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Comparative Evaluation of Lateral Flight Technical Error for Instrument Landing System and Localizer Only Approaches

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Flight Systems Laboratory
Flight Technologies and Procedures Division
Flight Standards Service

Comparative Evaluation of Lateral Flight Technical Error for Instrument Landing System and Localizer Only Approaches

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12. Abstract

The purpose of this study was to compare the lateral flight technical error of approaches flown to either a Localizer-only (LOC only) approach or an Instrument Landing System (ILS) approach and to consider the impact of the results on the safety of dependent and simultaneous independent approaches to parallel runways where the glideslope is unavailable on one runway. FAA Order 7110.65, paragraphs 5-9-6 and 5-9-7 provide guidance for Air Traffic during parallel operations. While both paragraphs require ILS, Air Traffic has conducted these operations in several situations where the GS for one runway was inoperative (Localizer only). The Air Traffic Safety Oversight Service (AOV) took exception to this practice and, along with Air Traffic, requested AFS-400 provide an evaluation of the risk of conducting these operations with a glideslope not available on one runway.

This analysis considered data from flight simulator Human in the Loop (HITL) testing and high speed computer modeling. In the test, ten crews representing six different airlines participated and performed approaches to JFK International and Tucson International airports. The two approach procedures selected provided a range of values for runway lengths and number of step-downs on the approach. Each pilot flew six ILS approaches and six Localizer only approaches. Lateral and vertical deviation data was collected and analyzed. The data analyses showed significant variations between pilots and between approaches. Lateral deviations with Localizer only were an average of 33% over that of full ILS but well within an acceptable range.

Further analysis was done with a high-fidelity, fast-time simulation tool used to evaluate the risk of these and similar operations. The results of the fast-time simulation of this operation showed similar risk to operations utilizing both glideslopes.

The collision risk as determined by this test was acceptable for one runway with Localizer only guidance. Specifically, this report is not intended to counter the inherent safety advantages of using vertical guidance. The availability of GS should not be discounted as a recognized substantial safety enhancement during all instrument approach operations

13. Key Words ILS LOC GLIDESLOPE	**14. Distribution Statement** Controlled by AFS-450
15. Security Classification of This Report Unclassified	**16. Security Classification of This Page** Unclassified

Executive Summary

The purpose of this study was to compare the lateral flight technical error of approaches flown to either a Localizer-only (LOC only) approach or an Instrument Landing System (ILS) approach and to consider the impact of the results on the safety of dependent and simultaneous independent approaches to parallel runways FAA Order 7110.65, paragraphs 5-9-6 and 5-9-7 provide guidance for Air Traffic during parallel operations. Air Traffic has conducted these operations in several situations where the GS for one runway was inoperative (Localizer only). The Air Traffic Safety Oversight Service (AOV) and Air Traffic, requested evaluation of the risk of conducting these operations..

This analysis considered data from flight simulator Human in the Loop (HITL) testing and high speed computer modeling. A data collection program was conducted by the Flight Operations Simulation Branch (AFS-440) utilizing the FAA's Boeing 737-800 and Airbus 330 full motion, Category D simulators. Ten crews representing six different airlines participated and performed approaches to JFK International and Tucson International airports. The two ILS approach procedures selected for the test provided a range of values for runway lengths and the number of stepdown fixes on each approach.

Approaches were hand flown utilizing Flight Director (FD). A moderate pilot workload was applied by input of wind and turbulence levels. Each pilot flew six ILS approaches and six Localizer only approaches. Lateral and vertical deviation data was collected and analyzed. The data analyses showed significant variations between pilots and between approaches. Lateral deviations with Localizer only were an average of 33% over those of the full ILS but within an acceptable range. Subject pilot stated that in the absence of an ILS GS, the common practice is to fly an advisory Vertical Navigation (VNAV) profile or a calculated descent rate.

AFS-450 incorporated these results into simulations of parallel approaches using their high-fidelity, fast-time simulation tool. The results of the fast-time simulations of the ILS / LOC operation showed collision risk similar to ILS / ILS operations.

Specifically, The study concluded that the lateral Flight Technical Error was measurably greater for a LOC only approach compared to the lateral Flight Technical Error on an ILS approach, but that the risk levels of a TCV for both an ILS to ILS scenario and an ILS to LOC scenario for approaches separated by 4300' are both well within the FAA specified acceptable level of risk of 1.0×10^{-9}.

The results of this study, measuring only lateral dispersions between operations should not be construed as the lone factor in determination of an operational approval and should be combined with other factors and mitigations prior to making an operational safety assessment. Based on longstanding Agency policy, the availability of a glideslope should not be discounted as a recognized safety enhancement during instrument approach operations.

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1.0 Introduction

The purpose of this study was to evaluate the lateral flight technical error (FTE) for approaches with and without precision vertical guidance, i.e. Instrument Landing System (ILS) versus Localizer only (LOC only) primarily to determine the relative safety of allowing LOC only approaches on one runway during the conduct of simultaneous dependent and independent ILS approaches to parallel runways. Note that the term "LOC only" will be used in this report to describe an approach with lateral guidance equivalent to an ILS precision approach but no vertical guidance. This could be due to equipment failure of the glideslope ground system or an onboard avionics problem. It could also cover cases where there is an actual Localizer approach with no glideslope equipment installed. The term "ILS" will be used for a case with both precision lateral and vertical guidance. This report does not address LPV approaches (or LP). FAA Order 7110.65, paragraphs 5-9-6 and 5-9-7 provide guidance for Air Traffic in conducting dependent and independent Instrument Landing System (ILS) approaches to parallel runways. While both paragraphs specify ILS, Air Traffic has applied the separation criteria in several situations where the glideslope for one runway was inoperative (considering it as an "ILS with Glideslope NA"). The Air Traffic Safety Oversight Service, AOV, has taken exception to this practice and in at least one case issued a Warning Notice to Air Traffic's Terminal Service Unit. The Flight Standards Service Flight Technologies and Procedures Division, AFS-400, was requested by both AOV and Air Traffic to provide an evaluation of the impact on the safety of these operations by the requirement for a glideslope. This analysis considered data from flight simulator Human in the Loop (HITL) testing and high speed computer modeling.

The Flight Systems Laboratory (AFS-450) was already engaged in a study comparing the lateral deviations of Localizer only (LOC) approaches flown using step-down fixes or procedural altitudes to establish the vertical profile against the lateral deviations of ILS approaches flown with the glideslope providing vertical guidance. A data collection program was conducted by the Flight Operations Simulation Branch (AFS-440) utilizing the FAA's Boeing 737-800 and Airbus 330 full flight, Category D simulators. Three simulator tests were conducted. Technical issues were identified with some data from the first two tests. This report focuses on the data and results from the third test. In that test, ten crews representing six different airlines participated and performed approaches to JFK International and Tucson International airports. The two ILS approach procedures selected for the test provided a range of values for airport altitudes, runway lengths and the number of stepdown fixes on each approach.

Approaches were hand flown utilizing Flight Director (FD). A moderate pilot workload was applied by input of wind and turbulence levels. Each pilot flew six ILS approaches and six LOC approaches. Lateral and vertical deviation data was collected and analyzed. The data analyses showed significant variations between pilots and between approaches. Lateral deviations with LOC only were an average of 33% larger than those of the ILS approaches but were still contained within the precision approach lateral obstruction clearance surfaces.

A large percentage of the subject pilots reported that the instructions required to collect the desired test data were contrary to their normal operating procedures for LOC only approaches. Their comments are summarized in Appendix 1.

2.0 Data Collection

The data collection efforts were conducted at the Mike Monroney Aeronautical Center. Ten crews flew the 24 scenarios shown in Table 1 (five crews in both the Airbus and Boeing). The crews came from six different airlines.

The approach plates to JFK Runway 04R and TUS Runway 11L are shown in Appendix 2. During half of the scenarios, the Captain was the pilot flying (PF) and the First Officer (FO) was the pilot monitoring. In the other half of the scenarios, the roles were reversed. Additionally, the scenarios were arranged such that each PF flew three ILS and three LOC only approaches to both JFK and TUS in Instrument Meteorological Conditions (IMC). Wind and turbulence were set to create moderate pilot workload, changing in direction and magnitude as the aircraft descended. Typical variations were from a quartering tail wind at altitude at 54 to 70 knots down to a quartering headwind (from the opposite side) at 13 to 15 knots at airport elevation. The turbulence setting was maintained at about 20% for all scenarios. All scenarios were initiated on centerline approximately 12 nautical miles from threshold at a nominal altitude of 2,000 or 3,000 feet above the airport for KJFK and KTUS respectively. Several runs were inadvertently initiated at different altitudes but did not appear to affect the relevant data of interest.

The pilots were instructed to fly the given scenario's altitude profile, i.e. "dive and drive" even though that may not have been their normal procedure[1]. The scenarios also included two wake encounters of moderate strength that occurred outside the portion of the approach where lateral data was being collected. The results from these wake encounters will be used in an ongoing AFS-400 wake vortex encounter project. Aside from the inoperative glideslope, all navigation, avionics, and aircraft systems were providing nominal performance.

In total the twenty pilots flew 12 approaches each. Data from 230 runs were suitable for analysis. Ten of the data files were either missing or corrupted, the run had simulator set-up issues, or the pilots (and/or pilot observers) noted the data was not representative.

[1] While the test subjects were all experienced line pilots, they consistently reported that they seldom flew a LOC only approach in this mode and that airline policy generally required vertical guidance on approaches. Where a glideslope was not available, barometric altimeter based vertical navigation (Baro-VNAV) was normally used to generate a glideslope-like vertical profile.

Table 1 – Scenarios

Number	Airport	Pilot Flying	Approach	Day/Night	Operation
1	TUS	Captain	ILS	Day	MA
2	TUS	FO	ILS	Day	Land
3	TUS	Captain	ILS	Day	Land
4	TUS	FO	ILS	Night	MA
5	TUS	Captain	ILS	Night	MA
6	TUS	FO	ILS	Night	Land
7	TUS	Captain	LOC	Day	Land
8	TUS	FO	LOC	Day	MA
9	TUS	Captain	LOC	Day	MA
10	TUS	FO	LOC	Night	Land
11	TUS	Captain	LOC	Night	Land
12	TUS	FO	LOC	Night	MA
13	JFK	Captain	ILS	Night	MA
14	JFK	FO	ILS	Night	Land
15	JFK	Captain	ILS	Night	Land
16	JFK	FO	ILS	Day	MA
17	JFK	Captain	ILS	Day	MA
18	JFK	FO	ILS	Day	Land
19	JFK	Captain	LOC	Night	Land
20	JFK	FO	LOC	Night	MA
21	JFK	Captain	LOC	Night	MA
22	JFK	FO	LOC	Day	Land
23	JFK	Captain	LOC	Day	Land
24	JFK	FO	LOC	Day	MA

3.0 Data Analysis

3.1 Graphical Representation of Data

Due to the removal of GS guidance (and direction to dive-and-drive), a substantial difference in vertical profile was expected between ILS and LOC. Figure 1 shows the four vertical profiles by airport/approach (TUS/JFK) and guidance (ILS/LOC).

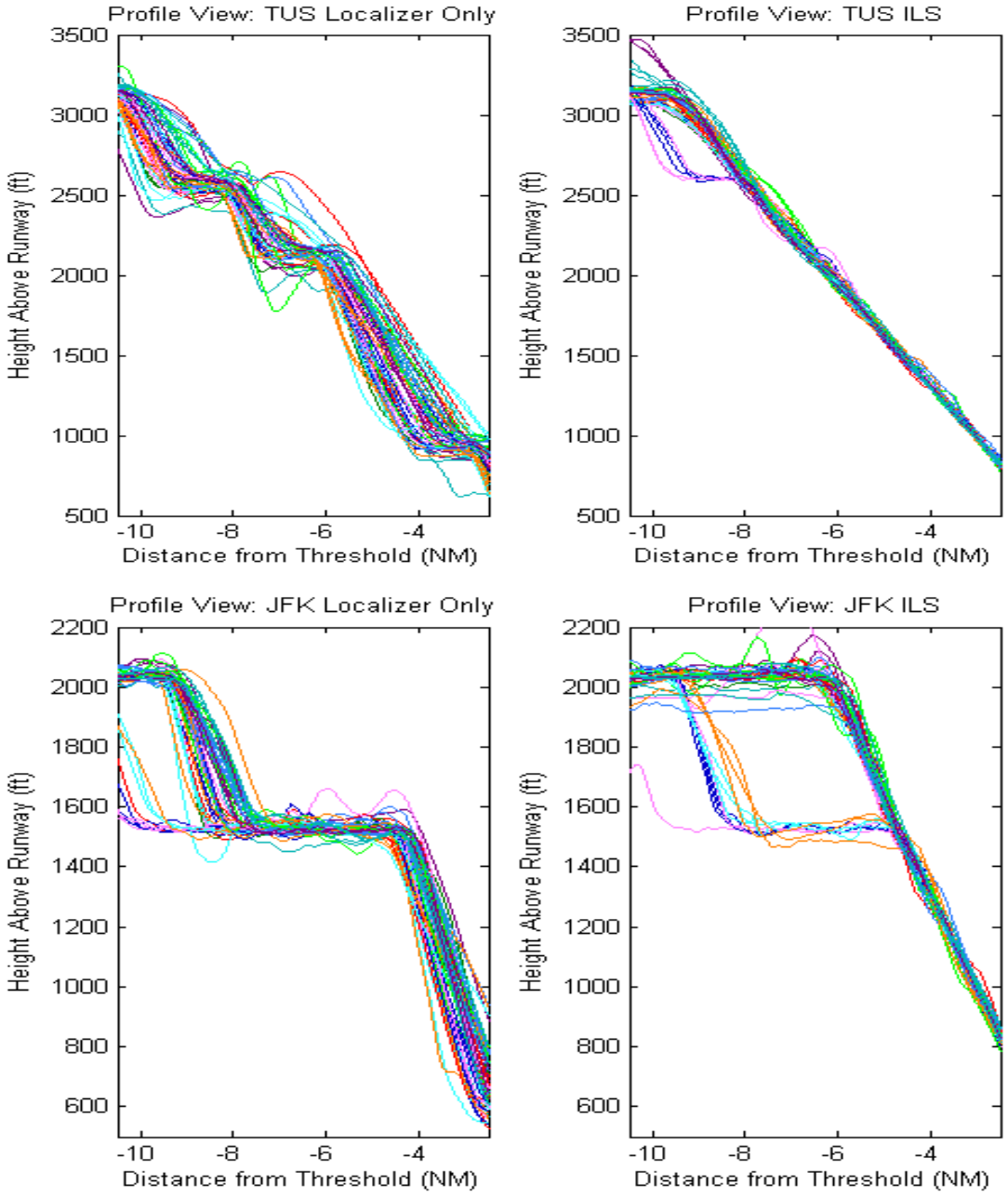

Figure 1 – Profile View: TUS LOC, TUS ILS, JFK LOC, JFK ILS

Figure 2 shows the four planform views, by airport/approach (TUS/JFK) and guidance (ILS/LOC). The graphical representation shows an appearance of higher lateral deviation in the LOC scenarios.

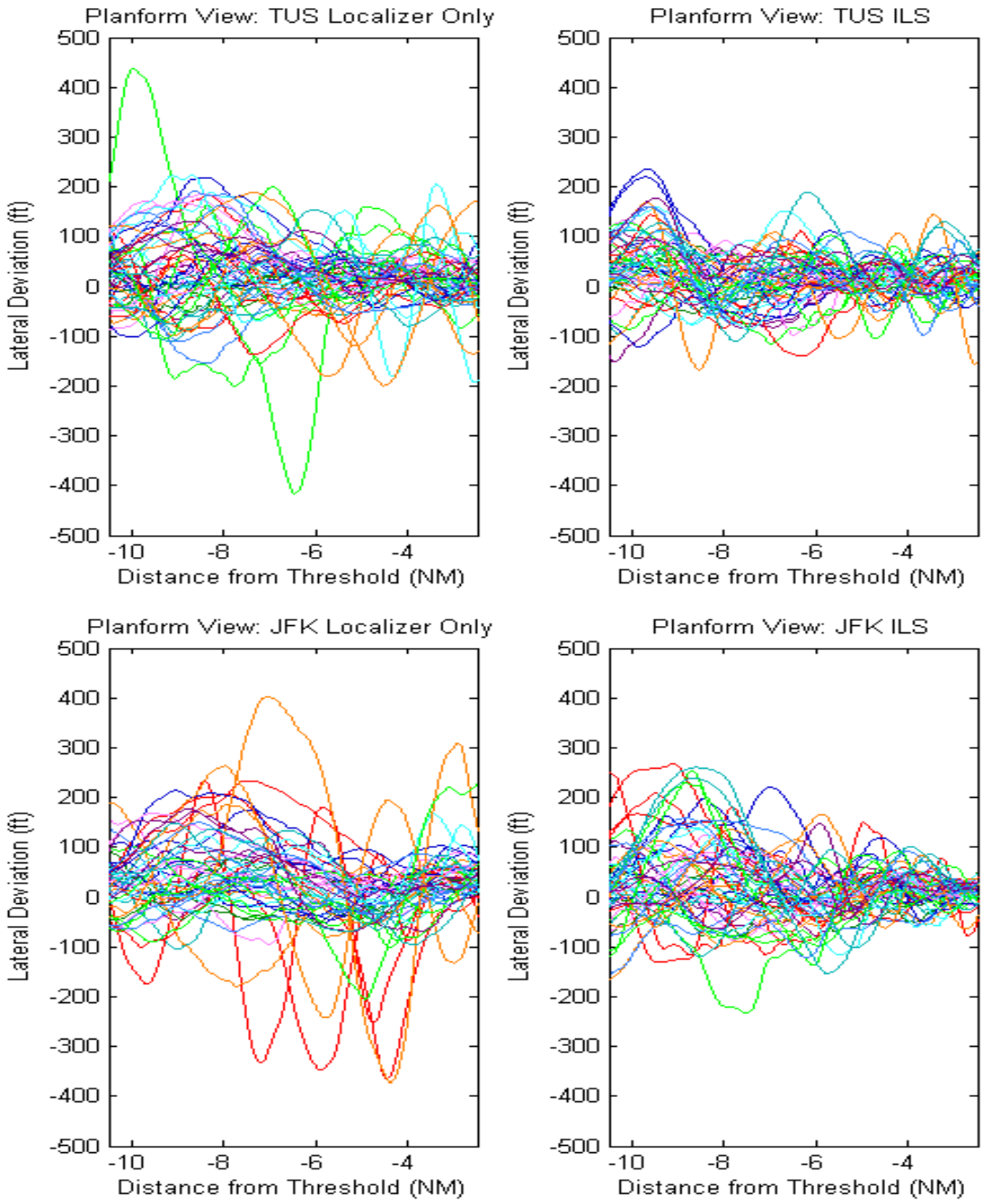

Figure 2 – Planform View: TUS LOC, TUS ILS, JFK LOC, JFK ILS

3.2 Numerical Results

Table 2 presents the standard deviations for the data at 1.0 NM spacings. Note that the LOC deviations are consistently larger than the ILS.

Table 2 – Standard Deviation (ft) of Lateral Deviation by Distance (NM) from Threshold

	10	9	8	7	6	5	4	3
ILS	66.0	67.3	65.9	53.3	54.2	30.8	27.1	27.4
LOC	89.4	89.4	85.6	86.8	85.0	62.0	71.0	53.6

3.3 Fast-Time Simulation

As discussed in the Introduction, the principal application of the results of this study is expected to be for dependent and simultaneous independent parallel approaches. The loss of glideslope is certainly not a regular occurrence, but does happen often enough to be a factor in system capacity if the loss of that service eliminates the ability of the airport to conduct simultaneous parallel operations.

The Flight Systems Laboratory uses high-fidelity, fast-time simulation tools to evaluate the risks associated with many aviation operations. The safety of parallel approaches has been addressed in many studies done by the lab using these tools. The fast-time simulation tool has input options including aircraft dynamics, lateral and vertical track distributions, surveillance, ATC monitoring systems, pilot and controller response times and environmental conditions. The simulation tool performs thousands of runs of each scenario to produce results that are used to calculate the risk (probability of a specific event). For this test, the "specific event" is a Test Criteria Violation (TCV), which was the penetration of one aircraft into the volume of space representing the other aircraft (a cylinder of 265 foot radius and 160 foot height to represent a worst case aircraft size, i.e. the Airbus 380) following a "blunder" or unexpected deviation from course toward the other traffic. For more details on the blunder scenario, refer to [3] and [4].

Two cases were examined using the simulation tool: an ILS to ILS and an ILS to LOC simultaneous parallel approach scenario. The inputs to the two simulation cases were identical with the exception of increased lateral deviations and the "dive and drive" vertical profile for the LOC only approach. The LOC lateral deviation was selected from the distributions represented by Table 2. The vertical profiles of the two cases were the same. Using the same vertical profile is the "worst case" as a higher incidence of vertical alignment would lead to a higher number of TCV's. Runway spacing was set at 4300' which is current standard without high update RADAR.

4.0 Results and Conclusions

ILS lateral and vertical performance data has been collected by the FAA for several decades. LOC only approaches were much less common and are classified as non-precision so there was less interest in dedicated data collection efforts. From a human factors viewpoint, the task/workload distribution is different. For the ILS, the pilot must keep the aircraft on course in 2 dimensions while monitoring other instruments, indicated airspeed, vertical speed, altimeter, etc. In a two pilot crew, some of these tasks are offloaded to the pilot monitoring. In a LOC only approach, the pilot must keep the aircraft on course in only one dimension. However attention to the altimeter and distance from threshold become more important and add workload not experienced in an ILS approach.

4.1 Simulator (Human-in-the-Loop) Results

As we are primarily concerned with the difference in lateral performance when flying a LOC only approach compared to flying an ILS approach, this analysis is based on performance differences. For every run, the total lateral deviation was calculated from 10.5 NM to 2.5 NM from the threshold. (This was to insure that the approaches to both airports were compared similarly and no visual data was contained in the calculation.) Figure 3 shows an example of the total lateral deviation for one of the 230 runs. Aircraft position is shown by the blue curve and the total lateral error is represented by the yellow shaded area. The chosen performance indicator for this study was the percentage increase of the total lateral deviation for a LOC only approach over the total lateral deviation for an equivalent ILS approach, i.e. all conditions were the same except for the availability of glideslope.

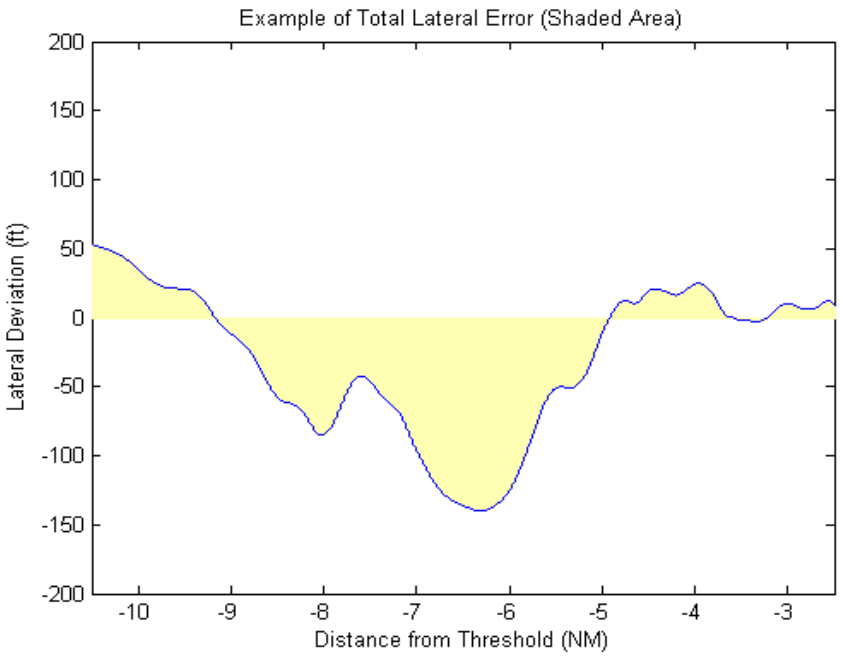

Figure 3 – Example of Total Lateral Error (Shaded Area)

Table 3 shows the percentage difference in the lateral performance (Total System Error) of each of the twenty pilots when flying a LOC only approach, as compared to the lateral performance when flying a full ILS approach. Total System Error (TSE) is the sum of FTE and Navigation System Error (NSE). For this test, the NSE was slight (averaging around 3 feet). Additionally, the NSE was equivalent in the ILS and LOC scenarios. Therefore, the NSE did not affect the percentage calculations. The table is presented grouped by magnitude. The differences ranged from lateral performance near the same (40%, in green), to moderate (40%, in yellow), to significant (20%, in red).

Table 3 – Performance Difference (Percentage) between LOC and ILS

-6%	-2%	4%	11%	33%	38%	55%	55%	74%	86%
-9%	-5%	2%	17%	20%	36%	44%	45%	81%	83%

4.2 Fast-Time Simulation Results

The results from the two cases evaluated in the fast-time simulation showed that the risk of a TCV for the ILS to ILS scenario was 3.76×10^{-10} per operation and 3.84×10^{-10} for the LOC to ILS scenario. The difference in these values is negligible and they are both less than 1.0×10^{-9}, which is the FAA Safety Management System acceptable value for risk of a catastrophic event.

4.3 Conclusions

Specifically, The study concluded that the lateral Flight Technical Error was measurably greater for a LOC only approach compared to the lateral Flight Technical Error on an ILS approach, but that the risk levels of a TCV for both an ILS to ILS scenario and an ILS to LOC scenario for approaches separated by 4300' are similar and both well within the FAA specified acceptable level of risk of 1.0×10^{-9}.

The results of this study, measuring only lateral dispersions between operations should not be construed as the lone factor in determination of an operational approval and should be combined with other factors and mitigations prior to making an operational safety assessment. Based on longstanding Agency policy, the availability of a glideslope should not be discounted as a recognized safety enhancement during instrument approach operations.

Appendix 1. Pilot Comments with regard to the Procedures

During the post simulation debriefs, numerous pilots stated that flying approaches with step-down fixes without advisory vertical guidance is a very infrequent occurrence in their normal day-to-day flying. When flying a non-precision approach without vertical guidance, the common practice is to fly an advisory Vertical Navigation (VNAV) profile or a calculated descent rate. Pilot feedback corroborates the benefits of vertical guidance. This report is not intended to counter the inherent safety advantages of using vertical guidance.

Here is a sample of pilot feedback with regard to the LOC only approach:

- Losing the glideslope and flying a LOC only approach would increase the overall pilot workload,
- The localizer at Tucson workload was high due to step-down requirements. Worse with tailwinds (i.e. the pace/number of tasks within a short period of time and space)
- Much less workload with glideslope
- Perceived that vertical track was much better with glideslope
- CP/FO: Tucson localizer a lot or work (Step-Downs) - Because we don't do them very often
- NOTE: If in very close proximity to parallel traffic, TCAS should be mandatory and /or a Stagger
- Dive and Drive caused a bit more mental requirements
- Would be uncomfortable with dive and drive. Would only shoot a constant rate descent.
- Pilots consciously configured early to stay ahead of the aircraft, understanding the rise in difficulty as they got to final
- After the FAF, the 'Dive and Drive' induced more workload
- Localizer Only just a bit higher (workload)
- Localizer-Only a bit more challenging so had to work a bit harder to achieve the same performance level.
- Dirtied-up Airplane early due to "dive and drive"

Appendix 2. ILS Approach Plates

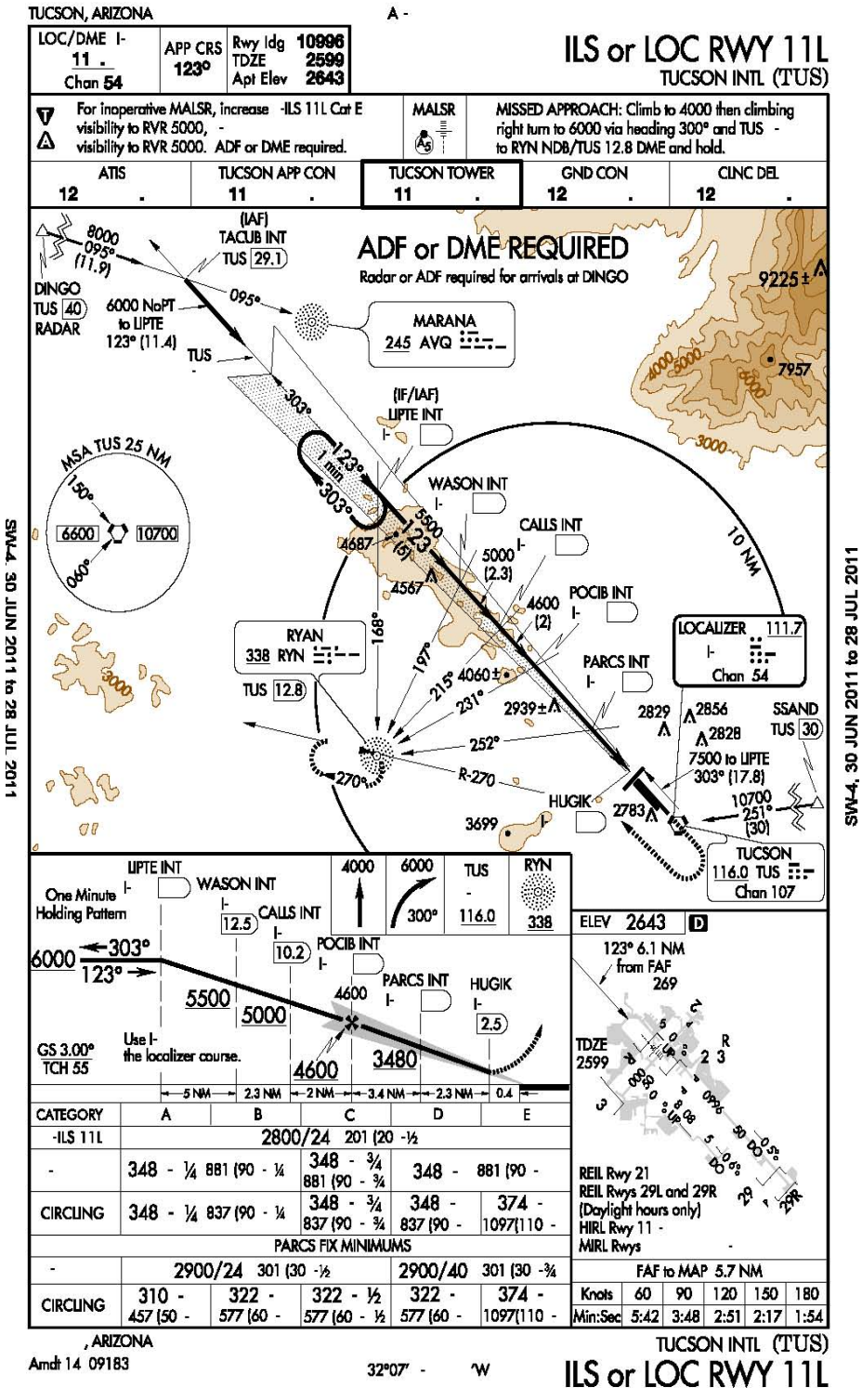

Figure B-1: Approach Plate for ILS to Tucson International Runway 11L

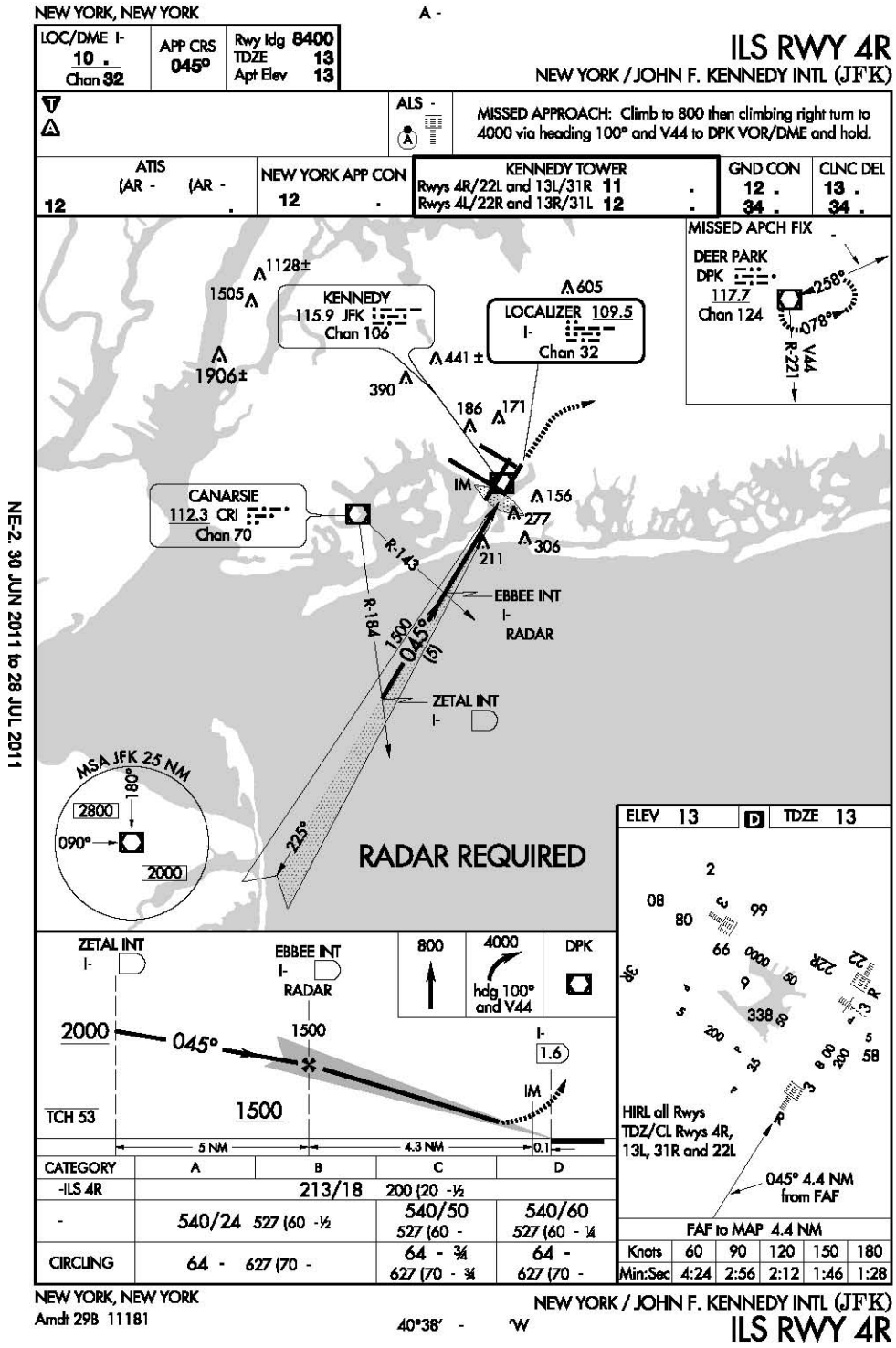

Figure B-2: Approach Plate for ILS to JFK International Runway 04R

References

[1] Federal Aviation Administration. (2010) *Air Traffic Control* (DOT/FAA Order 7110.65T). Washington, DC: Federal Aviation Administration.

[2] Commercial Aviation Safety Team, (1998) "*Joint Safety Analysis Team report on Controlled Flight Into Terrain Results and Analysis*", http://www.cast-safety.org/cast_reports.cfm

[3] McCartor, G., Moore, C., and Ladecky, S. (2007) *Safety Study Report on Simultaneous Parallel ILS and RNAV/RNP Approaches–Phases 1A and 2A* (DOT-FAA-AFS-440-29). FAA/AFS-440, Oklahoma City, OK.

[4] Greenhaw, R. (2011) *Geometric Models for Aircraft in Terminal Area Risk Analyses* (DOT-FAA-AFS-450-63). FAA/AFS-450, Oklahoma City, OK.