Implementation of Simultaneous Offset Instrument Approach (SOIA) Procedures

S. Dale Courtney
National Program Engineer
for Navigation
Air Traffic Organization
– Navigation Services
Federal Aviation Administration
800 Independence Avenue SW, 700W
Washington, DC 20591, USA
Email: dale.courtney@faa.gov

Charles J. Barbeau
Aviation Safety Inspector
Air Traffic Organization
– Aviation System Standards
6500 South MacArthur Boulevard
Oklahoma City, OK 73169, USA
Email: charles.j.barbeau@faa.gov

ABSTRACT

Closely spaced parallel runways present significant challenges to airport arrival rates when weather deteriorates from visual meteorological conditions to instrument meteorological conditions. SOIA procedures offer these airports the ability to maintain their airport arrival rate when weather deteriorates to instrument meteorological conditions through the use of flight procedures, navigation, surveillance, and communications equipment. SOIA utilizes a normal straight-in course to one of the runways while the other course is offset up to 3 degrees from normal runway alignment. The aircraft on the offset approach continues until visual separation between the two aircraft is required. At this point, the aircraft on the offset approach verifies visual contact with the aircraft on the straight-in approach and turns to align with the runway for landing. A Precision Runway Monitor allows Air Traffic Control (ATC) to monitor separation until the two aircraft reach the visual segment. A conventional Instrument Landing System (ILS) provides electronic guidance to the aircraft on the straight-in approach while a Localizer Directional Array (LDA) with Glide Slope, aligned to the offset course, provides electronic guidance to the aircraft on the offset approach. Additionally, Precision Approach Path Indicators (PAPI) provide visual cues to the aircraft on the offset approach for both the offset and straight-in segments. The offset LDA course does not cross the runway centerline thus keeping the aircraft safely separated laterally. This concept has been adopted at San Francisco International (KSFO) and Lambert/St. Louis International (KSTL) airports. Both airports have limited areas to locate the LDA resulting in the need for unusual siting and consequently innovative flight inspection techniques. The Federal Aviation Administration's (FAA) Automated Flight Inspection System is designed to evaluate conventionally sited facilities with localizer alignment measurement accuracy dependent upon the measurement area being close to the runway. In these operations, the Decision Height places the measurement area more than 3 miles from the runway, seriously derogating standard measurements. Siting becomes more difficult since the LDA facility must be positioned to provide guidance for the offset course. This siting, when combined with operational concerns of the airport, created multi-path problems at St. Louis and tidal influence issues at San Francisco. This paper provides an overview of SOIA procedures, focusing on flight procedures, siting, and flight inspection of the ground facilities as well as the actual procedure. Also presented are unsatisfactory and ultimately successful flight inspection procedures developed to overcome limitations of the Automated Flight Inspection System so the LDA can be adequately evaluated to the Decision Height and the Glide Slope to the conventional runway environment.

PURPOSE

To provide an instrument approach procedure that will sustain capacity at airports with closely spaced parallel runways when weather conditions deteriorate from visual meteorological conditions to marginal instrument meteorological conditions.

BACKGROUND

Parallel runways separated by a least 4,300 feet and both served by an ILS, are eligible to conduct simultaneous, parallel instrument approaches. Parallel runways separated by at least 3,400 feet are eligible to conduct simultaneous, parallel instrument approaches provided the 2,000 feet wide no-transgression zone is monitored by a high update rate surveillance system capable of a 1.0 second update interval such as precision runway monitor. Parallel runways separated as close as 3,000 feet may conduct simultaneous, parallel instrument approaches provided an offset ILS/Microwave Landing System of 2.5 to 3.0 degrees serves one of the runways and precision runway monitor is available. These three methods for conducting simultaneous parallel instrument approaches result in the same minima that could be achieved with a single runway.

Parallel runways can support an airport arrival rate of 60 landings per hour when visual meteorological conditions exist or simultaneous, parallel instrument approaches are authorized. Airports with closely spaced parallel runways (750 to 3,000 apart) must treat those runways as a single runway when weather does not support visual

meteorological conditions. When weather conditions are not visual, the airport arrival rate drops to 30 landing per hour. A capability is needed at high volume airports with closely spaced parallel runways to sustain capacity as the weather deteriorates from visual meteorological conditions to marginal instrument meteorological conditions.
The San Francisco International and Lambert/St. Louis International airports are two such locations needing this capability. The runway separation between runways 28R and 28L at San Francisco is 750 feet. The runway separation between runways 30R and 30L at St. Louis is 1,300 feet. SOIA offers these airports the ability to realize an airport arrival rate of approximately 40 landing per hour in marginal instrument meteorological conditions.

SOIA PROCEDURES [3]

SOIA refers to simultaneous approaches to a set of parallel runways utilizing a straight-in ILS approach to one runway and a LDA with glide slope instrument approach to the other runway. In SOIA, the approach course separation, instead of the runway separation, meets established parallel approach criteria. A visual segment of the LDA approach is established between the LDA missed approach point and the runway threshold, permitting aircraft to transition in visual conditions from the LDA course to align with the runway and be stabilized by 500 feet above the touchdown zone elevation. After accepting a clearance for an LDA precision runway monitor approach, pilots will remain on the LDA course until passing the LDA missed approach point prior to alignment with the runway centerline. If ATC advises that there is traffic on the adjacent ILS, pilots are authorized to continue past the LDA missed approach point to align with runway centerline if 1) the ILS traffic is in sight and is expected to remain in sight, and ATC has been so advised, and 2) the runway environment is in sight. Otherwise, a missed approach must be executed. Between the LDA missed approach point and the runway threshold, pilots of the LDA aircraft are responsible for separating themselves visually from traffic on the ILS approach, which means maneuvering the aircraft as necessary to avoid the ILS traffic until landing, and providing wake turbulence avoidance, if applicable. For the purpose of conducting SOIA operations, the two approaching aircraft are slightly staggered with the LDA aircraft being the trailing aircraft. The LDA aircraft must be trailing to facilitate the flight crew's ability to see the ILS traffic from which they must maintain visual separation from the nominal 30 seconds clear-of-clouds point to the LDA missed approach point.

The SOIA procedure design will position a stabilized approach point located at least 500 feet above the ground point of intercept and provide for a minimum straight flight segment of 1,000 feet between the turn at the LDA missed approach point and the turn to intercept the extended runway centerline at the stabilized approach point. Figure 1 illustrates a top view of the SOIA geometry.

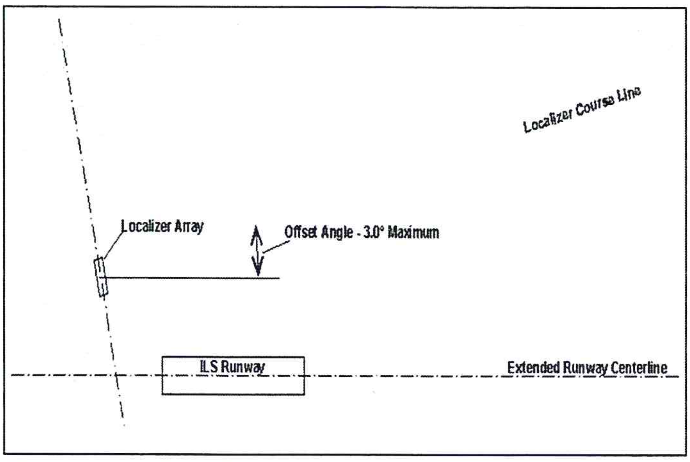


Figure 1: SOIA Geometry

At San Francisco, SOIA procedures achieve approach/landing minima to 200 feet above touchdown zone elevation for the straight-in approach and 1127 feet above touchdown zone elevation for the LDA approach. Minima achieved at St. Louis are somewhat better at 897 feet above touchdown zone elevation for the LDA approach and 200 feet for the straight-in approach.

EQUIPMENT SITING

An LDA, Glide Slope, Distance Measuring Equipment, PAPI, Precision Runway Monitor, and additional communications equipment are the ground facilities required to support SOIA. Precision runway monitor siting and the communications equipment will not be discussed in this paper since special attention to these facilities is not required to support SOIA. The distance measuring equipment also does not require special attention and will be considered collocated with the LDA facility.

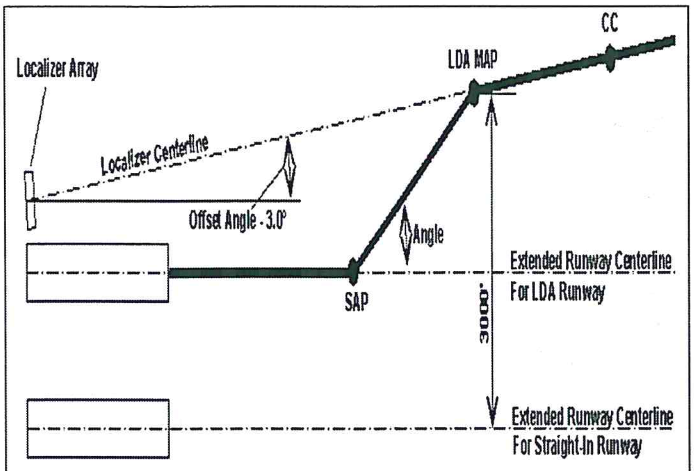
The LDA is sited such that the course produced by the LDA is that needed to support the SOIA procedure. The optimum use of SOIA is realized when the LDA course is offset 3.0 degrees with respect to the runway alignment. 3.0 degrees is also the maximum offset allowed.

The glide slope is conventionally sited to along the runway to produce a threshold crossing height of 55 feet. The glide slope tower and antenna array is canted toward the LDA course to assure coverage along the LDA course line as well as the straight-in visual segment.

Similar to the glide slope, the PAPI is conventionally sited but also canted to provide azimuth coverage that will support both the offset and straight-in segments of the approach.

LDA Considerations

As previously mentioned, the LDA is sited along the course line needed to support the SOIA operation. Consideration must be given in this situation such that the antenna array and shelter are located outside runway and taxiway safety area. Additional consideration must be given to not impact airport operations or have the equipment located such that it would be subject to jet blasts. General siting of the array is along the offset course line and is shown in Figure 2.



CC is the point the aircraft must be clear of clouds

LDA MAP is the missed approach point and where the aircraft begins the visual turn toward the runway

SAP is the stabilized approach point

Angle is determined by computer simulation of the type aircraft, including final approach Speed, planned to use the Approach

Figure 2: LDA Siting

Normally, LDA facilities are adjusted to provide a 6° course width. In the SOIA application, the LDA is adjusted to provide a tailored course width that would be the same as a straight-in ILS to the served runway. This allows course sensitivity to be similar to that of a normal parallel ILS approach.

San Francisco Siting. The optimum LDA siting at San Francisco was determined to be adjacent to the runway about 4,199 feet setback from the landing threshold. This placed the LDA at the edge of the San Francisco bay. This location led to fluctuations of the LDA alignment that were later discovered to be consistent with tidal changes in the bay.

Measured changes of the LDA alignment were ± 8 microamperes from mid tide to that of high and low tide. The alignment change is due to a varying ground plane seen by the LDA between high and low tide. During high tide, the array sees a uniform ground plane of seawater. During low tide, the array sees level seawater on the 150-Hertz side of the array but sees a sloping bank on the 90-Hertz side of the array. Since this deviation was within both the Flight Inspection tolerances[1] and Maintenance tolerances[2] for an LDA facility, it was deemed acceptable. Additionally, the deviation of the LDA course during tidal changes was evaluated with respect to the procedural azimuth and protection of the no-transgression zone. In the worst case, that of the alignment shifting closer to the straight-in course of runway 28L, there was still adequate protection of the procedure and no-transgression zone. Table 1 shows results of the LDA alignment 8 microamperes left of nominal.

Distance from Array	Deviation from Normal Course	Distance to NTZ
4 nm	56 feet	500 feet
6 nm	84 feet	825 feet
8 nm	113 feet	1147 feet
10 nm	141 feet	1467 feet
18 nm	254 feet	2724 feet

Table 1: LDA Alignment 8 uA Left of Course

The final issue with this array siting related to ground measurements of facility performance. Normally, LDA facilities require site technicians to perform ground checks using a portable ILS receiver at least 1,000 feet in front of the array. These checks verify alignment, width, and clearances. Since the array was sited at the edge of the bay, and boats are not available for routine maintenance, ground checks have to be conducted on the backside of the array. This arrangement proved reliable and was added to the ILS Maintenance Handbook2 as an alternate procedure for conducting ground checks of Localizer and LDA facilities.

St. Louis Siting. The optimum LDA siting at St. Louis was determined to be 3,993 feet set back from the stop end of the runway. This placed the LDA such that its front course signal radiation was in-line with the main terminal area. This location led to multi-path from the terminal environment as well as difficulty with flight inspection of the facility due to obstructions in the flight path.

The multi-path created from the terminal environment resulted in a bend of LDA alignment near the missed approach point. The bend was not of large enough amplitude to put the facility alignment out of tolerance. Additionally, it was determined to adjust the facility to produce proper alignment from the missed approach point out and not be concerned with alignment inside the missed approach point.

FLIGHT INSPECTION

Checking facility performance to support SOIA requires no changes from normal requirements for the straight-in ILS and essentially minor modifications to the LDA system requirements to accommodate an expanded service volume. These changes would be required regardless of the flight inspection system used and should primarily be limited to the glide slope as it must perform in a slightly different area than that for a standard approach.

Glide Slope Checks

Glide slope guidance is required from approximately 10 nautical miles from runway threshold on the LDA course, continuing through the visual side-step maneuver and ending at the traditional ILS Point "C". Clearance below path is flown in all required configurations on the LDA centerline and visual segments. As the glide slope standard service volume is 10 nautical miles from the antenna and 8 degrees either side of the runway centerline, an Expanded Service Volume was needed laterally on the LDA side of the runway to encompass the edge of the LDA course sector. This was an additional 2 degrees at St. Louis and 1 degree at San Francisco. Tilt checks were also performed at those limits in addition to those based on the normal runway geometry. A "mythical" localizer on the extended runway centerline using the actual localizer width enabled the automated flight inspection system to provide an accurate ground track for the angle optimization and standard tilt checks. Figure 3 depicts glide slope measurement geometry. Manual analysis of structure is required in the side-step area. Results of all checks on both glide slopes were satisfactory.

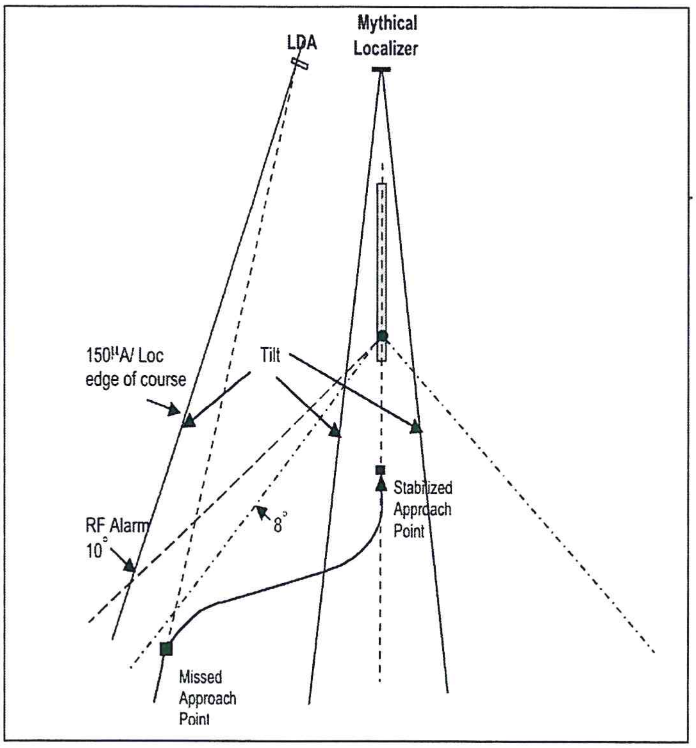


Figure 3: Glide Slope Measurement Geometry

Localizer Checks

Flight check of the LDA is essentially a straightforward process and consists of standard localizer requirements. The ability to correctly measure two parameters, course alignment and course structure, is heavily dependent on the type of flight inspection system used. The FAA Automated Flight Inspection System uses inertial based references corrected by position updates at each end of the precisely surveyed runway. As the optimally updated automated flight inspection system accuracy is known, inconsistency of results indicates either actual signal variations or measurement inaccuracy. Accuracy is derogated as a function of distance between measurement area and threshold update. At both SOIA installations, significant alignment variations were measured but initially attributed to facility equipment or environmental factors.

Site Problems and Resolutions

San Francisco. The unusually large offset of 981 feet with the approach course not crossing the runway centerline was correctly predicted to be beyond the capability of the automated flight inspection system to measure alignment. The tidal effect was also somewhat expected. An initial attempt produced run-to-run results that varied by over 40 microamperes. Later review indicated a facility data change between runs and apparent miscommunication between flight inspector and facility engineering.

The approach path and airfield environment allowed flying over a taxiway in-line with the LDA antenna. A Pseudo Runway was developed using the antenna and a painted target at a surveyed distance. This proved unsatisfactory as the target was difficult for the pilot to see until too late to maneuver close enough for the television positioning system camera. The second option of a slightly offset Pseudo Runway using the antenna and actual runway end produced excellent results. Many additional alignment runs at various tide levels proved that the alignment was both predictable and repeatable.

St. Louis. The St. Louis LDA was checked six times over a 17-month period before the actual causes of course alignment instability were proven. The initial symptoms pointed to a defective connector in the LDA antenna, but when it was repaired the alignment still varied during measurement. The next suspected cause, trees to one side of the course, resulted in the early removal of approximately 100 small trees with no improvement to the instability. On one inspection for the sole purpose of alignment investigation, 43 approaches were flown. One abnormal indication was a two to three fold change in airborne alignment for a given change in facility modulation balance. This occurred primarily when the alignment was measured in the one nautical mile segment prior the Decision Height point, an area containing a significant bend in the course. It also was more pronounced when the alignment was shifted to the left, towards the airport terminal area.

When the flight inspection system was suspected, theodolite and automated flight inspection system measurements were made on the same approaches; this proved that the basic instability was a function of the automated flight inspection system. Assuming the difference between modulation balance changes and automated flight inspection system results was also automated flight inspection system induced, no further check was made at that time. The automated flight inspection system manufacturer confirmed that the localizer alignment measurement accuracy degraded both with distance between measurement area and runway update due to inertial drift; this degradation increased with lateral aircraft movement.

As the FAA relies nearly exclusively on the automated flight inspection system, initial attempts to achieve stable results that could be referenced to the specified measurement area were based on standard techniques but with a Pseudo Runway built into the facility database. The preferred method of continuing inbound on the offset ground track and updating over identifiable surveyed points was impractical, as it would require flying over a congested taxiway and terminal building at a low altitude. Air traffic conditions dictated that flight inspection could maintain the offset ground track if at or above 500 feet above ground level until abeam the landing threshold, transitioning to runway centerline for updates at marked position at midfield and end of the runway. This method produced acceptable results, but was unsuitable as it required the pilot to "dive" from an already relatively low altitude to get low enough for the television positioning system to capture the landmark images. No more attempts were made toward automated flight inspection system alignment measurements.

The facility satisfactorily passed all alignment and structure parameters when measured using a Radio Telemetering Theodolite. The difference between the amount of modulation balance and airborne alignment shifts remained but was constrained by tighter than normal monitoring. The cause is believed to be signal multi-path from one of the two convex buildings on the left side of the course. As the alignment measurement area contains the course bend, the magnitude of the alignment shift is directly related to the amount of bend; as the alignment is shifted to the left, more of the reflector is illuminated.

Future Plans

Although the FAA previously chose not to incorporate a Differential Global Positioning System truth source into fight inspection, one is being adopted to support a Space Shuttle Microwave Landing System project. That differential global positioning system capability will be added to all automated flight inspection modes, replacing the radio-telemetering theodolite for use when traditional methods are not usable.

CONCLUSION

Based on lessons learned from implementing Simultaneous Offset Instrument Approach Procedures at San Francisco, California and St. Louis, Missouri, the following conclusions are reached:

1. Implementation of SOIA procedures can allow airports with closely spaced parallel runways to realize optimum airport efficiency and reduced arrival delays, under the conditions of restricted ceiling and visibility.

2. Ground equipment to support SOIA procedures can be sited to realize the benefits of SOIA.

3. Future application of SOIA should consider use of advanced avionics, RNAV, and Required Navigation Performance in lieu of establishing conventional ground based facilities.

4. Flight inspection procedures can be developed to properly evaluate SOIA procedures and verify operation of ground equipment required to support SOIA.

5. Flight inspection should be involved early in the planning stage of unusually sited facilities to allow time to develop special inspection procedures or modifications to the flight.

ACKNOWLEDGEMENTS

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REFERENCES

[1] United States Standard Flight Inspection Manual, FAA Order 8200.1

[2] Maintenance of Instrument Landing System (ILS) Facilities, FAA Order 6750.49

[3] Simultaneous Offset Instrument Approach (SOIA), FAA Order 8260.49

[4] United States Standard for Terminal Instrument Procedures, FAA Order 8260.3