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# An Powerful Instrument Landing System-A Review

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***Abstract:*** **It is commonly known that the directional pattern of the instrument landing system (ILS)-localizer antenna system, which constitutes the landing-course information for approaching aircraft, can be disturbed by reflections from large aircraft on the ground. Therefore, airport operators are interested in knowing configurations of landed and taxiing aircraft that lead to such ILS disturbance scenarios. Measurements on a real airport for investigating such scenarios are very cost-intensive and not sufficiently possible due to availability reasons. Therefore, a new scaled measurement setup is presented. Scaling down an aircraft by the factor of 144 requires a scaled ILS-localizer operating at a frequency of nearly 16 GHz, the development and realization of which is presented in this paper. Using this scaled ILS-localizer, measurements with an Airbus A380 and a Boeing B747 are conducted showing the feasibility of the scaled approach. Several configurations are shown where those aircraft lead to interferences of the ILS, exceeding allowed tolerances. A comparison of the reflection behavior of both aircraft shows only slight differences. Additionally, this paper presents the derivation of the bistatic radar cross section of both aircraft to be applicable to scenarios with arbitrary ILS patterns. The paper is the result of the seminar report undertaken by Mr. Naveen under the guidance of the faculty & the HOD.**

## I. INTRODUCTION

Instrument-landing system (ILS), ground-based radio system designed to provide an airplane pilot with precise guidance for the final approach in landing. The pilot flies his aircraft along a course delineated by the intersection of two radio beam the localizer beam for guidance in the horizontal plane and the glide-slope beam for guidance in the vertical plane. These beams activate an indicator in the aircraft that contains a horizontal needle sensitive to deviations from the glide slope and a vertical needle sensitive to deviations from the localizer path.

By keeping both needles centered, the pilot can guide his aircraft down to the end of the landing runway aligned with the runway center line. Limitations inherent in the system prevent it from being used safely in locations where the land beyond the approach end of the runway is not level. Also, false guidance can result from distortion of the radio beam by nearby buildings or mountains. Newer systems using microwave beams overcome most of these limitations. Radio marker beacons are also installed at several locations along the approach path to tell the pilot on the landing approach how far he is from the end of the runway.

ILS is an approach rather than a landing system. It is called instrument low approach system (ILAS) by the U.S. military air forces. As a supplementary safety measure, especially in bad weather and for emergency landings, the ground-controlled approach (GCA) system is used. Precision radar indicates the location and movement of an aircraft to the ground controller at an airport, enabling him to direct the pilot by voice radio.

### History

Tests of the ILS system began in 1929, and the Civil Aeronautics Administration (CAA) authorized installation of the system in 1941 at six locations. The first landing of a scheduled U.S. passenger airliner using ILS was on January 26, 1938, as a Pennsylvania Central Airlines Boeing 247-D flew from Washington, D.C., to Pittsburgh and landed in a snowstorm using only the Instrument Landing System. The first fully automatic landing using ILS occurred at Bedford Airport UK in March 1964.

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## II. PRINCIPLE OF OPERATION

An ILS consists of two independent sub-systems, one providing lateral guidance (Localizer), the other vertical guidance (Glideslope or Glide Path) to aircraft approaching a runway. Aircraft guidance is provided by the ILS receivers in the aircraft by performing a modulation depth comparison.

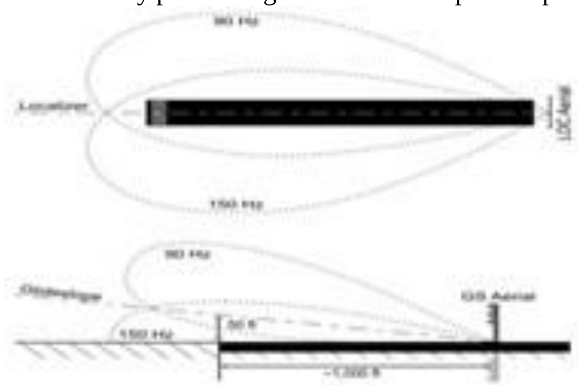


***Fig: 1 Localizer***

***Fig :2***

A localizer (LOC, or LLZ in Europe) antenna array is normally located beyond the departure end of the runway and generally consists of several pairs of directional antennas. Two signals are transmitted on one out of 40 ILS channels between the carrier frequency range 108.10 MHz and 111.95 MHz (but only the odd kHz, so 108.10 108.15 108.30 and so on are LOC frequencies but 108.20 108.25 108.40 and so on are not). One is modulated at 90 Hz, the other at 150 Hz and these are transmitted from separate but co-located antennas. Each antenna transmits a narrow beam, one slightly to the left of the runway centerline, the other to the right

If there is a predominance of either 90 Hz or 150 Hz modulation, the aircraft is off the centerline. In the cockpit, the needle on the Horizontal Situation Indicator, or HSI (The Instrument part of the ILS), or CDI (Course deviation indicator), will show that the aircraft needs to fly left or right to correct the error to fly down the center of the runway. If the DDM is zero the aircraft is on the centerline of the localizer coinciding with the physical runway centerline.

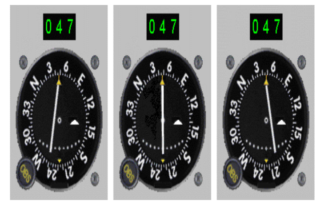


Fig: 3

A glideslope or Glidepath (GP) antenna array is sited to one side of the runway touchdown zone. The GP signal is transmitted on a carrier frequency between 329.15 and 335 MHz using a technique similar to that of the localizer. The centerline of the glideslope signal is arranged to define a glideslope of approximately 3° above horizontal (ground level). The beam is 1.4° deep; 0.7° below the glideslope centerline and 0.7° above the glideslope centerline.

Localizer and glideslope carrier frequencies are paired so that only one selection is required to tune both receivers. These signals are displayed on an indicator in the instrument panel. This instrument is generally called the omni-bearing indicator or nav indicator. The pilot controls the aircraft so that the indications on the instrument (i.e. the course deviation indicator) remain centered on the display. This ensures the aircraft is following the ILS centreline (i.e. it provides lateral guidance). Vertical guidance, shown on the instrument by the glideslope indicator, aids the pilot in reaching the runway at the proper touchdown point. Some aircraft possess the ability to route signals into the autopilot, allowing the approach to be flown automatically by the autopilot.

## III. GLIDE SLOPE EQUIPMENT

***Fig: 4***

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**3.1 TRANSMITTER:** The glide slope provides vertical guidance to the pilot during the approach. The ILS glide slope is produced by a ground-based UHF radio transmitter and antenna system, operating at a range of 329.30 MHz to 335.00 MHz, with a 50 kHz spacing between each channel. The transmitter is located 750 to 1,250 feet (ft) down the runway from the threshold, offset 400 to 600 ft from the runway centerline. Monitored to a tolerance of ± 1/2 degree, the UHF glide path is "paired" with (and usually automatically tuned by selecting) a corresponding VHF localizer frequency.

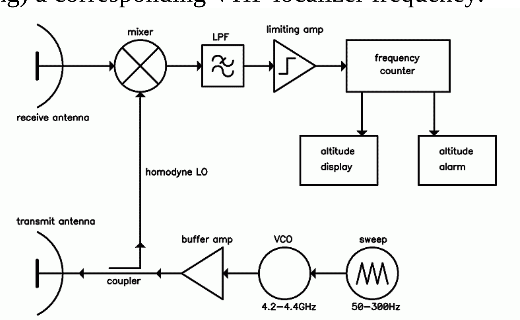


*Fig:5*

Like the localizer, the glide slope signal consists of two overlapping beams modulated at 90 Hz and 150 Hz (see Glide Slope Signal Pattern figure, below). Unlike the localizer, however, these signals are aligned above each other and are radiated primarily along the approach track. The thickness of the overlap area is 1.4º or .7º above and .7º below the optimum glide slope.

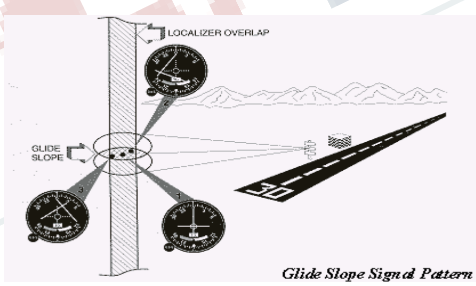


*Fig: 6*

This glide slope signal may be adjusted between 2º and 4.5º above a horizontal plane. A typical. adjustment is 2.5º to 3º, depending upon such factors as obstructions along the approach path and the runway slope.

False signals may be generated along the glide slope in multiples of the glide path angle, the first being approximately 6º degrees above horizontal. This false signal will be a reciprocal signal (i.e. the fly up and fly down commands will be reversed). The false signal at 9º will be oriented in the same manner as the true glide slope. There are no false signals below the actual slope. An aircraft flying according to the published approach procedure on a front course ILS should not encounter these false signals.

**3.2 SIGNAL RECEIVER:**
The glide slope signal is received by a UHF receiver in the aircraft. In modern avionics installations, the controls for this radio are integrated with the VOR controls so that the proper glide slope frequency is tuned automatically when the localizer frequency is selected. The glide slope signal activates the glide slope needle, located in conjunction with the TB (see Glide Slope Signal Pattern figure, above).

There is a separate OFF flag in the navigation indicator for the glide slope needle. This flag appears when the glide slope signal is too weak. As happens with the localizer, the glide slope needle shows full deflection until the aircraft reaches the point of signal overlap. At this time, the needle shows a partial deflection in the direction of the strongest signal. When both signals are equal, the needle centers horizontally, indicating that the aircraft is precisely on the glide path.

The pilot may determine precise location with respect to the approach path by referring to a single instrument because the navigation indicator provides both vertical and lateral guidance. In the Glide Slope Signal Pattern figure, above, position 1, shows both needles centered, indicating that the aircraft is located in the center of the approach path.

The indication at position 2 tells the pilot to fly down and left to correct the approach path. Position 3 shows the requirements to fly up and right to reach the proper path. With 1.4º of beam overlap, the area is approximately 1,500 ft thick at 10 nautical miles (NM), 150 ft at l NM, and less than one foot at touchdown. The apparent sensitivity of the instrument increases as the aircraft nears the runway. The pilot must monitor it carefully to keep the needle centered. As said before, a full deflection of the needle indicates that the aircraft is either high or low but there is no indication of how high or low.

## IV. ILS MARKER BEACONS

l . GENERAL: Instrument landing system marker beacons provide information on distance from the runway by identifying predetermined points along the approach track. These beacons are low-power transmitters; that operate at a frequency of 75 MHz with 3 W or less rated power output. They radiate an elliptical beam upward from the ground. At an altitude of 1,000 ft, the beam dimensions are 2,400 ft long and 4,200 ft wide. At higher altitudes, the dimensions increase significantly.

*Fig: 7*

### 4.1 OUTER MARKER (OM):

The outer marker (if installed) is located 3 1/2 to 6 NM from the threshold within 250 ft of the extended runway centerline. It intersects the glide slope vertically at approximately 1,400 ft above runway elevation. It also marks the approximate point at which aircraft normally intercept the glide slope, and designates the beginning of the final approach segment. The signal is modulated at 400 Hz, which is an audible low tone with continuous Morse code dashes at a rate of two dashes per second. The signal is received in the aircraft by a 75 MHz marker beacon receiver. The pilot bears a tone over the speaker or headset and sees a blue light that flashes in synchronization with the aural tone (see the Marker Beacon Lights figure, above right). Where geographic conditions prevent the positioning of an outer marker, a DME unit may be included as part of the ILS system to provide the pilot with the ability to make a positive position fix on the localizer. In most ILS installations, the OM is replaced by an NDB.

**4.2 MIDDLE MARKER (MM):** Middle markers have been removed from all ILS facilities in Canada bur are still used in the United States. The middle marker is located. approximately .5 to .8 NM from the threshold on the extendedrunway centerline. The middle marker crosses the glide slope at approximately 200 to 250 ft above the runway elevation and. is near the missed approach point for the ILS Category l approach.

**4.3 BACK MARKER (BM):** The back course marker (BM), if installed, is normally located on the localizer back course approximately four to six miles from the runway threshold. The BM low pitched tone (400 Hz) is beard as a series of dots. It illuminates the aircraft's white marker beacon light. An NDB or DME fix can also be used and in most locations replace the BM.

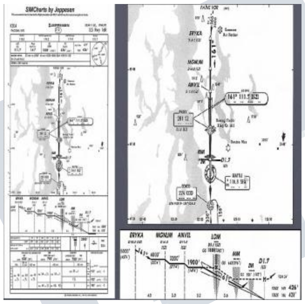

***Fig: 9 Marker Receiving Equipment***

The marker receiving installation used with the 75 MHz ground marker beacons comprises three basic elements:

a. Receiver
b. Indicator
c. Aerial.

**Receiver**

The receiver unit, which is fixed-tuned to the frequency of 75 MHz, feeds the signal received from the marker transmitter through conventional superheterodyne circuits to the aircraft intercommunication system for aural reception of the modulation tones and to the visual circuits where the modulation tones are fed through special filters to the indicating lights. The filters allow the signal to actuate only the light associated with the one modulation tone. For example the blue light is actuated by only a modulation tone of 400 Hz, the amber light by a tone of 1300 Hz, and the white light by a tone of 3000 Hz. Thus markers may be identified visually as well as aurally.

**Indicator**

Three lights are provided, blue, amber and white, which are actuated by the 400 Hz, 1300 Hz, and 3000 Hz modulation tones respectively. As the modulation tones identify the type of marker, the lights are designated in the following manner:

Blue (400 Hz Tone)—'Outer' (Marker for Ils)
Amber (1300 Hz Tone)—'Middle' (Marker for Ils)

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White (3000 Hz Tone)—'Airway' and 'Z' (Also Inner Marker for Ils) Not used in Australia.

## V. MARKER BEACON

ILS marker beacons have a rated power output of 3 watts or less and an antenna array designed to produce an elliptical pattern with dimensions, at 1,000 feet above the antenna, of approximately 2,400 feet in width and 4,200 feet in length. Airborne marker beacon receivers with a selective sensitivity feature should always be operated in the "low" sensitivity position for proper reception of ILS marker beacons. Ordinarily, there are two marker beacons associated with an ILS, the OM and MM. Locations with a Category II and III ILS also have an inner marker (IM). When an aircraft passes over a marker, the pilot will receive the following indications:

**Table 1**

1. ----------------------
2. MARKER CODE LIGHT
3. ----------------------
4. OM --- BLUE
5. MM .-.- AMBER
6. IM .... WHITE
7. BC .. .. WHITE
8. ----------------------

- The OM normally indicates a position at which an aircraft at the appropriate altitude on the localizer course will intercept the ILS glidepath.

- The MM indicates a position approximately 3,500 feet from the landing threshold. This is also the position where an aircraft on the glidepath will be at an altitude of approximately 200 feet above the elevation of the touchdown zone.
- The inner marker (IM) will indicate a point at which an aircraft is at a designated decision height (DH) on the glidepath between the MM and landing threshold.
- A back course marker normally indicates the ILS back course final approach fix where approach descent is commenced.

COMPASS LOCATOR

1. Compass locator transmitters are often situated at the MM and OM sites. The transmitters have a power of less than 25 watts, a range of at least 15 miles and operate between 190 and 535 kHz. At some locations, higher powered radio beacons, up to 400 watts, are used as OM compass locators. These generally carry Transcribed Weather Broadcast (TWEB) information.
2. Compass locators transmit two letter identification groups. The outer locator transmits the first two letters of the localizer identification group, and the middle locator transmits the last two letters of the localizer identification group.

**ILS FREQUENCY INOPERATIVE ILS COMPONENTS**

1. Inoperative localizer: When the localizer fails, an ILS approach is not authorized.
2. Inoperative glideslope: When the glideslope fails, the ILS reverts to a nonprecision localizer approach.

**ILS COURSE DISTORTION**

1.All pilots should be aware that disturbances to ILS localizer and glideslope courses may occur when surface vehicles or aircraft are operated near the localizer or glideslope antennas. Most ILS installations are subject to signal interference by either surface vehicles, aircraft or both. ILS CRITICAL AREAS are established near each localizer and glideslope antenna.

2.ATC issues control instructions to avoid interfering operations within ILS critical areas at controlled airports during the hours the Airport Traffic Control Tower (ATCT) is in operations as follows:

Weather Conditions - Less than ceiling 800 feet and/or visibility 2 miles.

**5.1 .LOCALIZER CRITICAL AREA** - Except for aircraft that land, exit a runway, depart or miss approach, vehicles and aircraft are not authorized in or over the critical area when an arriving aircraft is between the ILS final approach fix and the airport. Additionally, when the ceiling is less than 200 feet and/or the visibility is RVR 2,000 or less, vehicle and aircraft operations in or over the area are not authorized when an arriving aircraft is inside the ILS MM.

**5.2.GLIDE SLOPE CRITICAL AREA** - Vehicles and aircraft are not authorized in the area when an arriving aircraft is between the ILS final approach fix and the airport unless the aircraft has reported the airport in sight and is circling or sidestepping to land on a runway other than the ILS runway.
b.Weather Conditions - At or above ceiling 800 feet and/or visibility 2 miles.

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1.No critical area protective action is provided under these conditions.
2.A flight crew, under these conditions, should advise the tower that it will conduct an AUTOLAND or COUPLED approach to ensure that the ILS critical areas are protected when the aircraft is inside the ILS MM.

**5.3 EXAMPLE: GLIDESLOPE SIGNAL NOT PROTECTED.**

3.Aircraft holding below 5000 feet between the outer marker and the airport may cause localizer signal variations for aircraft conducting the ILS Approach. Accordingly, such holding is not authorized when weather or visibility conditions are less than ceiling 800 feet and/or visibility 2 miles.
4. Pilots are cautioned that vehicular traffic not subject to ATC may cause momentary deviation to ILS course or glideslope signals. Also, critical areas are not protected at uncontrolled airports or at airports with an operating control tower when weather or visibility conditions are above those requiring protective measures. Aircraft conducting coupled or autoland operations should be especially alert in monitoring automatic flight control systems.
NOTE - Unless otherwise coordinated through flight standards, ILS signals to Category I runways are not flight inspected below 100 feet AGL. Guidance signal anomalies may be encountered below this altitude.
ILS [FAA Instrument Landing System] Standard Characteristics and Terminology
I LS approach charts should be consulted to obtain variations of individual systems.
VHF Localizer - Provides Horizontal Guidance108.10 to 111.95 MHz. Radiates about 100 watts. Horizontal polarization. Modulation frequencies 90 and 150 Hz. Modulation depth on-course 20% for each frequency. Code identification (1020 Hz, 5%) and voice communication (modulated 50%) provided on same channel. 1000 feet typical [distance from departure end of runway]. Localizer transmitter building is offset 250 feet minimum from center of antenna array and within 90 degrees plus or minus 30 degrees from approach end. Antenna is on centerline and normally is under 50:1 clearance plane.
UHF Glideslope Transmitter - Provides Vertical Guidance
329.3 to 335.0 MHz. Radiates about 5 watts. Horizontal polarization, modulation on path 40% for 90 Hz and 150 Hz. The standard glideslope angle is 3.0 degrees. It may be higher depending on local terrain.
Middle Marker - Indicates approximate Decision Height PointModulation 1300 Hz, 95%. Keying: 95 alternate dot and dash combinations per minute. Amber light.Located 3000 to 6000 feet from threshold.
Outer Marker - Provides Final Approach Fix for Nonprecision Approach
Modulation 400 Hz, 95%. Keying: Two dashes per second. Blue light.Located 4 to 7 miles from end of runway, where glideslope intersects the procedure turn (minimum holding) altitude, plus or minus 50 feet vertically.Sited to provide 55 feet (plus/minus 5 feet) runway threshold crossing height,
[Displaced laterally] 250 to 600 feet from centerline of runway.
All marker transmitters approximately 2 watts of 75 MHz modulated about 95%.Course width varies between 3 to 6 degrees, tailored to provide 700 feet at threshold (full scale limits).
NOTE: Compass locators, rated at 25 watts output 190 to 535 kHz, are installed at many outer and some middle markers. A 400 Hz or a 1020 Hz tone, modulating the carrier about 95%, is keyed with the first two letters of the ILS identification on the outer locator and the last two letters on the middle locator. At some locators, simultaneous voice transmissions from the control tower are provided, with appropriate reduction in identification percentage.

**KOREAN AIR TESTS**

**Korean Air-ILS System Test Results**

Following the Korean Air Flight 801 accident, Korean Air devised and performed a seriesof tests on various ILS receivers to determine the effects of extraneous signals on the ILSequipment. The NTSB, Boeing, and Rockwell Collins did not participate in the testing; however,the test methods and results were provided to all accident investigation parties.A 335 MHz test signal (ILS frequency of 110.3 MHz), -90dBmw, 120 Hz modulation at100% was applied to the ILS receiver under test while the glide slope indicator and flag weremonitored for movement.

The following results were noted:
Receiver Glide Slope indicator ~deviation
51RV-5B -58 mV out of view
51RV-1 -5 mV (centered) out of view
51RV-2B -58 mV out of view (at 270mV)
ILS-70 -1.01 v out of view

RIA-32A n/a in viewILS-700 series n/a NCD (no computed data)The test was repeated with the same results using a radio transmitter powered by a fullwave rectified DC with the oscillator frequency set at 83.75 MHz (one fourth of 335

MHz).The test was repeated on an airplane on the ground with 120 Hz pulsating current feedingthe RF signal generator. The indicationsrecorded were:
VOR tuned to 115.3 MHz, course set as 063: NAV captureNAV tuned to 110.3 MHz: LOC, GS flag out of viewLOC Center, GS 0.8 Dot upFD Green NAV. White GSRockwell Collins response to Korean Air Tests Rockwell Collins technical specialists evaluated the performance of the 51 -RV5(B) according to the test defined by Korean Air and responded in a 19 December 1997 letter from Mr.R.A. Patterson to Mr. S. R. Cho of Korean Air:,.. findings are similar to those of KAL; the receiver response to a single 120 Hztone, 100 percent modulation at 335.0 MHz is an out of view flag. However this isconsistent with the standards to which the product was designed and qualified.
The ILS Glide Slope receiver function of tbe 51 -RV5(B) complies with RTCADO- 132A which specifies warning flag operation for no tone, reduced tonemodulation, and loss of tone, These specify that the warning flag shall be in viewwhen one tone (90 or 150 Hz) is maintained at the normal 40 percent level and theother is reduced to zero. The 51 -RV5(B) complies with this specification.ICAO Annex 10 Appendix 3 provides specifications for ILS transmitter stations.
This specification stipulates, that for Glide Slope signals, the depth of modulationof the radio frequency carrier at each of the 90 and 150 Hz shall be approximately47.5 percent. Limits are set at 45 and 50 percent “in order to achieve the maximumbenefit from the airborne receiver flag alarm system.”
The 51 -RV5(B) implementation employs resistive/capacitive networks filters todetect 90 and 150 Hz tones. When the carrier signal is greatly over modulated, it ispossible to couple sufficient energy through these filters to cause the alarm flag tomove out of view. The test procedure defined by Korean Air represents acondition outside the specifications for either the transmitter or the receiver.
As with any other skill, perfection in flying the ILS is acquired with practice.
Use of the Instrument Landing System
At controlled airports, air traffic control will direct aircraft to the localizer via assigned headings, making sure aircraft do not get too close to each other (maintain separation), but also avoiding delay as much as possible. Several aircraft can be on the ILS at the same time, several miles apart. An aircraft that has come within two and a half degrees of the localizer course (half scale deflection shown by the course deviation indicator) is said to be established on the approach. Typically, an aircraft will be established by at least two miles prior to the final approach fix (glideslope intercept at the specified altitude).
Aircraft deviation from the optimal path is indicated to the flight crew by means of display with "needles" (a carry over from when an analog meter movement would indicate deviation from the course line via voltages sent from the ILS receiver).
The output from the ILS receiver goes both to the display system (Head Down Display and Head-Up Display if installed) and can also go to the Flight Control Computer. An aircraft landing procedure can be either "coupled", where the Flight Control Computer directly flies the aircraft and the flight crew monitor the operation; or "uncoupled" (manual) where the flight crew fly the aircraft uses the HUD and manually control the aircraft to minimize the deviation from flight path to the runway centreline.

## VI. LIMITATIONS AND ALTERNATIVES

Due to the complexity of ILS localizer and glideslope systems, there are some limitations. Localizer systems are sensitive to obstructions in the signal broadcast area like large buildings or hangars. Glideslope systems are also limited by the terrain in front of the glideslope antennas. If terrain is sloping or uneven, reflections can create an uneven glidepath causing unwanted needle deflections. Additionally, since the ILS signals are pointed in one direction by the positioning of the arrays, ILS only supports straight in approaches (though a modified ILS called an Instrument Guidance System (IGS) is also occasionally used, the most famous example being that which was in use at one of the runways of Kai Tak Airport, Hong Kong to accommodate a non-straight approach.). Installation of ILS can also be costly due to the complexity of the antenna system and siting criteria.
The advent of the Global Positioning System (GPS) provides an alternative source of approach for aircraft. In the US, the Wide Area Augmentation System (WAAS) has been available to provide precision guidance to Category I standards since 2007, and the equivalent in Europe, the European Geostationary Navigation Overlay Service (EGNOS), is currently undergoing final trials and will be certified for safety of life applications in 2010. Other methods of augmentation are in development to provide for Category III minimums or better, such as the Local Area Augmentation System (LAAS).
The FAA Ground-Based Augmentation System (GBAS) office is currently working with industry in anticipation of the certification of the first GBAS ground station in Memphis, TN; Sydney, Australia; Bremen, Germany; Spain and Newark,

NJ. All four countries have installed GBAS systems and are involved in technical and operational evaluation activities. The Honeywell and FAA team are working on the System Design Approval of the world's first Non-Federal U.S. approval for LAAS Category I operations; expected in first quarter 2009 and compliant with International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs) Category I LAAS.

## VII. CONCLUSION

1 A safe landing during Instrument metrological condition such as low ceiling or reduced visibility condition.
2 It provides a air traffic control for a dynamic increase in air traffic.

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