing performance is based on the assumption that touchdown will occur in the TDZ. Very high TCH's will not permit some aircraft to safely touch down within the TDZ; therefore, maximum acceptable TCH's must also be established.

(2) TCH's at Foreign Airports. Glideslope TCH's at foreign airports may not be equivalent to U.S. criteria. It is important for pilots and operators using foreign airports to understand the significance of TCH and to know the minimum TCH's that can be safely used by their aircraft. Operations should not be conducted to runways with TCH's below minimum acceptable TCH's for any particular aircraft, unless special limitations are placed on the conduct of the operation. These special limitations must be such that a pilot can safely and consistently touch down within the TDZ and safely complete the rollout on the available runway length.

509. VISUAL ILLUSIONS. Human perceptual limitations can cause visual illusions during all-weather terminal area operations. Generally, visual illusions are due to limitations in a pilot's ability to accurately perceive the three-dimensional position of the aircraft, its velocity, and/or its acceleration in relation to a takeoff or landing surface. These illusions usually become more prevalent as seeing-conditions deteriorate. The following is a discussion on the significance of some visual illusions that can occur during approach and landing operations.

A. Vertical Height and Flightpath Illusions. The ability to visually perceive vertical height and vertical flightpath in relation to a surface depends upon many factors. These factors include the size and orientation of a surface in relation to its background (level, tilted up/down, or tilted left/right) and the number of discrete visual features available. An example of a vertical position illusion caused by the size of a landing surface is when a pilot perceives that the aircraft is lower than it actually is when landing on a wider than normal runway or on a large, smooth water surface. This illusion can occur even in excellent seeing-conditions and often results in "flaring-high." Conversely, an illusion of "being too high" can occur during a landing on very narrow surfaces. The distance from a particular surface is also difficult to determine visually, unless numerous visual features are available within a pilot's near-field vision. The absence of features in the near-field vision, such as in the situation commonly referred to as a "black hole," can create an illusion of being "too high." This illusion is caused by the absence of discrete features in a pilot's near-field vision resulting in the incorrect perception that the distance to the landing surface is closer than it actually is during an approach. This illusion can cause a pilot to believe the aircraft is too high. The pilot's response to this illusion can be to fly the aircraft below the desired approach path. As weather conditions deteriorate, the reduction in external visual cues in the near-field vision can have similar effects. Visual determination of vertical flightpath is strongly influenced by the orientation of the plane of the landing surface and/or the orientation of its surrounding background. For example, an upward sloping runway or background can create an illusion that a 3-degree vertical flightpath is too steep since a 2-degree upslope can make a 3-degree flightpath look like 5 degrees. The pilot's ability to accurately perceive vertical height and flightpath rapidly degrades as seeing-conditions deteriorate. This degraded ability is caused by reductions in the number of visual features available in a pilot's near-field vision. For CAT I operations with minimums below 3/4 statute mile, it is necessary to establish certain criteria to negate the adverse effects of vertical height and flightpath illusions. Some of these criteria are as follows:

- Maximum acceptable runway gradients
- Maximum acceptable gradients (up or down) for the approach lights
- The installation of approach and in-runway lights and runway markings to more clearly define the plane of the landing surface

B. Lateral Position and Flightpath Illusions. The ability to accurately perceive lateral position and lateral rates of movement in relationship to the orientation of the landing or takeoff surface depends upon the number of discrete visual features in a pilot's far-field vision. With sufficient visual cues in the far-field vision, a pilot can readily orient the aircraft's lateral position, direction, and rate of movement, with respect to the orientation of the surface. Lateral position errors can also be readily detected by visual features in a pilot's near-field vision. In fact, deteriorating seeing-conditions can enhance a pilot's ability to perceive the aircraft's lateral position with respect to the takeoff or landing surface by restricting the pilot's vision to near-field vision. The pilot's ability to perceive the aircraft's directional orientation in relation to the runway is significantly degraded, however, when there is a deterioration or loss of visual features in the pilot's far-field vision. This deterioration in directional cues increases the difficulty of manually maintaining directional control or manually establishing the drift correction necessary for tracking runway centerline. If the pilot's primary visual task is to assess the performance of an automatic flight control system, near-field visual features permit the detection of an abnormal autopilot tracking performance sooner, because of the enhanced ability to perceive lateral displacement and rates of change in lateral position. During manual takeoffs and landings, however, this lateral illusion can, in certain circumstances, adversely affect the pilot's ability to control the aircraft. This illusion exaggerates lateral position errors and/or the rate of displacement from runway centerline. As a result, a pilot may tend to over-compensate (overcorrect) when making heading changes and get into a "pilot-induced oscillation." Pilot-induced oscillations can lead to loss of directional control and possible departure from the runway. Criteria that have been established to negate the effects of lateral illusions include the following:

- Installation of approach and in-runway lights to more clearly define the orientation (direction) of the landing surface
- Use of automatic flight control systems (autoland) or special flight instruments (such as heads-up display)
- Special flightcrew training and qualification requirements

C. Other Illusions. Poor seeing-conditions, especially in patchy or variable weather conditions, can create illusions that affect a pilot's ability to accurately perceive aircraft attitude and/or ground speed. Visual roll (bank) cues are usually available during the latter stages of approach and landing (even in most CAT III operations). In very poor seeing-conditions, however, a subtle deterioration in visual roll cues can occur, which can affect a pilot's ability to quickly recognize an unacceptable touchdown roll attitude (bank angle). This illusion, that the visual roll cues are better than they actually are, can result in the wingtip or flap track contacting the runway. Pitch attitude illusions can occur during operations conducted in patchy or variable weather conditions. Most pilots have learned through experience that the visual scene expands as an aircraft descends and that it contracts when the aircraft pitch attitude increases. As a result, a descent into rapidly deteriorating seeing-conditions, during the final phases on an approach and landing, can create a "pitch-up" or "leveling off" illusion. Conversely, a descent into rapidly improving seeing-conditions such as "breaking out" in a mature fog condition can create a pitch down or rapid descent illusion.The ability to correctly perceive ground speed can also be significantly degraded by deteriorated visual cues, especially during operations in CAT III weather conditions. Unsafe taxi speeds can result in CAT IIIb taxi operations, unless special equipment (such as inertial navigation system (INS) ground speed) or special procedures are used.

NOTE: Human perceptual limitations and the resulting visual illusions are prime reasons for establishing specific requirements as prerequisites for conducting various categories of all-weather terminal area operations. Some of these specific requirements include the establishment of operating minimums, special operating procedures, special flightcrew training and qualification, and special airborne and ground-based equipment. Operations not in compliance with these specific requirements are unsafe.

511. STABILIZED APPROACH CONCEPT. In instrument weather conditions, a pilot must continuously assess instrument information throughout an approach to properly maneuver the aircraft (or monitor autopilot performance) and to decide on the proper course of action at the decision point (DH or MDA/MAP). Significant speed and configuration changes during an approach can seriously complicate tasks associated with aircraft control, increase the difficulty of properly evaluating an approach as it progresses, and complicate the decision of the proper action to take at the decision point. The handling and engine-response characteristics of most turbojet aircraft further complicate pilot tasks during approach and landing operations. A pilot must begin formulating a decision concerning the probable success of an approach before reaching the decision point. The pilot's decision-making process requires the pilot to be able to determine displacements from the course or glidepath centerline, to mentally project the aircraft's three-dimensional flightpath by referring to flight instruments, and to then apply control inputs as necessary to achieve and maintain the desired approach path. This process is simplified by maintaining a stable approach speed, descent rate, vertical flightpath, and configuration during the final stages of an approach. Maintaining a stable speed, descent rate, vertical flightpaths, and configuration is a procedure commonly referred to as the stabilized approach concept. Operational experience has shown that the stabilized approach concept is essential for safe operations with turbojet aircraft, and it is strongly recommended for all other aircraft. Configuration changes at low altitude should be limited to those changes that can be easily accommodated without adversely affecting pilot workload. A stabilized approach for turbojet aircraft means that the aircraft must be in an approved landing configuration (including a circling configuration, if appropriate), must maintain the proper approach speed with the engines spooled-up, and must be established on the proper flightpath before descending below the minimum "stabilized approach height" specified for the type of operation being conducted. These conditions must be maintained throughout the rest of the approach for it to be considered a stabilized approach. Operators of turbojet aircraft must establish and use procedures that result in stabilized approaches. Pilots operating propeller-driven aircraft should also maintain a stable speed and flightpath on final approach. A stabilized approach must be established before descending below the following minimum stabilized approach heights:

- 500 feet above the airport elevation during VFR or visual approaches and during straight-in instrument approaches in VFR weather conditions
- MDA or 500 feet above airport elevation, whichever is lower, if a circling maneuver is to be conducted after completing an instrument approach
- 1,000 feet above the airport or TDZ elevation during any straight-in instrument approach in instrument flight conditions
- 1,000 feet above the airport during contact approaches

NOTE: Principal inspectors shall not approve an operator's procedure unless the stabilized approach concept is used for all turbojet aircraft operations. It is recommended for all propeller-driven aircraft and rotorcraft in IFR weather conditions.

513. AIR TRAFFIC CONTROL CONCEPTS. ATC services are important elements of operations in instrument weather conditions. These services are essential for the safe conduct of CAT II or CAT III operations. The requirement for ATC to provide certain services to flightcrews becomes more critical as seeing-conditions deteriorate. In such conditions, a higher degree of reliance must be placed on both the guidance provided by the electronic and visual aids, and by the necessary ATC services that ensure that those aids provide reliable guidance. In poor seeing-conditions, controllers and pilots cannot see other traffic in the terminal area, and increased reliance must also be placed on ATC information and collision-prevention services. The objectives of ATC services in all-weather terminal area operations are as follows:

- Preventing collisions between aircraft
- Preventing collisions between aircraft and obstacles during operations on maneuvering areas of the airport
- Expediting and maintaining an orderly flow of traffic
- Providing necessary protection to the runway safety areas, obstacle critical areas, and ILS/MLS critical areas
- Providing advice and information necessary for safe and efficient operations
- Providing notification and assistance during crash, fire, and rescue operations

A. Prevention of Collisions. Seeing conditions associated with most CAT I operations permit pilots to see and avoid other traffic and obstacles during ground movement and during the final stages of landing. Under the same seeing-conditions, however, air traffic controllers may not be able to visually identify the aircraft or obstacles. In many CAT I situations and during CAT II and CAT III operations, neither controllers nor pilots will be able to see all traffic or obstacles that could affect safe operations. Therefore, it is essential during these conditions, to use a system and/or procedures that effectively ensures the separation of an aircraft from other aircraft and an aircraft from vehicles and obstacles. The systems and procedures used to satisfy these objectives must be tailored to accommodate the unique environment of each airport. The overall system used usually incorporates the following general principles:

- Control procedures that ensure that the runway is kept free of other aircraft and obstructions while an aircraft is landing or taking off on that runway
- Use of procedures, visual aids, and/or systems (such as surface movement radar (ASDE) to facilitate ground movement)
- Training for ground personnel
- Procedures to deny access to nonessential personnel and vehicles in aircraft movement areas
- The requirement for vehicles in movement areas to maintain radio contact with ATC
- Procedures to notify persons operating within movement areas when the restrictions change due to varying weather conditions

B. Maintaining an Orderly Flow of Air Traffic. It is preferable that ATC arrange the traffic flow so that aircraft equipped for CAT II and CAT III operations are not unnecessarily delayed by aircraft not equipped for those operations. ATC may need to provide additional longitudinal separation between successive landing aircraft since poorer seeing-conditions increase the difficulty of ground movement. In these situations pilots require more time to exit the runway and its associated runway safety areas, obstacle-free zones, and ILS/MLS critical areas. During weather conditions requiring precision approaches, adjustments in traffic flow must be made to establish an aircraft on a proper course for interception of the final approach course (maximum of 45 degrees offset) before glidepath interception. In these conditions, speed restrictions must be removed in enough time for the pilot to begin a stabilized approach before descending below 1,000 feet AGL.

C. Runway Safety Area, Obstacle-Free Zone, and ILS Critical Area Protection. Seeing conditions encountered during all-weather terminal area operations may prohibit a pilot from seeing and avoiding all obstacles. As a result, the pilot must rely on the ground-based electronic guidance, ATC control equipment, and ATC procedures and techniques to avoid obstacles. These procedures and equipment must ensure that other aircraft and/or vehicles are not within the runway safety areas, obstacle-free zones, and the ILS or MLS critical areas when an aircraft is in the final stages of an approach and landing or when taking off on that runway. Runway safety areas and obstacle-free zones must be controlled to ensure that obstacle protection is provided during takeoff, approach, and landing, and during a missed approach from low altitudes. ILS or MLS critical areas must be controlled to ensure that electronic guidance signal integrity is maintained. Aircraft and/or vehicles within these critical areas can cause significant disturbances to electronic guidance signals. ILS or MLS signals can also be disturbed by reflections caused by aircraft overflying an ILS or MLS antenna or flying through the on-course signal between an ILS or MLS antenna and a landing aircraft. Aircraft and/or vehicles can also adversely affect glidepath signals if they are in close proximity to a glideslope or elevation antenna. In CAT II and particularly CAT III operations, additional longitudinal separation between landing aircraft may be required to allow an aircraft to complete the landing and to taxi clear of the critical areas or zones before the next aircraft enters a critical phase of an approach.

D. Advice and Information. During instrument flight operations in the terminal area, it is essential for pilots and operators to have accurate information concerning weather conditions, runway surface conditions, and the status of necessary facilities and services. The types of advice and information needed to conduct instrument flight operations in terminal areas include the following:

- Reports of weather conditions (such as altimeter settings, visibility, RVR, winds, and cloud heights)
- Operational status of navigation facilities
- The degree of protection provided to ILS or MLS critical areas, obstacle-free zones, and runway safety areas
- Factors that could significantly affect ground movement and control of ground movement
- Reports on runway surface conditions (such as wet, snow-covered, icy) and braking action reports, if appropriate
- Notices to Airmen (NOTAM) that could affect operations

E. Crash, Fire, and Rescue. Poor seeing-conditions increase the difficulty of identifying, locating, and responding to aircraft requiring crash, fire, and rescue (CFR) services. As seeing-conditions deteriorate, the role of ATC in notifying CFR facilities and assisting CFR efforts increases in significance. Procedures, systems, and techniques must be used to ensure that aircraft requiring assistance can be quickly identified and located, and that CFR services can be dispatched and provided expeditiously.

515. AIRPORT FACILITIES AND SERVICES. The varied seeing-conditions encountered in all-weather terminal area operations require pilots to rely heavily on visual aids, electronic guidance from ground-based facilities, and other facilities and services provided by the airport. Therefore, basic VFR airport facilities and services must be enhanced before safe operations can be conducted in instrument flight conditions. Runways and taxiways must meet more stringent criteria with respect to width, length, marking, and lighting. Instrument approach aids and instrument approach procedures are required. Visual aids are needed to assist a flightcrew during transition from instrument to visual flight and during ground movement. Meteorological observation and measurement equipment must be available to provide real-time information on weather conditions. Equipment and procedures must be established to provide aeronautical information on runway surface conditions and the status of airport facilities and services. Enhancements to basic VFR airport facilities and services necessary to support instrument flight operations include the following general factors:

- Physical characteristics of the runway environment, including approach, departure, and prethreshold terrain characteristics
- Obstacles and the obstacle limitation assessment surfaces
- Visual aids
- Electronic aids
- Secondary (standby) power supplies

A. Physical Characteristics. Physical characteristics of a runway environment become increasingly important as seeing-conditions deteriorate. Excessive runway or approach light gradients can create undesirable visual illusions and can cause hard or long landings. Longer runway lengths are necessary for reasons such as the tendency to land farther down the runway because of visual illusions and the increased difficulty in controlling the aircraft's flightpath. The topography in the approach and prethreshold areas should be regular and preferably level to ensure proper operation of radio (radar) altimeters, flight director systems, and automatic landing systems. The operation of automatic landing systems and other systems that provide flight guidance during flare and landing, such as heads-up display (HUD), are dependent on input from radio altimeters. As a result, the flare profile, touchdown sink rate, and touchdown point can be adversely affected by the profile of the prethreshold terrain. Where the prethreshold terrain for a particular runway could affect safe operations (examples include SEA 16R, CVG 36, MSP 29L, and PIT 10L), an in-flight demonstration must be made to determine that the flight control system of a particular aircraft is not adversely affected by the prethreshold terrain profile. Additionally, the prethreshold terrain at certain runways (examples include, SEA 16R, CVG 36, MSP 29L, and PIT 10L) may not permit a radio altimeter to be used to define DH for CAT II or alert height (AH)/DH for CAT III operations for certain aircraft. In certain situations, an inner marker (IM) can be used to define the CAT II DH or the CAT III AH.

B. Obstacles and Obstacle Limitation Assessment Surfaces. Degraded seeing-conditions decrease a pilot's ability to see and avoid obstacles. Therefore, it is essential that obstacle protection be provided along the approach paths, missed approach and departure flightpaths, and in areas on or near runways used for takeoffs and landings. Obstacle protection criteria for different categories of operations and the various phases of an approach, landing, missed approach, takeoff, and departure are specified in U.S. TERPS, ICAO PANS-OPS, and applicable advisory circulars (AC). In certain situations, obstacles may prevent the conduct of CAT II or CAT III operations. In other situations, higher than normal minimums for CAT I or CAT II operations may be required to provide necessary seeing-conditions to see and avoid controlling obstacles. During precision approach operations, it is essential to provide obstacle protection in runway safety areas and obstacle-free zones. A runway safety area is an area adjacent to the runway that must be free from fixed or mobile "nonfrangible" obstructions. Runway safety areas reduce the potential for catastrophic accidents if portions of the aircraft structure (such as a wingtip) extend beyond the runway edge, or if an aircraft departs the runway during a landing or takeoff roll. An obstacle-free zone is a three-dimensional area including portions of the landing surface, which provides obstacle clearance during landings or during rejected landings, including missed approaches after touchdown. The only fixed obstructions permitted in runway safety areas or obstacle-free zones are frangible objects or obstructions that are fixed by their functional purpose. "Fixed by their functional purpose" means that the installation of the object in those areas is essential to the safe conduct of operations on the runway; there are no alternative locations (examples include such objects as runway lights, glideslope/elevation antennas, and RVR reporting systems). Mobile obstructions (such as aircraft and/or vehicles) are not permitted within runway safety areas or obstacle-free zones while aircraft are using the runway. Aircraft, vehicles, and other objects that could disturb ILS or MLS electronic guidance are not permitted in ILS or MLS critical areas when other aircraft are critically dependent on this type of guidance. Since protection of these areas or zones is critical to safe operations (particularly during degraded seeing-conditions), visual aids (such as signs, markings, or lighting) must be provided for identifying the boundaries of these areas to pilots and operators of other vehicular traffic. ATC procedures and ground movement restrictions must be provided to ensure that these areas are protected.

C. Visual Aids. Visual aids are essential for most all-weather terminal area operations. The functions of visual aids during takeoffs and landings are discussed in paragraph 477. Visual aids are also important for the safe and expeditious guidance and control of taxiing aircraft. These aids include signs, markings, and lights, which identify holding points or indicate directions, and the marking or lighting of the taxiway centerline and edges. The conspicuousness of runway and taxiway markings deteriorates rapidly, especially at busy airports. These markings must be frequently inspected and maintained, particularly for CAT II or CAT III operations. All lighting systems should be monitored by ATC so that timely information on system failures or malfunctions can be provided to pilots. Regular visual inspections of all sections of the lighting systems are normally used to determine the status of individual lights. Therefore, it is usually only necessary for ATC to remotely monitor lighting circuits to determine whether the proper amount of power is being demanded by, and delivered to, the lighting systems. Remote monitoring of approach, runway edge, and in-runway lighting is essential during CAT II and CAT III operations, unless frequent visual inspections (every 2 hours) or timely pilot reports indicate the lights are serviceable for the operations in progress.

D. Nonvisual (Electronic) Aids. Ground-based or space-based systems that provide electronic guidance must provide the quality of guidance (flight inspected course structure), integrity (degree of trust that can be placed on the accuracy of the guidance), and continuity of service (protection against loss of signal) appropriate to the category of the operation being conducted (CAT I/II/III). Systems used for precision approach operations must provide acceptable glidepath angles and acceptable TCH's. A classification system has been established through ICAO for ground-based electronic precision approach systems. This classification system reflects the ground-based system configuration, course quality, integrity, and continuity of service capabilities (see FAA Order 6750.24, "ILS and Ancillary Electronic Component Configuration and Performance Requirement"). Since the electronic aids provide such a critical function, pilots conducting takeoff or landing operations must be notified immediately of any changes in system status, or of any malfunctions or failures. To meet this requirement, all facilities associated with ILS or MLS ground equipment must be constantly monitored by ATC or other appropriate personnel. The required levels of reliability, integrity, and continuity of service for these facilities are usually provided by automatic electronic monitoring systems, on-line standby equipment (backup transmitters), duplication of key functions, and secondary power supplies.

E. Secondary Power Supplies. Secondary power sources (standby power supplies) are essential for ensuring that visual aids, electronic aids, meteorological reporting systems, and communication facilities continue to function, even if the main source of power is interrupted. Loss of power to these systems becomes more critical as seeing-conditions deteriorate. Therefore, as conditions change from CAT I to CAT II or CAT III, the levels of required redundancy increase, and stand-by power switch-over times decrease. Secondary power supply requirements are established in ICAO annexes 10 and 14 and various FAA orders and AC's.

516.-530. RESERVED

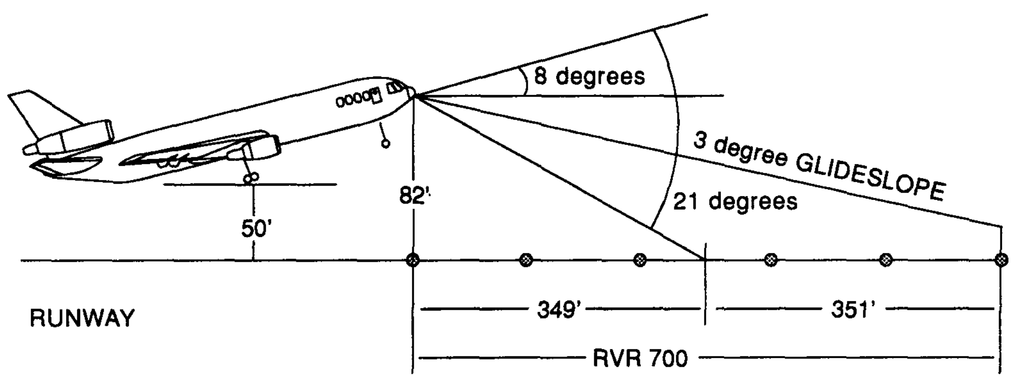
FIGURE 4.2.3.1.
VISUAL SEGMENT VS. RADIO ALTITUDE

HOMOGENEOUS ATMOSPHERE (AIRCRAFT TYPE L1011 ON A 3-DEGREE GLIDEPATH AT 1800 FEET RVR)

Distance to Touchdown	Pilot's Eye Height (Ft.)	Radio Altitude (Ft.)	Segment Visible (Ft.)
7633	404	373	0
6223	331	300	333
5746	306	275	445
5269	281	250	558
4792	256	225	670
4315	231	200 (DH)	782
3838	206	175	893
3361	181	150	1004
2884	156	125	1115
2407	131	100	1225
1930	106	75	1335
1453	81	50	1444
968	61	30	1532
484	44	13	1606
TD	31	TD	1663

FIGURE 4.2.3.2.
COMPARISON OF VISUAL SEGMENT AT 50 FEET AND DURING ROLLOUT

RUNWAY VISIBLE AT 50 FEET



ROLLOUT SEEING CONDITIONS

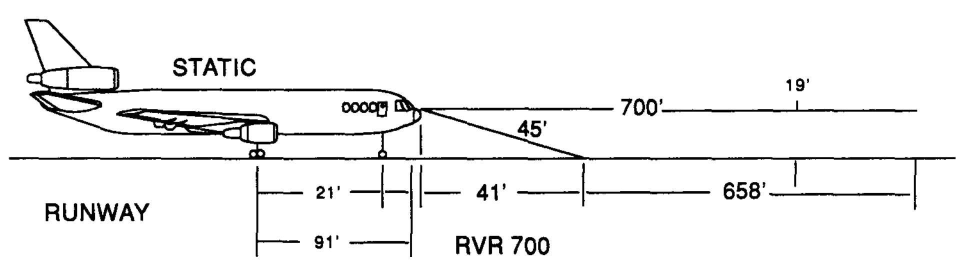
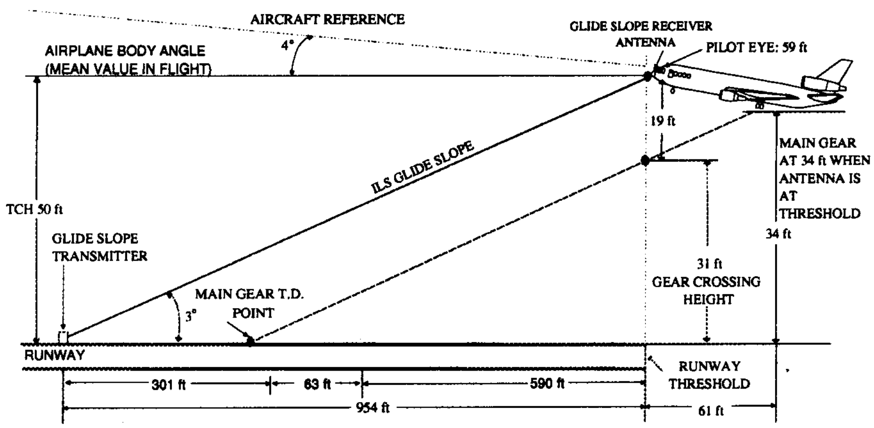


FIGURE 4.2.3.3.
EFFECTS OF AIRCRAFT AND COCKPIT DESIGN ON SEEING CONDITIONS

ILLUSTRATION A

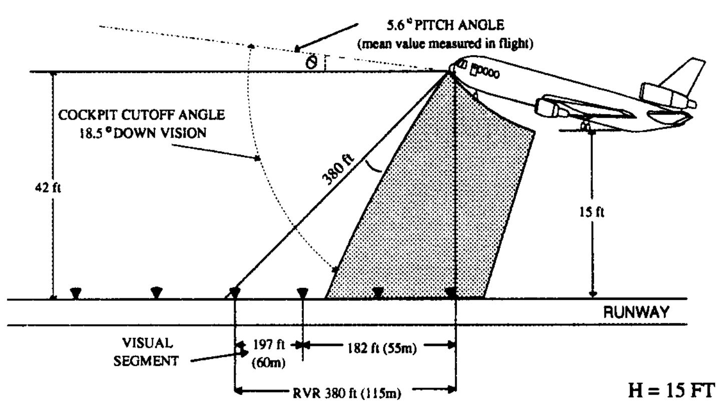


ESTIMATED ILS APPROACH

AIRPLANE FOLLOWING STRAIGHT LINE EXTENSION OF GLIDE PATH AIRPLANE AT THRESHOLD

ILLUSTRATION B

VISUAL GROUND SEGMENTS
LANDING APPROACH



H = 15 FT

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