United States of America
Federal Aviation Administration
Aviation System Standards
Flight Inspection Operations Division
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TRANSPONDER LANDING SYSTEM FLIGHT INSPECTION

ABSTRACT

The Transponder Landing System (TLS) is essentially a computer-controlled pair of signal generators transmitting "ILS Look-Alike" signals to guide the intended single aircraft from its known position along an "ILS-Type" approach path. Precise aircraft location is derived from time and carrier signal phase angle differences of the aircraft transponder return as it arrives at ground sensor antennas. Only one aircraft at a time can use the TLS.

Airborne evaluation of the TLS requires some traditional Instrument Landing System (ILS) measurement techniques and modifications to ILS inspection parameters checklists. This paper discusses the U.S. philosophy and process for these inspections. Lessons learned during prototype testing and results of flight inspections are presented. Also discussed are the challenges to further adapt flight inspection methods and equipment to support future use of the TLS in increasingly difficult siting conditions.

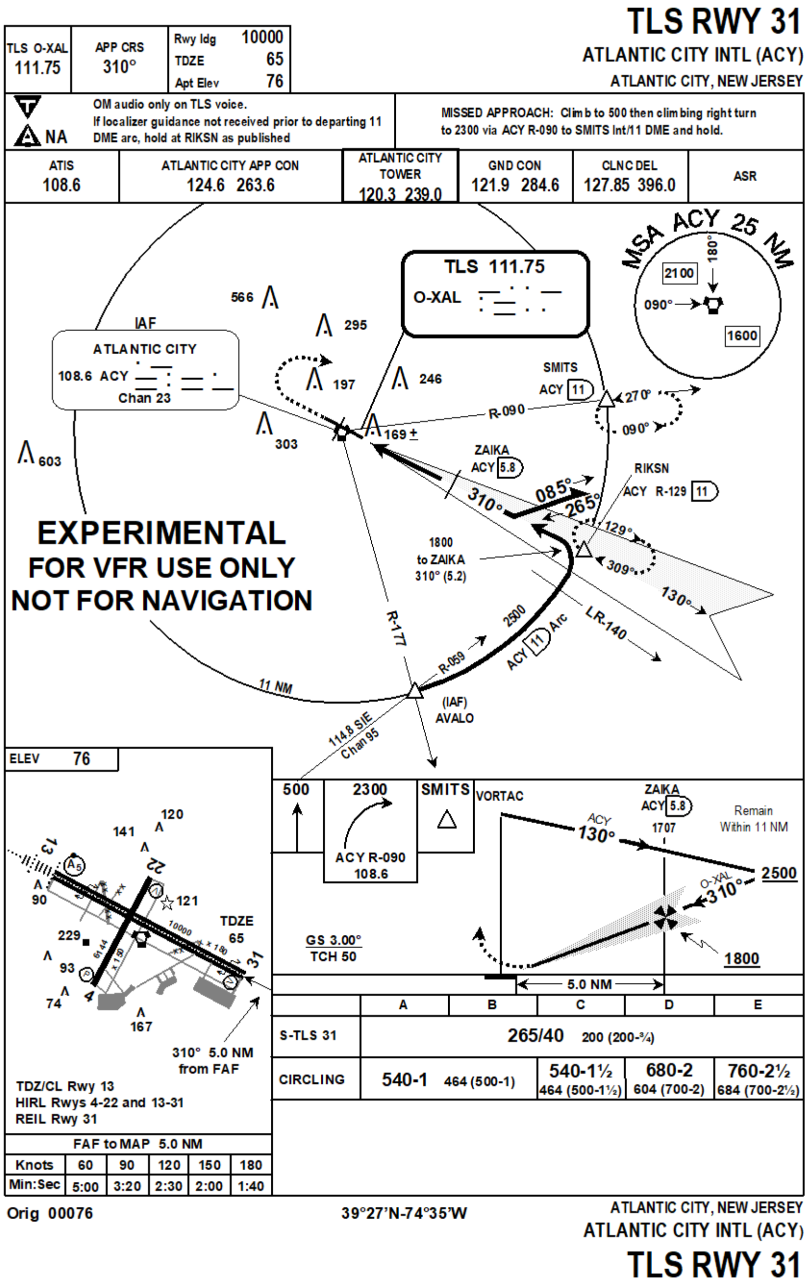
CONSIDERATIONS

Although the TLS produces an ILS signal, the procedures and flight inspection specialists must consider the applicable system differences to efficiently accomplish their tasks. For data dependent flight inspections, the capability of checking non-traditionally sited approaches may require software modification. Procedural design may be more intricate to best use the TLS capability in adverse sites. Flight Inspectors may need familiarization training to avoid TLS peculiarities being perceived as defects and inspectors may need to remember the “roots” of the profession to design inspection methods to suit their particular requirements.

Procedural Design

The design of the Instrument Approach Procedure is the same as for a traditional ILS, with the exception of the need for a fix within the TLS tracking volume and defined by another navigation source. This "TLS Acquisition Point" (TAP) defines the earliest point in the procedure where the pilot should request TLS "Acquisition" which activates the guidance. If "Acquisition" is requested outside the service volume, the system will perform a Built-in-test (BIT) and, failing to find the aircraft transponder code, return to "Standby Mode". The BIT generates a short test signal that a pilot could confuse with actual "Acquisition" followed by some system failure. If a TAP fix is on the localizer course, the holding pattern should either be totally inside or outside the glide slope tracking volume to avoid the automatic "Abort" which occurs when the aircraft departs the service volume of either the localizer or glide slope. Holding on normal procedures would place the aircraft outside the standard glide slope service volume on the outbound leg. The easiest remedy for this situation is to configure the TLS glide slope service volume to encompass the entire holding pattern. Figure 1 is the approach plate for the Atlantic City test station, which was produced prior to the requirement for a TAP.

Figure 1
Typical TLS Approach Plate



Screening

The TLS is most likely to be installed in locations unsuitable for an ILS due to adverse terrain or buildings. The line-of-sight screening by these features may preclude signal reception at planned procedural altitudes. It is important that the procedures specialist consider signal screening effects in the design of the approach. The flight inspector also should plan inspection profiles to avoid unnecessarily looking for a signal where screening precludes their reception. Verifying a projected facility restriction is easier and more efficient than defining one through multiple runs at increasing altitudes. The TLS installers, who also provide other facility data, measure screening angles based on the transponder link.

U.S. Flight Inspection Policy

FAA Order 8200.40A, Flight Inspection of the Transponder Landing System (TLS), the current U.S. guidance document, was derived from ILS procedures in the U.S. Standard Flight Inspection Manual, FAA Order 8200.1. There are no differences between ILS and TLS tolerances for measured parameters. The separate, "stand-alone" policy order is relatively easy to amend as increased knowledge of TLS warrants. Eventually, the TLS peculiarities will be included in the ILS guidance of Order 8200.1 and the separate order cancelled.

Flight Inspection Profiles

The flight inspection checks needed to determine system adequacy and accuracy are the same as for ILS; however, the scope of the inspection can be greatly reduced due to the nature of the TLS. The guidance signals are produced by computer-controlled RF signal generators rather than by individually phased antennas. There is no need to check the effects of phase changes through equipment deterioration or terrain irregularities. System displacement sensitivity/width is also a computer-controlled function unaffected by the carrier and sideband power ratios of the traditional ILS; therefore, there are no width monitors. The remaining checks are for signal coverage and calibration of transponder power and receiver sensitivity and guidance course/path alignment and width. An example of the currently used U.S. commissioning profile is in Figure 3.

Transponder Optimization and Validation

The installation team normally establishes ground interrogator power levels, side lobe suppression, and receiver sensitivity using non-flight inspection aircraft. These aircraft may not have a well-calibrated transponder, and validation of these adjustments must be by flight inspection with a calibrated transponder. Both the pre-commissioning set-up and flight inspection validation are arcs at the distances and limits indicated in Steps 1 through 8 in Figure 3. With the exception of the 12 nm arcs, which can provide valid course width information, no usable guidance information is received during these checks.

Peculiarities

The TLS has unique attributes that require changes in flight inspection techniques and increased situational awareness by the flight inspection crew. The sharp edge of the tracking volume may make maneuvering the aircraft to intercept a 35° clearance arc and being "Acquired" prior to the measurement area difficult in a limited airspace situation. In these cases, it may be necessary to start the run inside the guidance volume and fly outbound to the edges of required coverage. The approach used to validate the 7° upper limit of localizer coverage will place the aircraft outside the glide slope service volume, resulting in an automatic "TLS Abort". The solution to this is to have maintenance turn the glide slope function OFF during this check. Neither of these two situations makes flight inspection difficult.

One TLS feature that has caused extra work is the maximum glide slope proportional clearance value of approximately 200 μA. To ensure obstacle clearance while maintaining the beyond full scale value of 180 μA, it is typical in ILS flight inspection to descend further below path maintaining approximately 220 μA of fly-up signal. This allows some maneuvering room to preclude aircraft pitch changes in the last part of the approach. With a maximum of 200 μA proportional to aircraft displacement available, the inspector has no means to judge whether the aircraft is barely at or well below the 200 μA point. This lack of judgment ability has resulted in several runs to validate clearance below path. As the TLS is likely to be at a challenging airport and this run places the flight inspection aircraft close to obstacles, this feature causes concern by flight inspectors. This situation affects only the flight inspection aircraft and is of no concern for normal users.

Marker Indications

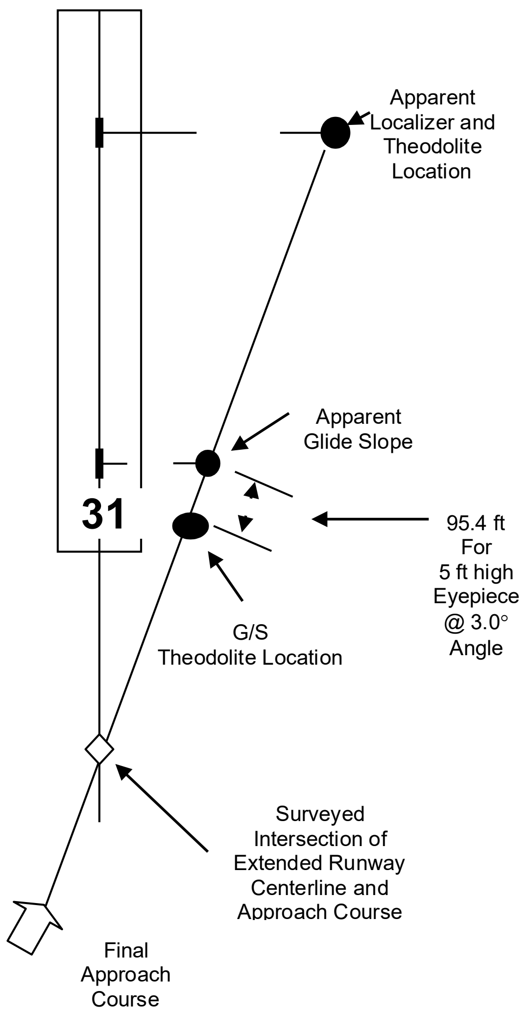
The TLS produces aural "Pseudo Marker Beacon" indications in a rectangular area at programmed Outer and Middle Marker locations along the approach path. The "Outer Marker" consists of continuous 700 Hz dashes keyed at 180 characters per minute, and the "Middle Marker" indication is alternating 2000 Hz dots and dashes keyed at a 120 per minute rate. As these "Markers" are transmitted on the localizer audio and not from a 75 MHz transmitter, they do not light the normal marker indicator lights, and their adequacy cannot be measured by reference to light activation signal level. To measure the width along course, it is necessary to manually note the amount of time that the aural indication is present and apply the aircraft ground speed. The most practical method is to mark the recordings at the applicable points. The major axis should be verified in the same way, except through flight along the localizer off-course indication. As the indications are solely determined by the horizontal position of the aircraft, height deviations have no effect on width. Any variations in width from check to check can most likely be attributed to the aural acuity and reaction time of the analysts.

Theodolite Procedures

Use of a theodolite as the positional truth source requires additional survey work, as the instrument cannot be placed in relation to antennas that exist only in mathematics. For a standard runway centerline approach, the apparent localizer antenna will most likely be on the runway at the point of theoretical emanation designed to produce a tailored course width of 700 feet at threshold. The glide slope apparent antenna will be on the runway centerline at the procedural touchdown point. For these installations, theodolite use, therefore, requires runway closure.

As some TLS procedures will be to airports which cannot support straight-in procedure, we must adapt the measurement techniques to fit the situation. For Localizer Directional Aid (LDA) procedures not aligned with a runway, the apparent localizer and glide slope antennas will most likely not be on the runway. The only way to use a theodolite will be to use surveyed points representing both apparent antennas. To check the "localizer", the theodolite should be located at the "apparent localizer" surveyed point, and aimed along the procedural centerline, which can be defined by reference to the point where it crosses the extended runway centerline. Consideration must be given to any actual structures which may occupy the location of the "apparent" antenna. The theodolite may have to be moved forward or backward along the procedural course, causing some amount of parallax determined by the amount of theodolite displacement from optimum. Minor parallax errors will have negligible effect on the centerline and measured structure but will induce some error in width measurements. The correct glide slope theodolite position is easily determined by reference to the eyepiece height corresponding with the glide angle. It is important that these theodolite locations be permanently marked to avoid measurement errors induced by incorrect positioning on subsequent checks. Figure 2 depicts possible theodolite locations to support the inspection of a TLS sited for an "LDA/with GS" approach.

Figure 2
Theodolite Locations for TLS LDA with GS Configuration



Flight Inspection Results

Only one TLS has so far been commissioned for Instrument Flight Rules (IFR) use. Several others are installed and awaiting sponsorship and procedural design.

Subic Bay, Philippines. This station was commissioned in 1998 as an 8.87° offset LDA with Glide Slope with an approach course through a rugged mountain valley. The 420-feet Height Above Touchdown (HAT) minima was dictated by obstructions. Line-of-sight screening caused coverage restrictions beyond 7° from centerline. Maximum localizer and glide slope structure in the procedural use area was approximately 66% of tolerance.

Atlantic City, New Jersey. This system was installed as the FAA test-bed. Commissioning profiles were flown to support glide angles of 2.5, 3.0, and 4.0°. Signal structure was well within Category I tolerances at all angles; but at the intended procedural altitudes for the 2.5° approach, coverage was unsatisfactory beyond 14 miles below 1725 feet above site elevation. Both the 2.5 and 3.0° procedures also were unusable beyond 17.3 miles below 2425 feet above site elevation.

Pullman, Washington. This system is still in a Visual Flight Rules Operational Demonstration status. This facility is completely surrounded by significantly higher terrain, resulting in "an airport in a bowl". Signal screening resulted in low altitude coverage restrictions off-course and beyond 13 miles on course. Maximum localizer structure was 4 μA, and the maximum glide slope structure above the 300 ft HAT decision height was 20 μA. At ILS point "C", angle alignment resulted in a measured structure of 38 μA, resulting in a glide slope restriction below decision height. Flight inspection of an approach software correction for this restriction has not yet been accomplished.

Watertown, Wisconsin. Another "airport-in-a-bowl", this has been the site of some testing which indicates the facility will have screening restrictions.

Long-Term Stability Data

A result of changes in direction by the FAA in the acceptance of the TLS has been the inability to gather periodic flight inspection results on any one facility. No data yet exists to show any signal quality changes over an extended period. As Atlantic City is the base for some FAA flight inspection aircraft and TLS facilities are now in the flight inspection aircraft database, it is now possible to economically and easily perform a flight inspection approach on a frequent basis. These samples may provide information on signal stability much earlier than can be gathered only on periodic flight inspections.

Future Needs

The present international standards for ILS address only the traditional runway centerline-oriented approach path. Offset ILS and TLS installations will become more common as precision approaches are demanded at more challenging airfields. These installations may have Decision Heights and Missed Approach Points more than two miles from touchdown while users desire signals for a stabilized approach completely to the runway. Service volume requirements must be redefined to address these issues. As the TLS has the capability to provide a curved approach path similar to Microwave Landing Systems, we must adapt inspection methods, standards, and equipment to measure signal adequacy. Some conceptual work has been done on curved-path evaluations; that work must continue so that flight inspection is ready before the TLS to avoid delays in providing service.

CONCLUSION

The TLS can provide a satisfactory Category I "ILS-Like" instrument approach to many airports unsuitable for traditional ILS equipment. Flight inspection can use many standard ILS inspection techniques to determine the adequacy of the guidance for most installations but creative uses of the TLS call for adaptation of inspection services.

RECOMMENDATIONS

1. Increase tracking and guidance volume distance limits as necessary to provide signals beyond the formally required “Service Volume” to give pilots a signal where they expect one.

2. Increase Glide Slope proportion deviation limit to approximately 225 μA to ease flight inspection

Figure 3
TLS Commissioning Profile
(continued on next page)

Step	Guidance TX Config (LOC/GS)	Ground Xpndr Config	Aircraft Xpndr Settings: FI Sel/Low Pwr Sel	Type Maneuver	Start Distance	Start AZ	Start Alt (MSL)	Stop Distance	Stop AZ	Stop Alt (MSL)	Remarks
1	Norm/Norm	P1/P3 "ON" Attenuation "IN", P2 "OFF"	ON/OFF	ARC	22 nm	5° Left	GSI	22 nm	15° Right	GSI	System set-up. Runs not needed if set during pre-commissioning.
2	Norm/Norm	P1/P3 "ON" Attenuation "IN", Ps "OFF"	ON/OFF	ARC	22 nm	5° Right	GSI	22 nm	15° Left	GSI	System set-up. Runs not needed if set during pre-commissioning.
3	Norm/Norm	P1/P3 "ON", P2 "ON" (STANDARD)	ON/OFF	ARC	12 nm	10° Left	GSI	12 nm	90° Right	GSI	System set-up. Runs not needed if set during pre-commissioning.
4	Norm/Norm	STANDARD	ON/OFF	ARC	12 nm	10° Right	GSI	12 nm	90° Left	GSI	System set-up. Runs not needed if set during pre-commissioning.
5	Norm/Norm	STANDARD	ON/OFF	ARC	22 nm	5° Left	GSI	22 nm	15° Right	GSI	Expect no guidance signal.
6	Norm/Norm	STANDARD	ON/OFF	ARC	22 nm	5° Right	GSI	22 nm	15° Left	GSI	Expect no guidance signal.
7	Norm/Norm	STANDARD	ON/OFF	ARC	12 nm	10° Left	GSI	12 nm	45° Right	GSI	Get Preliminary Localizer Width, request adjustment if necessary.
8	Norm/Norm	STANDARD	ON/OFF	ARC	12 nm	10° Right	GSI	12 nm	45° Left	GSI	Recheck width
9	Norm/Norm	STANDARD	ON/ON	ARC	10 nm	35° Left	GSI	10 nm	35° Right	GSI	OPTIMIZE WIDTH - Repeat 10-10 if needed
10	Norm/Norm	STANDARD	ON/ON	ARC	10 nm	35° Right	GSI	10 nm	35° Left	GSI	High Angle Clearance

Figure 3
TLS Commissioning Profile
(continued)

Step	Guidance TX Config (LOC/GS)	Ground Xpndr Config	Aircraft Xpndr Settings: FI Sel/Low Pwr Sel	Type Maneuver	Start Distance	Start AZ	Start Alt (MSL)	Stop Distance	Stop AZ	Stop Alt (MSL)	Remarks
11	LOW/ANY	STANDARD	ON/ON	ARC	18 nm	10° Left	4500 AGL	18 nm	10° Right	4500 AGL	
12	LOW/ANY	STANDARD	ON/ON	ARC	18 nm	10° Right	4500 AGL	18 nm	10° Left	4500 AGL	
13	LOW/OFF	STANDARD	ON/ON	APCH	18 nm	C/L	GSI	T	C/L	GSI	DISABLE G/S TO STOP ABORT ON LEAVING SV
14	LOW/ANY	STANDARD	ON/ON	ARC	10 nm	35° Right	GSI	10 nm	35° Left	GSI	Restore Glide Slope. Get Preliminary Width
15	ANY/LOW	STANDARD	ON/ON	LEVEL	10 nm	C/L	GSI	~ 3 nm	C/L	GSI	
16	ANY/LOW	STANDARD	ON/ON	LEVEL	10 nm	8° Right	GSI	~ 3 nm	8° Right	GSI	
17	ANY/LOW	STANDARD	ON/ON	LEVEL	10 nm	8° Left	GSI	~ 3 nm	8°Left	GSI	
18	Norm/Norm	STANDARD	ON/ON	LEVEL	10 nm	C/L	GSI	~ 3 nm	C/L	GSI	Optimize Width
19	Norm/Norm	STANDARD	ON/ON	APCH	18 nm	C/L	Proc	SER	C/L	50 AGL	Optimize Angle & Alignment
20	Norm/Norm	STANDARD	ON/ON	APCH	FAF	C/L	Proc ++	SER	C/L	50 AGL	Mean Width Above
21	Norm/Norm	STANDARD	ON/ON	APCH	FAF	C/L	Proc --	SER	C/L	50 AGL	Mean Width Below
22	Norm/Norm	STANDARD	ON/ON	APCH	FAF	C/L	LOW	T(C)	C/L	LOW	Clearance Below Path. RESET CROSSPOINTER CALIBRATION
23	Norm/Norm	STANDARD	ON/ON	APCH	FAF	150 μA Left	LOW	B	150 μA Left	LOW	Clearance Below Path
24	Norm/Norm	P1/P3 "ON", P2 "ON" (STANDARD)	ON/ON	APCH	FAF	150 μA Right	LOW	B	150 μA Right	LOW	Clearance Below Path