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Minima Reduction Simulation Test Results

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16. Abstract

This report presents the results of tests conducted in a Beech-200 (B-200) simulator located at the Beech Learning Center in Wichita, Kansas, and operated by FlightSafety International (FSI). The testing was conducted to examine the feasibility of reducing approach minimums below Category I by utilizing a highly accurate navigation signal, such as the Microwave Landing System (MLS), when standard Category II approach and runway lighting are not available.

Results are presented which indicate that properly trained crews using flight director-equipped aircraft can operate to lower approach minima than standard Category I without full Category II approach and runway lighting. Performance in the visual segment and touchdown performance is shown to be equivalent regardless of the availability of touchdown zone or runway centerline lighting. The benefits of a Category II approach lighting system (ALSF-2) are mitigated by the fact that when the aircraft breaks out of weather at the lower decision heights (DH's), i.e., 150 feet above ground level (AGL), most of the approach light system is already behind the aircraft.

Recommendations are made for further testing in actual aircraft.

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EXECUTIVE SUMMARY

A flight simulation study was conducted using a Beech-200 (B-200) simulator located at the Beech Learning Center in Wichita, Kansas. This facility is operated by FlightSafety International (FSI). The purpose of the evaluation was to determine the feasibility of establishing an intermediate Category II approach minima when certain conditions are met and a Category II runway lighting environment is not available.

The required conditions include:

1. The aircraft is instrumented for Category II approaches as required by appendix A to Federal Air Regulations (FAR) Part 91.

2. An approved landing system which provides Category II signal accuracy to the runway threshold, such as the Microwave Landing System (MLS), is used.

3. Accurate ranging information to support the approach procedure is used.

4. The crew is trained to conduct approaches to at least the intermediate Category II level.

Currently, in order to conduct approach operations to decision heights (DH's) below Category I (200 feet height above touchdown (HAT)), considerable upgrades are required to both the instrument landing aid and the landing area environment. The runway lighting environment, for example, must include an approach lighting system with sequenced flashers (ALSF-2), high intensity runway lights (HIRL), touchdown zone lighting (TDZ), and centerline lighting (CL). This lighting ensemble is extremely costly to install and maintain. In cases where a new landing system such as MLS could provide Category II signal accuracy or better, retrofit installation of the currently required lighting systems could render such action cost prohibitive.

Twenty airline crews from Regional Airline Association (RAA) member carriers participated in this evaluation. After minimal training and simulator familiarity, each crew flew up to 19 different approaches. A number of variables, including weather (ceiling, visibility, winds), the availability of a flight director, and approach lighting configurations, were presented.

Test measures were of two types: objective and subjective. The objective measures included continuous tracking of aircraft position-in-space from 1000 feet Above Ground Level (AGL) to touchdown, lateral and vertical deviation from centerline and glideslope at DH, lateral and vertical position at threshold crossing, and touchdown point dispersion. Subjective measures were derived from test crew responses to several different

questionnaires designed to comparatively measure their perceptions.

Based on the objective and subjective test results, it can be concluded from the simulation that approach minima reduction, based upon improved approach system accuracy, is feasible, without requiring current Category II approach and runway lighting. It is recommended that actual flight tests be conducted in an instrumented Federal Aviation Administration (FAA) B-200 aircraft with dual flight directors to verify these results.

INTRODUCTION

BACKGROUND.

Precision approaches are categorized according to the minimum permissible weather conditions (ceiling and visibility) under which an instrument approach can be attempted during Instrument Meteorological Conditions (IMC). As the weather conditions deteriorate, reliance on ground and airborne instrument guidance becomes increasingly critical. In addition, factors such as crew training and visual enhancement of the landing area environment become progressively more demanding.

Currently, there are three approach minima categories:

Category-I: Allows for a decision height (DH) no lower than 200 feet height above touchdown (HAT). The minimum visibility is 3/4 mile (Runway Visual Range (RVR) = 4000 feet), with a reduction to 1/2 mile (RVR = 2400 feet) achievable with a proper approach lighting system, and a further reduction to 3/8 mile (RVR = 1800 feet) with the addition of touchdown zone and centerline lighting. These are the lowest standard instrument approach minima. Operations to lesser minima fall into Category-II or III, and require specialized ground and airborne equipment, aircrew training, and aircraft and aircrew certification.

Category-II: Allows for a DH as low as 100 feet HAT, and a minimum 1/4 mile visibility (RVR = 1200 feet).

Category-III: This category has three subcategories. Category-IIIa permits DH's between 100 and 0 feet HAT, with RVR's of 700 feet or greater. Category-IIIb permits DH's between 50 and 0 feet HAT, with RVR's between 700 and 150 feet. Category-IIIc is for 0 feet DH and 0 feet RVR.

For operation under Category-II and III conditions, air carrier operators are required to develop and implement special operating procedures [1]. These procedures are approved by the Federal Aviation Administration (FAA) on an airline/aircraft-type/airport/aircrew specific basis.

Approach minimums for a particular runway are a function of: required obstacle clearances, guidance signal accuracy, stability, continuity of service and integrity, runway and approach lighting, aircraft systems (flight controls, avionics, autopilot, etc.), and special aircrew training. Unlike most Instrument Landing System (ILS) installations, every ground Microwave Landing System (MLS) has an inherent signal quality equivalent to that required for Category-III ILS. Furthermore, testing has shown that MLS signal quality is superior to ILS in a variety of difficult siting and terrain conditions [2].

Because Category-III accuracy is available with every MLS installation, the ability to conduct approaches to lower than Category-I minima to runways not currently approved for Category-II and III warranted investigation. A major impediment to implementing Category-II/III approach capabilities at most airports is the cost of procurement, installation, operation, and maintenance of the enhanced approach and runway lighting required to support it. If it can be shown that the increased accuracy inherent in MLS will permit safe operation to minima below Category-I without the need for expensive approach and runway lighting, many more runways can remain usable longer, under adverse weather conditions.

Testing and certification activities have shown that the improved MLS signal quality and accuracy can be readily integrated with current flight directors, flight control systems, and autopilots. Integrating MLS with a flight director and other information, such as distance to threshold and radar altitude, can result in a significant reduction of lateral and vertical tracking errors during an approach. With proper crew training, this avionics configuration may assist the pilot in consistently delivering the aircraft to a more accurate DH point with MLS than with most Category-I ILS. This principle (fully explained in reference 3) is illustrated in figure 1. The ability of the pilot to determine DH, laterally and vertically with today's ILS using barometric altimetry and without flight director aiding, are described by a rectangular box 120 feet high by 240 feet wide by 2290 feet long (taken from reference 3). Performance within this box is acceptable for Category-I (nominally 200 feet DH) ILS today. With an optimized flight director, ranging information from precision distance measuring equipment (DME/P) and radar altimeter input (or MLS-derived altitude), the MLS delivery box for a 150-foot DH is 18 feet high by 101 feet wide by 234 feet long (derived in reference 3). The 150 foot DH box for MLS is entirely contained within the currently acceptable ILS Category-I delivery box for a 200-foot DH. To obtain the depicted performance, altitude determination on the glidepath is critical. While achievable with radar altimetry in areas of compatible terrain, MLS permits the calculation of an extremely accurate computed height value using MLS elevation and DME/P information under all terrain conditions.

The evaluation described in this report was designed to measure the possible benefits that can be derived from the increased guidance signal accuracy of MLS. The results would apply to any navigation system meeting or exceeding the accuracy of MLS. An example would be an ILS signal of Category-II quality and an underlying terrain that would support the use of a radar altimeter.

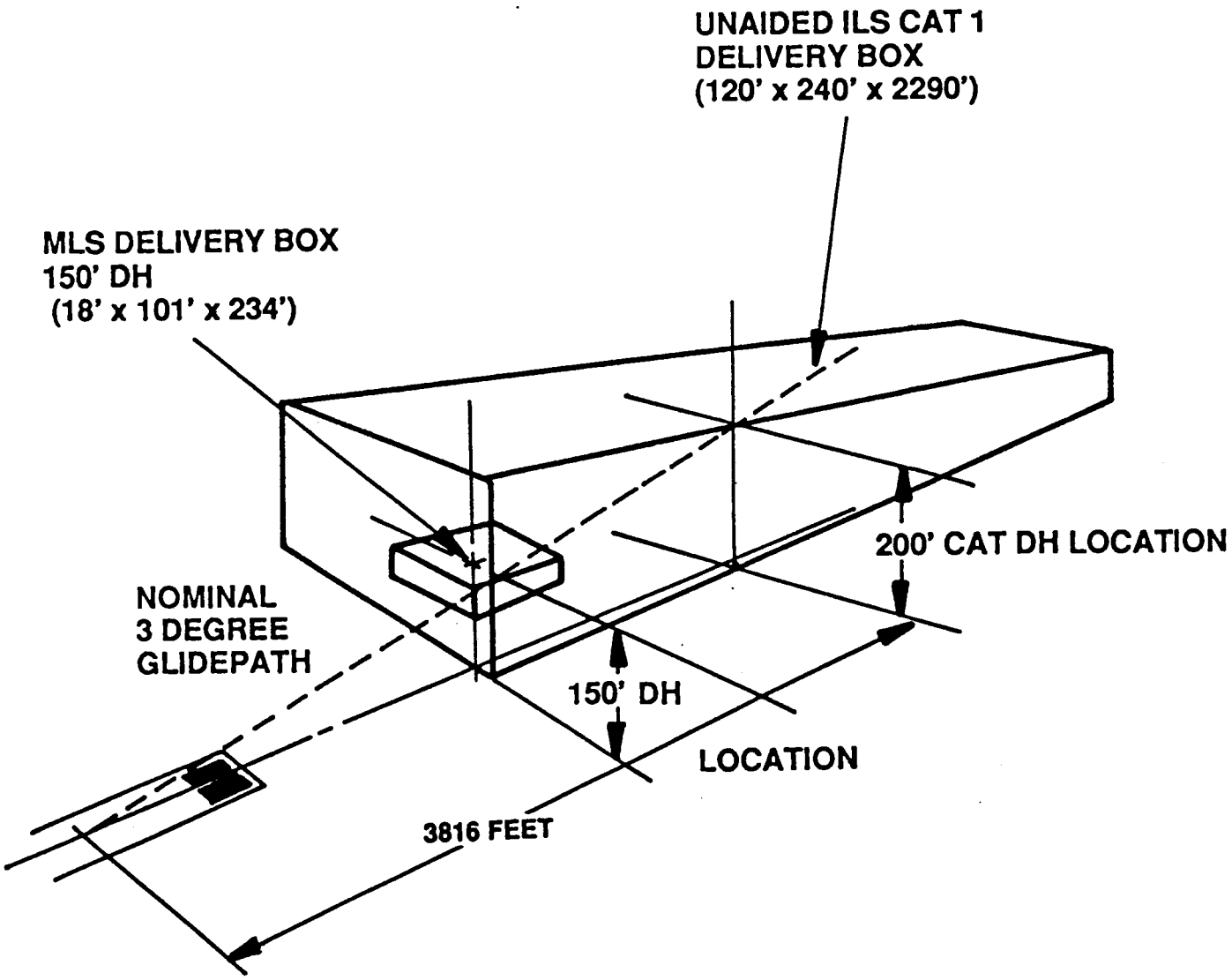


FIGURE 1. PRECISION APPROACH DELIVERY ENVELOPE

RUNWAY LIGHTING ENVIRONMENT.

At, or before, aircraft arrival at DH during Category-I and II approaches, the pilot must visually acquire the landing area environment and, using those visual cues, complete the landing. A major element impacting crew performance in the visual segment is the available runway and approach light system. Typical approach light systems in use today for Category-I and II are, respectively, Medium Intensity Approach Light System with Runway Alignment Indicator Lights (MALSR) and the Approach Lighting System with Sequenced Flashing Lights (ALSF-2). An ALSF-2 extends at least 2400 feet, and in many cases, 3000 feet from the runway threshold. The MALSR extends a minimum of 1400 feet from runway threshold, and may also contain a system of sequenced flashers. Typical configurations are depicted in figure 2. Except under special circumstances, an ALSF-2 is required for Category-II and III operations.

Several different types of runway lighting systems exist. Runway edge lighting can consist of either High Intensity Runway Lights (HIRL) or Medium Intensity Runway Lights (MIRL). In the field, MIRL has been almost entirely replaced by HIRL. Two common types of in-runway lighting are Touchdown Zone Lighting (TDZ) and Centerline Lighting (CL). Currently, to operate below standard Category-I minimums (200 feet DH/2400 feet RVR) requires that TDZ and CL be in place on the runway. ALSF-2, TDZ, and CL are costly to install and maintain, and may be the limiting factor in permitting operation to DH's below Category-I at many airports.

TEST OBJECTIVE.

The objective of this simulator program was to evaluate pilot performance in executing manually flown, raw data (crosspointers only) and flight director aided precision approaches under various test conditions. The conditions included DH's ranging from 100 to 200 feet HAT, and RVR's from 2400 feet down to 1200 feet. Various runway lighting environments were employed to evaluate runway and approach light system effects on pilot performance.

The data presented in this report represent the results of the first phase of testing to determine if a reduction in approach minima is feasible using the consistent Category-III accuracy of MLS when a current Category-I landing visual environment exists. It is assumed that the crews are properly trained to conduct such operations, and that the aircraft is properly equipped. The evaluation was divided into two 5-week segments, each consisting of 10 crews. This structure was adopted to allow for evaluation and modification of the test conditions, should the results from the first 10 crews warrant it.

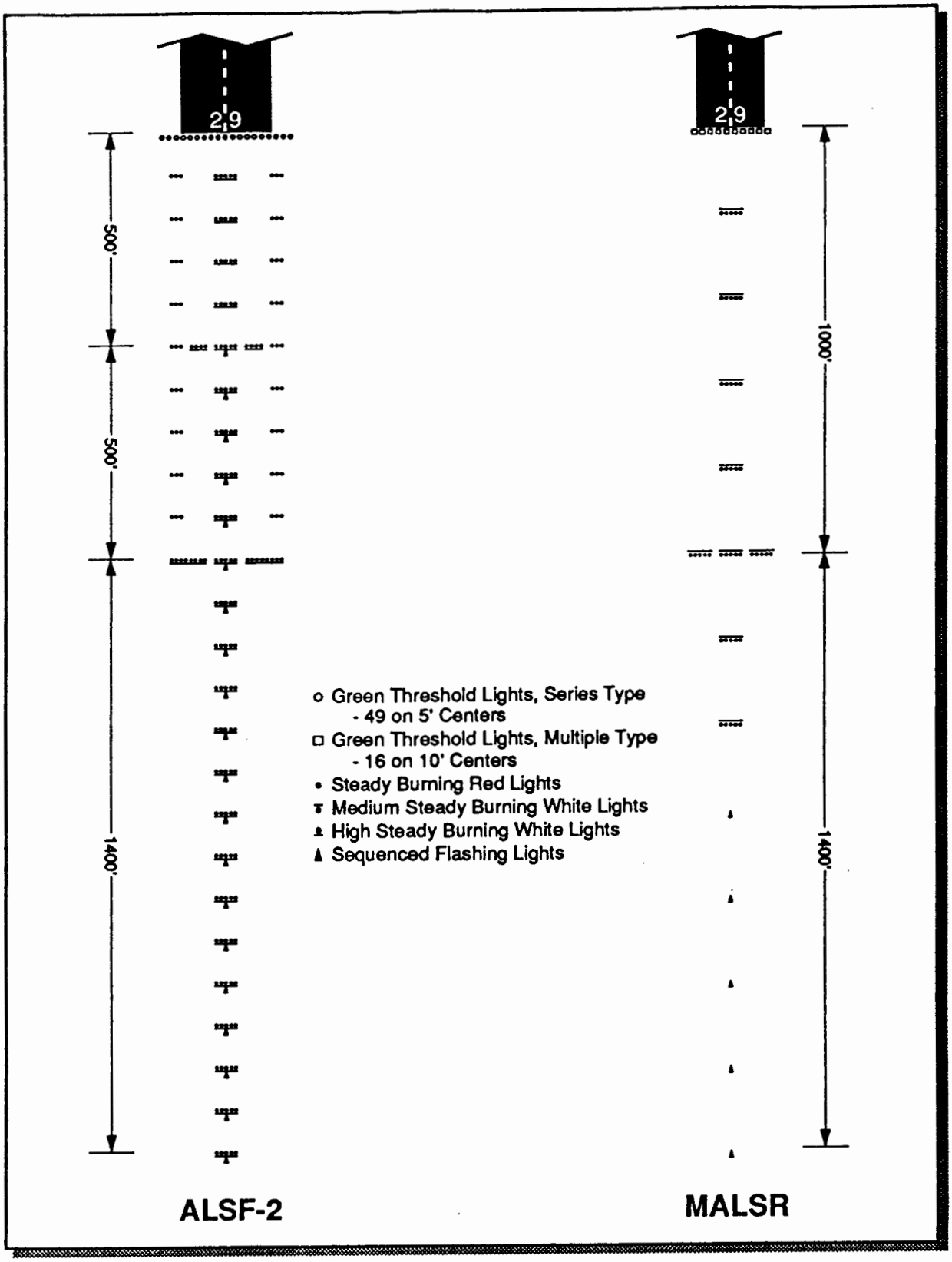


FIGURE 2. ALSF-2 AND MALSR

There were some recognized limitations in conducting the evaluation in a simulator. One was the fidelity of the simulator's handling qualities in the landing configuration, particularly from threshold crossing through roll-out on the runway when landing flaps were selected. Another limitation was the unavailability of an accurate MLS signal error model for implementation in aircraft simulators. Because MLS signal error is known to be extremely small, the error used in the simulation was set to zero. Since only the feasibility of landing minima reduction was being addressed, these limitations were deemed acceptable. If the concept proved feasible in the simulator, follow-up flight testing would be conducted in an FAA King Air 200 test aircraft, unencumbered by the limitations of simulation.

SIMULATOR DESCRIPTION.

A Beech King Air 200 simulator, located at the Beech Learning Center in Wichita, Kansas, and operated by FlightSafety International, was selected for the evaluation. This model simulator was selected because of the plan to conduct second phase flight testing in an FAA King Air model 200 test aircraft. The simulator was equipped in accordance with FAA Part 91, Appendix A, for Category-II operations. This equipment included:

1. Dual cockpit instrumentation
2. Approved flight control system
3. Radio altimeter
4. Flight director
5. DME

The simulator's visual scene provided for weather conditions ranging from 200-foot ceiling and RVR=2400 feet to a 100-foot ceiling with RVR=1200 feet. Flight conditions included crosswinds of 10 knots, tailwinds of 5 knots, and moderate turbulence. The different runway lighting test conditions used are depicted in table 1.

It should be noted that the MALSR/HIRL/CL combination of approach lights and runway lighting is not a standard configuration. It was "created" for the evaluation to provide an alternative to a full Category-II runway lighting system.

TABLE 1. RUNWAY LIGHTING ENVIRONMENT TEST COMBINATIONS

TEST CONDITION	APPROACH LIGHT SYSTEM	RUNWAY EDGE LIGHT SYSTEM	IN RUNWAY LIGHTS
MALSR/H	MALSR	HIRL	None
MALSR/M	MALSR	MIRL	None
ALSF-2/H	ALSF-2	HIRL	CL, TDZ
MALSR/H/CL	MALSR	HIRL	CL

During pre-test trials, several aspects of the landing area environment were reviewed. During the review, the simulator was placed on final approach at various DH locations, with a fixed set of weather conditions (ceiling and RVR). Figure 3, for example, depicts what a pilot would be expected see on final approach with MALSR/HIRL at a 150-foot DH, with a ceiling of 150 feet and RVR=1800 feet. Similarly, figure 4 depicts ALSF-2/HIRL at the same location and weather from 150 Feet HAT conditions. Note that the ALSF-2 approach lights present little added information than the MALSR from this vantage point, since at the 150-foot DH location, at least one-half of the ALSF-2 lights are behind the aircraft. Also note that the runway markings are barely visible. Throughout the testing, crews commented that, based on their experience, actual runway markings are much more conspicuous than those presented in the simulator.

TEST SCENARIO

SUBJECT PILOTS.

The subject test crews consisted of two pilots, a captain and first officer. Twenty test crews participated in the evaluation. Crew participation was coordinated by the Regional Airline Association. All crews were type rated and current in the Beech King Air 200 and/or 1900 aircraft. All crews had flight director experience. While it was desired that participating crews possess Category-II operational experience, only one did. Very little simulator time was available to train the crews in the crew coordination requirements for low visibility approaches. Thus, the test measures represent results obtained using crews that have had no formal training in Category-II/III operations. The overall flight experience levels of the crews is in the appendix.

PRE-TEST ACTIVITIES.

FlightSafety International provided 2 hours of classroom instruction prior to beginning the simulator evaluation. The syllabus for the ground instruction included:

1. Review of test objectives.

2. Description of MLS and the inherent accuracy of the system.

3. Review of standardized crew coordination procedures for low visibility operations.

4. Review of test factors.

5. Review of approach and runway lighting configurations.

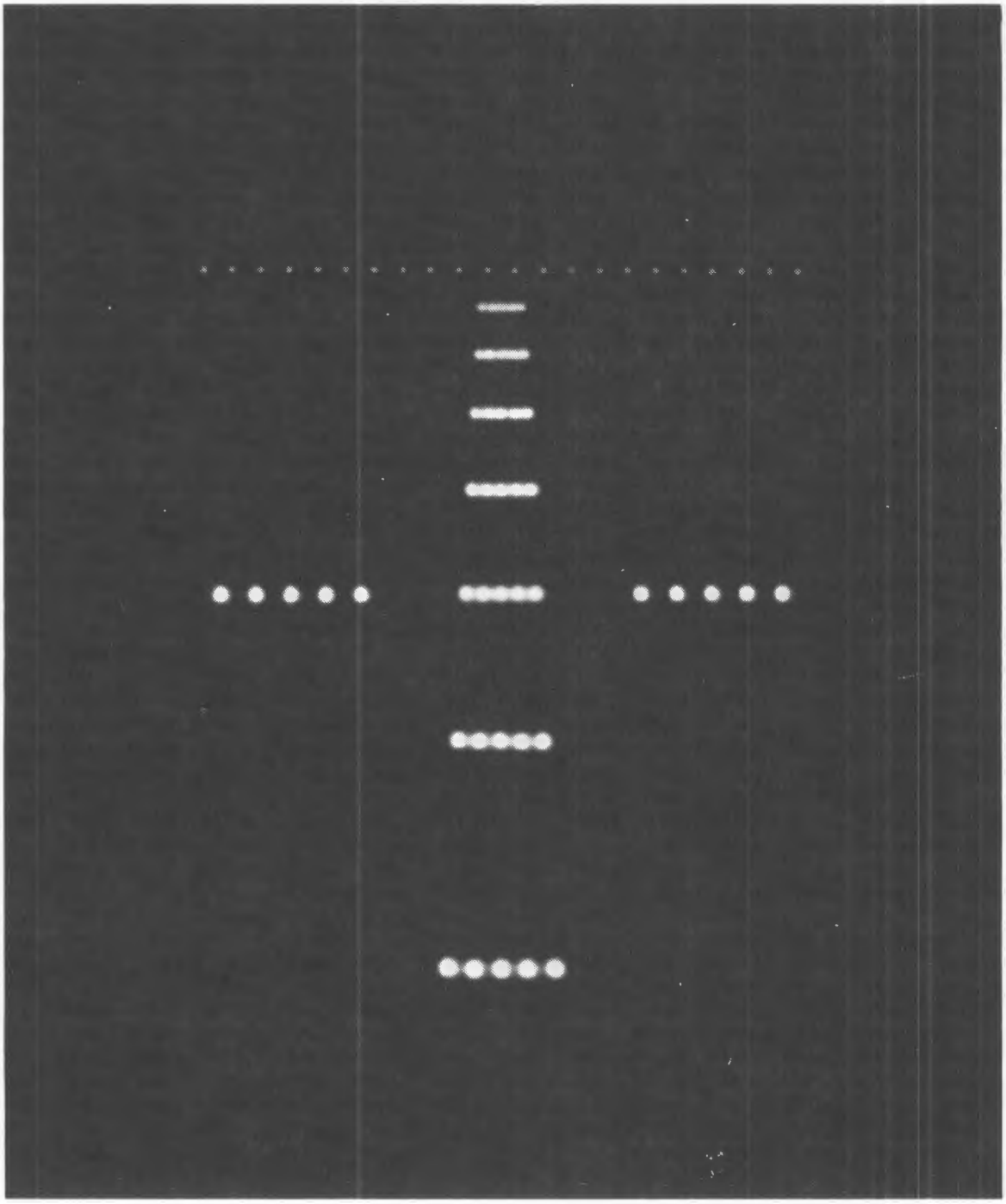


FIGURE 3. MALSR/HIRL APPROACH LIGHTS AS VIEWED FROM 150 FEET HAT

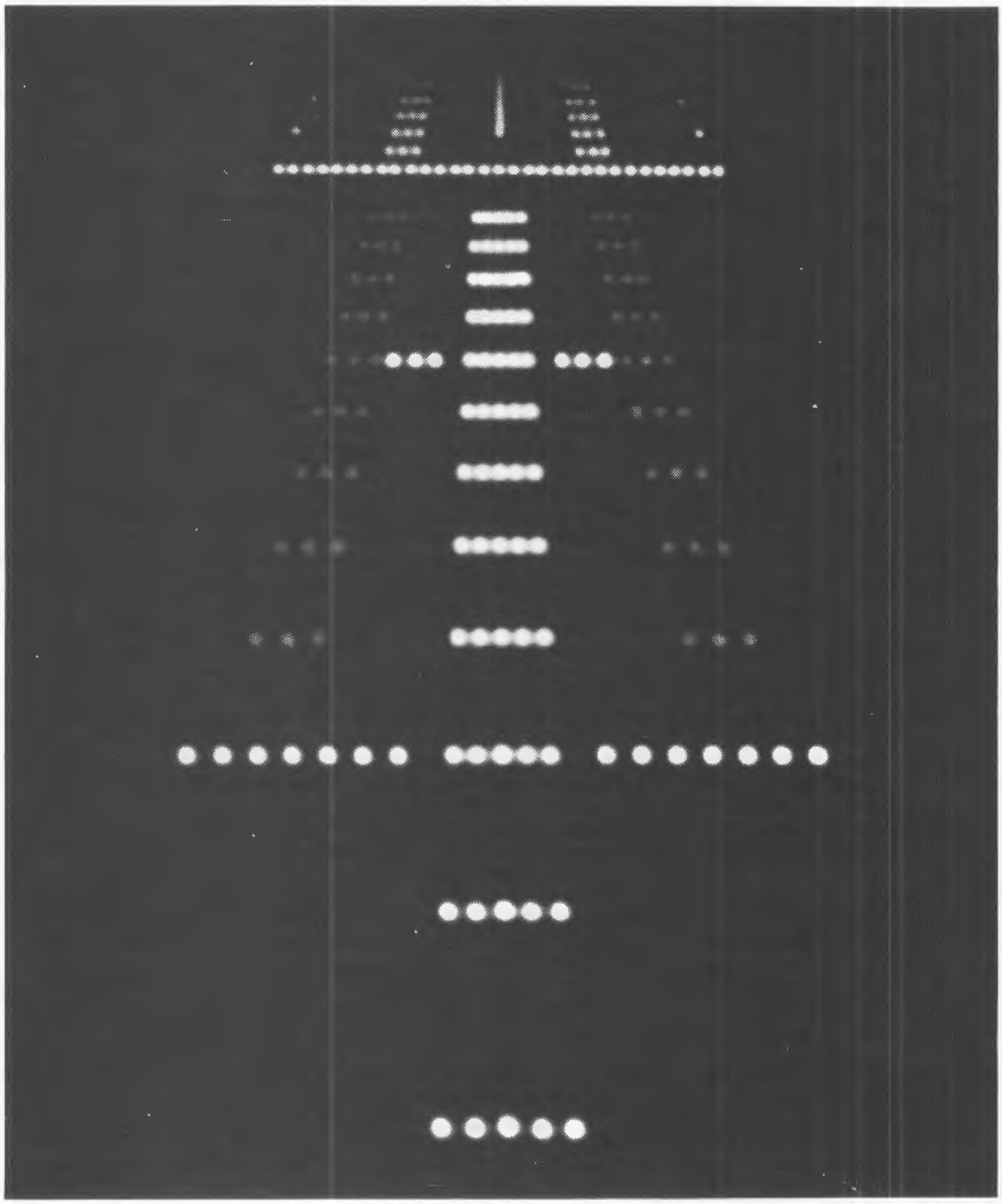


FIGURE 4. ALSF-2/HIRL APPROACH LIGHTS AS VIEWED
AS VIEWED FROM 150 FEET HAT

6. Description of approach and missed approach procedures to be flown.

7. Familiarization with the Pilot Questionnaire Rating Scheme, the Modified Cooper Harper Rating Scale, which is depicted in figure 5.

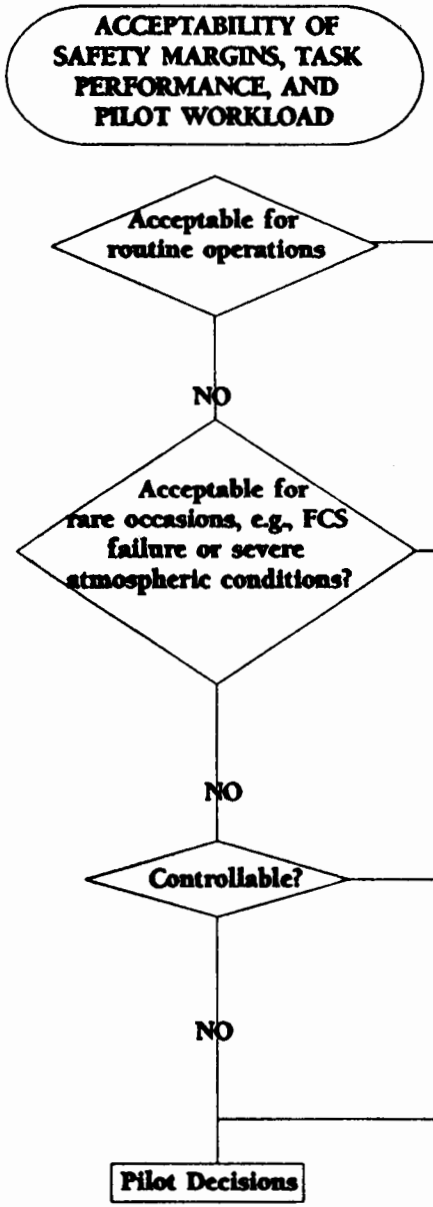
An FAA representative, who served as the official observer, briefed the subject crews on administrative details of the evaluation. Prior to any classroom instruction, each participant completed a pre-test questionnaire. This questionnaire was used to obtain statistical data concerning each pilot's experience and operational knowledge concerning low visibility approaches. It was also used to determine any preconceived notions the participants may have regarding the objectives of the tests.

TEST DESCRIPTION.

Each crew participated in a 4-hour simulator evaluation divided into two, 2-hour sessions. The crew members initially flew the aircraft from the crew station they normally occupied, captains-left seat and first officers-right seat. However, since only the captain's station was equipped with a flight director, the first 10 crews swapped seats for the last five approaches. This permitted the collection of some test data with the first officer flying the aircraft with the aid of a flight director.

For each approach, the simulator was positioned outside the final approach fix, in level flight, on a vector heading to intercept the final approach course. The aircraft was configured for approach. The crews were given Automatic Terminal Information Service (ATIS) type weather information that approximated the actual weather conditions at the arrival airport, except for the second 10 crews, where two approaches were designed to intentionally evoke a missed approach response. This was a modified test condition introduced for the second 10 crews to keep them from assuming that each approach would result in a landing. Each approach was flown to a full stop landing, or through the initiation of the missed approach with the aircraft stabilized in a climb.

Prior to the start of data collection, each pilot was permitted to fly the simulator for familiarity. During this simulator orientation, the crews were able to get a "feel" for the handling qualities and performance of the simulator. Instrument approach and crew coordination procedures were reviewed, and the various approach and runway lighting configurations were observed. Up to four approaches were flown during the orientation. Following the simulator orientation, each crew would attempt to complete 18 evaluation runs.



GENERAL CHARACTERISTICS	SAFETY MARGINS	DEMANDS ON THE PILOT	PILOT RATING
Excellent highly desirable	Clearly adequate	Pilot compensation not a factor for desired performance	1
Good negligible deficiencies	Clearly adequate	Pilot compensation not a factor for desired performance	2
Fair - some mildly unpleasant deficiencies	Clearly adequate	Minimal pilot compensation required for desired performance	3
Minor but annoying deficiencies	Clearly adequate	Desired performance requires moderate pilot compensation	4
Moderately objectionable deficiencies	Adequate	Adequate performance requires considerable pilot compensation	5
Very objectionable but tolerant deficiencies	Marginal	Adequate performance requires extensive pilot compensation	6
Major deficiencies	Inadequate	Adequate performance not attainable with maximum tolerable pilot compensation - Controllability not in question	7
Major deficiencies	Inadequate	Considerable pilot compensation is required for control	8
Major deficiencies	Inadequate	Intense pilot compensation is required to retain control	9
Major deficiencies	None	Control will be lost during some portion of required operation	10

FIGURE 5. MODIFIED COOPER-HARPER RATING SCHEME

TEST RUN SCHEDULES.

The first 10 crews flew the simulator under test conditions depicted in table 2. As indicated in table 2, there were a number of variables in different combinations used during the evaluation. The first variable was the DH at the arrival airport. Three different DH's were used: 200 feet HAT (Category-I), 150 feet HAT (intermediate Category-II for this test), and 100 feet HAT (Category-II). The second variable was the weather (ceiling and visibility) at the arrival airport. The ceiling for each approach was set approximately 25 feet above the specified DH for that particular procedure. For 200-foot DH runs, the RVR was always 2400 feet. This represents the standard Category-I weather minima (without TDZ/CL). Two different RVR values, 1800 feet and 1600 feet, were used with the 150-foot DH conditions. These weather conditions represent those below standard Category-I, but not as low as the test condition of 100-foot DH and 1200-foot RVR. This condition represents the lowest Category-II RVR. The winds for the 18 evaluated approaches were either direct were assigned randomly, and thus are not considered in the data analysis. The third variable was the availability of a flight cross winds of 10 knots, or tailwinds of 5 knots. These winds director (FD), denoted by Y in the FD column. If the flight director was not available, the pilot flew in response to

TABLE 2. TEST APPROACH SCHEDULE FOR CREWS 1 TO 10

Run Number	DH (Feet)	RVR (Feet)	FD	Lighting	Pilot Flying
1	200	2400	N	MALSR/M	C
2	200	2400	N	MALSR/M	F
3	100	1200	Y	ALSF-2/H	C
4	150	1800	Y	MALSR/H	C
5	150	1800	N	MALSR/H	F
6	150	1800	N	MALSR/H	C
7	150	1800	Y	MALSR/M	C
8	150	1800	N	MALSR/M	F
9	150	1800	N	MALSR/M	C
10	150	1600	Y	MALSR/H	C
11	150	1600	N	MALSR/H	F
12	150	1600	N	MALSR/H	C
13	100	1200	Y	MALSR/H	C
14	150	1800	Y	MALSR/H	F
15	150	1800	Y	MALSR/M	F
16	150	1600	Y	MALSR/H	F
17	100	1200	Y	ALSF-2/H	F
18	100	1200	Y	MALSR/H	F

standard vertical and lateral cross pointer deviations. The fourth variable was the approach/runway lighting. The four treatments of this factor were MALSR/M, MALSR/H, MALSR/H/CL (used only in the second half), and ALSF-2/H. The final variable considered was the pilot flying (C=Captain, F=First Officer).

Following a preliminary review of the data from the first 10 crews, minor changes were made to some of the variables used. The reasons for the changes are presented later in the data analysis portion of the report. The first change was the elimination of the MALSR/M lighting configuration, owing to its ineffectiveness as observed from the performance of the first 10 crews. The second change involved the addition of a new runway lighting configuration, MALSR/H/CL. The third change introduced a planned test condition (ceiling lower than the indicated DH) intended to evoke a missed approach response on two approaches. The run schedule for the second 10 crews is depicted in table 3.

As shown in table 3, approaches 7 and 12 for crews 11 through 20 were designed to cause missed approaches. For these approaches the crews were given the weather information identified in table 3. However, the ceiling and visibility were actually set to zero to force the missed approach. This permitted the collection of data concerning height loss during initiation of the missed approach. The incidence of weather which required a missed

TABLE 3. TEST APPROACH SCHEDULE FOR CREWS 11-20

Run Number	DH (Feet)	RVR (Feet)	FD	Lighting	Pilot Flying
1	200	2400	N	MALSR/H	C
2	200	2400	N	MALSR/H	F
3	200	1800	Y	ALSF-2/H	C
4	200	1800	N	ALSF-2/H	F
5	150	1800	Y	MALSR/H/CL	C
6	150	1800	N	MALSR/H/CL	F
7*	150	1800	Y	ALSF-2/H	C
8	150	1800	N	ALSF-2/H	F
9	150	1800	Y	ALSF-2/H	C
10	150	1800	Y	MALSR/H	C
11	150	1800	N	MALSR/H	F
12*	150	1600	N	MALSR/H/CL	F
13	150	1600	Y	MALSR/H/CL	C
14	150	1600	N	MALSR/H/CL	F
15	150	1600	Y	ALSF-2/H	C
16	150	1600	N	ALSF-2/H	F
17	150	1600	Y	MALSR/H	C
18	150	1600	N	MALSR/H	F
19	150	1600	Y	MALSR/H	C

* Missed Approach Runs

approach prevented the pilot from automatically assuming he would reach a breakout condition at DH. Approach 19 for the second 10 crews was made only if sufficient simulator time remained at the end of the test period. Approach 19 test conditions duplicated the test conditions for approach 17.

DATA ANALYSIS

Both subjective and objective data, were collected. Subjective data were collected through pilot questionnaires. Each crew responded to three different questionnaires: pre-evaluation, post-procedure, and post-evaluation. The pre-evaluation questionnaire, as described earlier, was used to gather pilot experience data and to determine any predisposition toward the test. The post-procedure questionnaire contained questions to be answered by the crew following each approach. The questions were keyed to what the crew had experienced on the approach they had just completed. Some of the questions required a numerical response based on the modified Cooper-Harper Rating Scale (figure 5). The post-evaluation questionnaires asked the participants for their overall impressions of the test, and attempted to ascertain any change in their perceptions about MLS from the pre-evaluation questionnaire.

Several different forms of objective data were collected. For each approach, lateral and vertical deviations from the reference path were collected. Statistics were compiled for the cross track and vertical track deviations at DH for the approach being flown. As a measure of pilot performance in the visual segment, statistics for cross track and vertical deviations from the reference threshold crossing position were also computed. Plots were generated of the threshold crossing position for each approach relative to the reference threshold crossing position.

Other objective test data included plotting of continuous cross track and vertical track position from 1000 feet Above Ground Level (AGL) to touchdown. These plots permitted the identification of pilot characteristic performance in both the instrument and visual segments. The last plot developed was of touchdown dispersion for a given set of test conditions.

PILOT PERFORMANCE AT DH.

One factor that affects instrument approach minima is the ability of the pilot to precisely track the navigation signal, and arrive properly aligned with the runway centerline at DH. The more accurately the aircraft is positioned at DH, the more likely the pilot will acquire the landing area environment, and continue to a successful landing. However, as the DH is lowered, the tracking task becomes much more demanding due to proximity to the signal source. To evaluate pilot performance at DH, lateral and vertical position errors at DH were obtained for each approach.

Observations for a given set of test conditions were combined for statistical analysis. Table 4 presents the DH statistics for the first 10 crews. "2*SD" represents twice the sample error standard deviation in the observed lateral and vertical position at DH.

Since the approach and runway lights were not visible to the pilot prior to DH, the only factors affecting instrument flight tracking performance were the skills of the pilot flying, the availability of the flight director, and the DH to which the approach is being flown. The effects of these factors on pilot tracking performance at DH are depicted in table 5. The baseline test condition for the captain is presented in approach No. 1. The baseline condition for the first officer is presented in approach No. 2. A standard accuracy measure is the estimate of the 95 percent critical values from the sample error distribution. This estimate is obtained by adding twice the sample standard deviation to the absolute value of the sample mean.

TABLE 4. LATERAL AND VERTICAL ERROR STATISTICS AT DH FOR THE FIRST 10 CREWS

APP #	FD	Pilot Fly	Lights	RVR (Ft)	DH (Ft)	Vertical Mean	Vertical 2*SD	Lateral Mean	Lateral 2*SD
1	N	C	MALSR/M	2400	200	27.4	48.1	48.8	163.0
2	N	F	MALSR/M	2400	200	-29.0	63.8	-20.5	101.1
3	Y	C	ALSF2	1200	100	-3.6	9.8	-17.8	33.5
4	Y	C	MALSR/H	1800	150	-6.6	17.7	4.9	16.7
5	N	F	MALSR/H	1800	150	-7.4	49.7	10.1	119.4
6	N	C	MALSR/H	1800	150	-23.0	52.9	6.1	139.0
7	Y	C	MALSR/M	1800	150	-6.5	15.8	4.0	37.0
8	N	F	MALSR/M	1800	150	-20.9	34.0	-38.3	139.9
9	N	C	MALSR/M	1800	150	5.3	32.9	16.3	94.8
10	Y	C	MALSR/H	1600	150	-12.2	13.6	-4.4	30.5
11	N	F	MALSR/H	1600	150	-6.3	57.8	-30.6	155.2
12	N	C	MALSR/H	1600	150	3.5	17.7	36.2	123.2
13	Y	C	MALSR/H	1200	100	-5.0	10.6	-18.1	28.3
14	Y	F	MALSR/H	1800	150	-10.9	12.6	-3.1	37.6
15	Y	F	MALSR/M	1800	150	-13.1	13.5	-14.0	23.7
16	Y	F	MALSR/H	1600	150	-7.2	18.2	-31.5	17.1
17	Y	F	ALSF2	1200	100	-6.2	12.4	2.5	27.6
18	Y	F	MALSR/H	1200	100	-7.0	7.8	-25.1	27.2

When the data in table 5 is reviewed, the dominant factor that consistently improves performance at DH is the availability of

the flight director. Regardless of DH, lateral errors are reduced by a factor of three or more when the flight director is available. This result held true regardless of which pilot was flying. In the vertical dimension, the impact of the flight director appears even more pronounced. Except for approach 12 results, the smallest 95 percent critical vertical error value without flight director (approach 9) is greater than the largest 95 percent critical vertical error value with flight director (approach 5).

It was concluded, based on the performance data collected for the first 10 crews, that manual flight using flight director information supports the accurate lateral and vertical pilot tracking performance necessary to the lower DH's. All of the approaches flown with flight director aiding resulted in 95 percent critical lateral error values two to three times less than the lateral MLS 150-foot DH delivery envelope dimension depicted in figure 1. Vertically, the largest 95 percent flight director error value was 26.6 feet. Although this is slightly larger than the vertical dimension of the 150-foot DH MLS delivery envelope, it is well within the confines of the ILS Category-I delivery envelope.

TABLE 5. 95% CRITICAL ERROR VALUES AT DH FOR FIRST 10 CREWS

APP #	FD	Pilot Flying	DH (Feet)	95% Critical Values (Feet) Vertical	Lateral
1	N	C	200	75.5	211.8
2	N	F	200	92.8	121.6
3	Y	C	100	13.4	51.3
4	Y	C	150	24.3	21.6
5	N	F	150	57.1	129.5
6	N	C	150	75.9	145.1
7	Y	C	150	22.3	41.0
8	N	F	150	54.9	178.2
9	N	C	150	38.2	111.1
10	Y	C	150	25.8	34.9
11	N	F	150	64.1	185.5
12	N	C	150	21.2	159.2
13	Y	C	100	15.6	46.4
14	Y	F	150	23.5	40.7
15	Y	F	150	26.6	37.7
16	Y	F	150	25.4	48.6
17	Y	F	100	18.6	30.1
18	Y	F	100	14.8	52.3

The same analysis was repeated to assess the performance of the second set of crews. Table 6 presents the statistical data gathered on pilot tracking performance at DH for the second 10 crews. Table 7 presents the 95 percent critical error values at DH for the second 10 crews.

TABLE 6. LATERAL AND VERTICAL ERROR STATISTICS AT DH FOR CREWS 11-20

APP #	FD	Pilot Fly	Lights	RVR (Ft)	DH (Ft)	Vertical Mean	Vertical 2*SD	Lateral Mean	Lateral 2*SD
1	N	C	MALSR/H	2400	200	-15.6	55.8	53.5	184.1
2	N	F	MALSR/H	2400	200	7.6	32.2	-9.7	213.9
3	Y	C	ALSF2/H	1800	200	1.1	5.9	-21.9	19.5
4	N	F	ALSF2/H	1800	200	-0.4	44.8	-6.2	133.5
5	Y	C	MALSR/H/CL	1800	150	-2.9	14.7	-30.7	25.7
6	N	F	MALSR/H/CL	1800	150	-4.2	48.2	8.2	184.3
7	Y	C	ALSF2/H	1800	150	(Missed Approach)			
8	N	F	ALSF2/H	1800	150	-16.3	44.7	-14.6	165.1
9	Y	C	ALSF2/H	1800	150	-2.7	17.1	7.0	22.2
10	Y	C	MALSR/H	1800	150	-4.0	12.9	-28.9	21.5
11	N	F	MALSR/H	1800	150	-0.9	44.2	8.4	120.9
12	N	F	MALSR/H/CL	1600	150	(Missed Approach)			
13	Y	C	MALSR/H/CL	1600	150	-0.4	18.1	1.3	40.3
14	N	F	MALSR/H/CL	1600	150	12.9	68.4	-39.6	110.6
15	Y	C	ALSF2/H	1600	150	-2.6	10.0	-2.9	27.4
16	N	F	ALSF2/H	1600	150	1.4	70.0	-39.6	178.8
17	Y	C	MALSR/H	1600	150	-8.7	14.7	3.2	22.6
18	N	F	MALSR/H	1600	150	-5.5	34.5	-39.4	150.8
19	Y	C	MALSR/H	1600	150	-1.8	5.9	6.8	2.6

For the second 10 crews, the impact of flight director availability is again quite apparent. Regardless of the DH, use of the flight director consistently resulted in a reduction in the 95 percent critical values for lateral error at DH by a factor of 3 or more. In the vertical domain, the largest 95 percent critical error value with the flight director (approach 17) was about one-half the magnitude of the smallest error value without the flight director (approach 2).

The flight director results from this test indicate that properly trained crews should be able to manually fly, with flight director aiding, to DH's lower than today's standard Category-I DH, arriving properly aligned with the runway centerline for continuation to a successful landing. Again, the 95 percent lateral critical error values with the flight director were fully contained in the MLS 150-foot delivery box depicted in figure 1.

TABLE 7. 95% CRITICAL ERROR VALUES AT DH FOR THE SECOND 10 CREWS

App #	FD	Pilot Flying	DH (Feet)	95% Critical Values (Feet) Vertical	Lateral
1	N	C	200	71.4	237.6
2	N	F	200	39.8	224.6
3	Y	C	200	7.0	41.4
4	N	F	100	45.2	139.7
5	Y	C	150	17.6	56.4
6	N	F	150	52.4	192.4
7	Y	C	150	(Missed Approach)	
8	N	F	150	61.0	179.7
9	Y	C	150	19.8	29.2
10	Y	C	150	16.9	50.4
11	N	F	150	45.1	129.3
12	N	F	150	(Missed Approach)	
13	Y	C	150	18.5	41.6
14	N	F	150	71.3	150.2
15	Y	C	150	12.6	30.3
16	N	F	150	71.4	218.4
17	Y	C	150	23.4	25.8
18	N	F	150	40.0	190.2
19	Y	C	150	7.7	9.4

ABILITY TO COMPLETE THE APPROACH.

At DH, the crew continued the approach if the runway environment was in sight, and other pertinent parameters were perceived as being correct. In addition to visually aligning the aircraft prior to landing, it was observed that some crews continued to cross check their Course Deviation Indicator (CDI)/Vertical Deviation Indicator (VDI) position relative to course and glidepath, and flight director cueing to make tracking corrections.

An undesirable sequence of events is the decision to continue the approach beyond DH, followed by a go-around initiated in the visual segment. This sequence of actions is termed a balked landing, for which obstruction protection is not provided. The number of balked landings for the various test conditions can be determined from a review of the vertical profile data. Also of interest is the number of times the crew initiated a missed approach in the instrument portion of the approach, prior to reaching DH. These missed approaches are termed premature missed approaches.

The analysis of balked landing and premature missed approach occurrence rates is summarized in table 8. One measure of pilot tracking performance is the ability to reach DH sufficiently aligned with the extended runway centerline so that a landing can be completed. When the pilot initiated a missed approach prior to arriving at DH (in the instrument segment), a premature missed approach was declared. A review of table 8 indicates that the largest percentage (50%) of premature missed approaches occurred when the flight director was not available. When the flight director was available, the percentage of premature missed approaches were nearly equal regardless of the DH (0 to 12%).

When the flight director was available, 6 premature missed approaches resulted when operating to DH's below 200 feet. These six premature missed approaches represent 4 percent of all approaches flown to these DH's with a flight director. Since these missed approaches occurred prior to reaching visual meteorological conditions, the lighting environment had no bearing on the initiation of the missed approach.

The highest percentage of balked landings also occurred when the flight director was not available (22%). This was most pronounced when the first officer was flying. In some cases, without the availability of a flight director, the first officer balked landing rate exceeded 20 percent. Many of these balked landings occurred because the pilot did not have sufficient time to compensate for the poorer tracking performance to DH without the flight director. This left the pilot with no chance to properly align the aircraft for landing.

When the flight director was available, two first officer balked landings occurred when DH=100 feet and RVR=1200 feet (Category-II). One balked landing occurred when the lighting condition was ALSF-2/HIRL and the other occurred with a MALSR/HIRL test condition. On the approach with ALSF-2/HIRL available, the post-procedure questionnaire indicated that the first officer executed a missed approach because he felt he was too high to complete the landing. On the approach MALSR/HIRL available, the first officer executed a "go-around" because he felt the approach was unacceptable.

For the 150-foot DH test condition, 100 percent of the first officer flight director aided approaches (28) were continued to a successful landing. The lighting systems were MALSR/MIRL or MALSR/HIRL for all of these approaches.

When the captain was flying with the aid of a flight director, 4 of 108 approaches (3.6 percent) resulted in a balked landing. With DH=150 feet and RVR=1800 feet, one balked landing resulted with MALSR/MIRL , which is the standard Category-II lighting environment. The captain commented that the lighting was marginal for completion of the approach. The second occurred

environment. The captain commented that the lighting was marginal for completion of the approach. The second occurred

TABLE 8. PERCENTAGE OF BALKED LANDINGS AND PREMATURE MISSED APPROACHES

Pilot Flying	FD	DH (Feet)	RVR (Feet)	Lighting	# Balked Landings	(%)	# Pre-Mature Missed App	(%)
C	N	200	2400	MALSR/H	0	0	0	0
C	N	200	2400	MALSR/M	1	10	0	0
C	N	150	1800	MALSR/H	1	10	2	20
C	N	150	1600	MALSR/H	0	0	1	10
C	N	150	1800	MALSR/M	0	0	0	0
C	Y	200	1800	ALSF2	0	0	0	0
C	Y	150	1800	MALSR/H	0	0	1	5
C	Y	150	1800	MALSR/M	1	11	1	11
C	Y	150	1800	MALSR/CL	0	0	0	0
C	Y	150	1800	ALSF2	1	12	1	12
C	Y	150	1600	MALSR/H	0	0	1	4
C	Y	150	1600	MALSR/CL	1	12	0	0
C	Y	150	1600	ALSF2	0	0	1	12
C	Y	100	1200	MALSR/H	1	10	0	0
C	Y	100	1200	ALSF2	0	0	0	0
F	N	200	2400	MALSR/M	1	11	0	0
F	N	200	2400	MALSR/H	1	12	1	12
F	N	200	1800	ALSF2	1	12	1	12
F	N	150	1800	MALSR/M	0	0	0	0
F	N	150	1800	MALSR/H	3	15	1	5
F	N	150	1800	MALSR/CL	0	0	1	12
F	N	150	1800	ALSF2	1	17	3	50
F	N	150	1600	MALSR/H	2	12	1	6
F	N	150	1600	MALSR/CL	2	22	1	11
F	N	150	1600	ALSF2	2	22	1	11
F	Y	150	1800	MALSR/H	0	0	1	11
F	Y	150	1800	MALSR/M	0	0	0	0
F	Y	150	1600	MALSR/H	0	0	0	0
F	Y	100	1200	MALSR/H	1	11	0	0
F	Y	100	1200	ALSF2	1	11	0	0

with ALSF-2/HIRL. The captain remarked that he could not find the runway in all the lights. With DH=150 feet and RVR=1600 feet, one balked landing occurred with MALSR/HIRL/CL. The captain stated that he could not see enough of the runway to complete the landing. The final balked landing was to Category-II minimums when less than Category-II lighting was available.

All approaches flown with a flight director by captains to DH's below standard Category-I DH were completed when the lighting condition was MALSR/HIRL, with the exception of one CAT-II approach to a DH of 100 feet. The analysis indicated that on reduced minima approaches, once the pilot emerges into visual conditions, approach completion probabilities were equivalent for ALSF-2/HIRL and MALSR/HIRL. This result held for both captain and first officer approaches.

AIRCRAFT POSITION AT THRESHOLD CROSSING.

Another objective measure of crew performance in the visual segment is the position of the aircraft at threshold crossing. The reference threshold crossing position used is the glideslope threshold crossing height (50 feet) and the runway centerline. Large deviations from this reference position would indicate alignment, and more important, descent control difficulties in the visual segment.

The threshold crossing statistics for the first 10 crews are shown in table 9. Unlike the analysis of performance at DH, where instrument flight capabilities are measured, the analysis of deviations at threshold crossing must consider the position at breakout, Runway Visual Range (RVR), and landing area environment (principally runway marking and lighting). For each measurement

TABLE 9. THRESHOLD CROSSING STATISTICS FOR FIRST 10 CREWS

APP		Pilot		RVR	DH	Vertical Error (Ft)			Lateral Error (Ft)		
#	FD	Fly	Lights	(Ft)	(Ft)	Mean	Min	Max	Mean	Left	Right
1	N	C	MALSR/M	2400	200	23.6	-24.6	21.8	15.4	-108.6	89.9
2	N	F	MALSR/M	2400	200	-10.5	-35.8	37.2	-20.2	-107.0	29.9
3	Y	C	ALSF2	1200	100	-0.7	-22.6	4.5	-7.3	-33.6	30.8
4	Y	C	MALSR/H	1800	150	-13.0	-25.0	0.4	-9.9	-32.4	7.2
5	N	F	MALSR/H	1800	150	-0.4	-35.9	27.3	34.7	-42.6	144.8
6	N	C	MALSR/H	1800	150	-3.2	-40.8	8.5	-1.6	-49.7	43.9
7	Y	C	MALSR/M	1800	150	-11.6	-35.0	27.6	-16.6	-35.6	67.6
8	N	F	MALSR/M	1800	150	-26.3	-35.0	18.2	16.7	-35.6	67.6
9	N	C	MALSR/M	1800	150	4.6	-21.4	23.1	-24.0	-56.9	15.6
10	Y	C	MALSR/H	1600	150	-10.6	-22.9	11.5	2.0	-19.5	34.9
11	N	F	MALSR/H	1600	150	-21.4	-32.7	34.3	23.4	-30.9	75.9
12	N	C	MALSR/H	1600	150	-6.3	-18.9	17.9	-8.5	-36.3	39.2
13	Y	C	MALSR/H	1200	100	-4.7	-18.3	2.5	-14.3	-42.5	18.3
14	Y	F	MALSR/H	1800	150	-20.6	-35.2	26.5	-22.9	-46.0	- 1.8
15	Y	F	MALSR/M	1800	150	-13.6	-43.5	14.3	-11.7	-39.2	23.9
16	Y	F	MALSR/H	1600	150	4.6	-12.6	16.0	-9.7	-26.0	10.2
17	Y	F	ALSF2	1200	100	-13.2	-19.0	3.9	-7.4	-38.5	1.9
18	Y	F	MALSR/H	1200	100	-3.6	-22.3	6.9	-4.5	-24.0	31.8

domain, table 9 depicts the mean error in threshold crossing position, and the largest observed error in each direction. Vertical values represent errors below (min) or above (max) the reference threshold crossing height. Lateral values represent the largest observed errors to the left or right of the runway centerline. All values are expressed in feet.

First Officers' Results.

The results obtained when the first officer was flying will be reviewed first. As expected, the first officer's tracking performance at threshold crossing was always better when flight director aiding was available during the approach. Since an assumption in the testing was that the flight director was required for operation below standard Category-I DH, only the flight director results will be analyzed (crews 1-10, approach numbers 14 to 18).

The two factors most significantly influencing the test results are the weather conditions (ceiling and visibility) and the landing area environment (primarily approach and runway lighting). Poorer performance was observed on approach 14 than on either approaches 16 or 18. This occurred despite the fact the ceiling and visibility were higher on approach 14. This may be due to approach 14 being the first flight director approach flown by the first officer, and the first flown from the left. The smallest vertical mean errors were observed on approaches 16 and 18 (MALSR/HIRL). The range of vertical errors in threshold crossing height with MALSR/HIRL was equivalent to that obtained with ALSF-2/HIRL on approach 17. The largest error below the reference height (-43.5 feet) was observed with MALSR/MIRL. This is only 4 feet above the threshold.

The vertical tracking performance of the first 10 crews on approach number 18 is presented in figure 6. One balked landing occurred both for MALSR/HIRL and ALSF-2/HIRL with DH=100 feet. Figure 7 depicts performance in the visual segment with ALSF-2/HIRL. Differences in vertical tracking performance with the two different lighting systems are insignificant.

When analyzing lateral performance, the same comparative patterns resulted. The best lateral performance was observed on approaches 16 and 18 when MALSR/HIRL was in use. The visual segment lateral results for approach 18 are shown in figure 8. The smallest mean errors resulted with MALSR/HIRL. The range of lateral errors for approach 16 (MALSR/HIRL) with DH=150 feet was 36.2 feet. This was slightly better than the 40.4-foot range of lateral error for approach 17 (ALSF2/HIRL). Figure 9 depicts the threshold crossing positions with DH reduced to 100 feet and ALSF-2/HIRL. Figure 10 depicts the results under the same conditions with MALSR/HIRL. The difference in the results are insignificant.

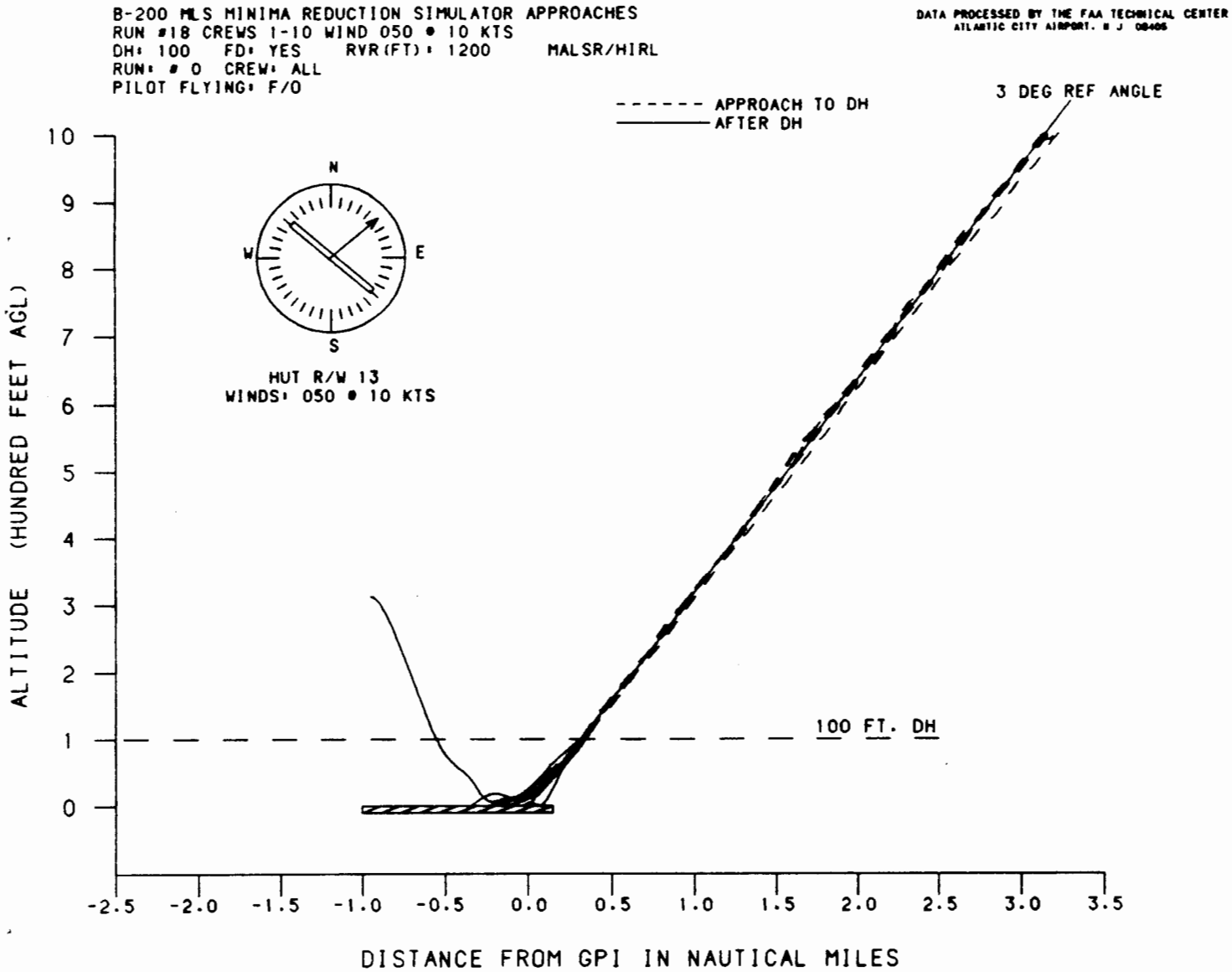


FIGURE 6. VERTICAL TRACKING RESULTS WITH DH=100 FEET, RVR=1200 FEET, AND MALSR/HIRL (FO FLYING)

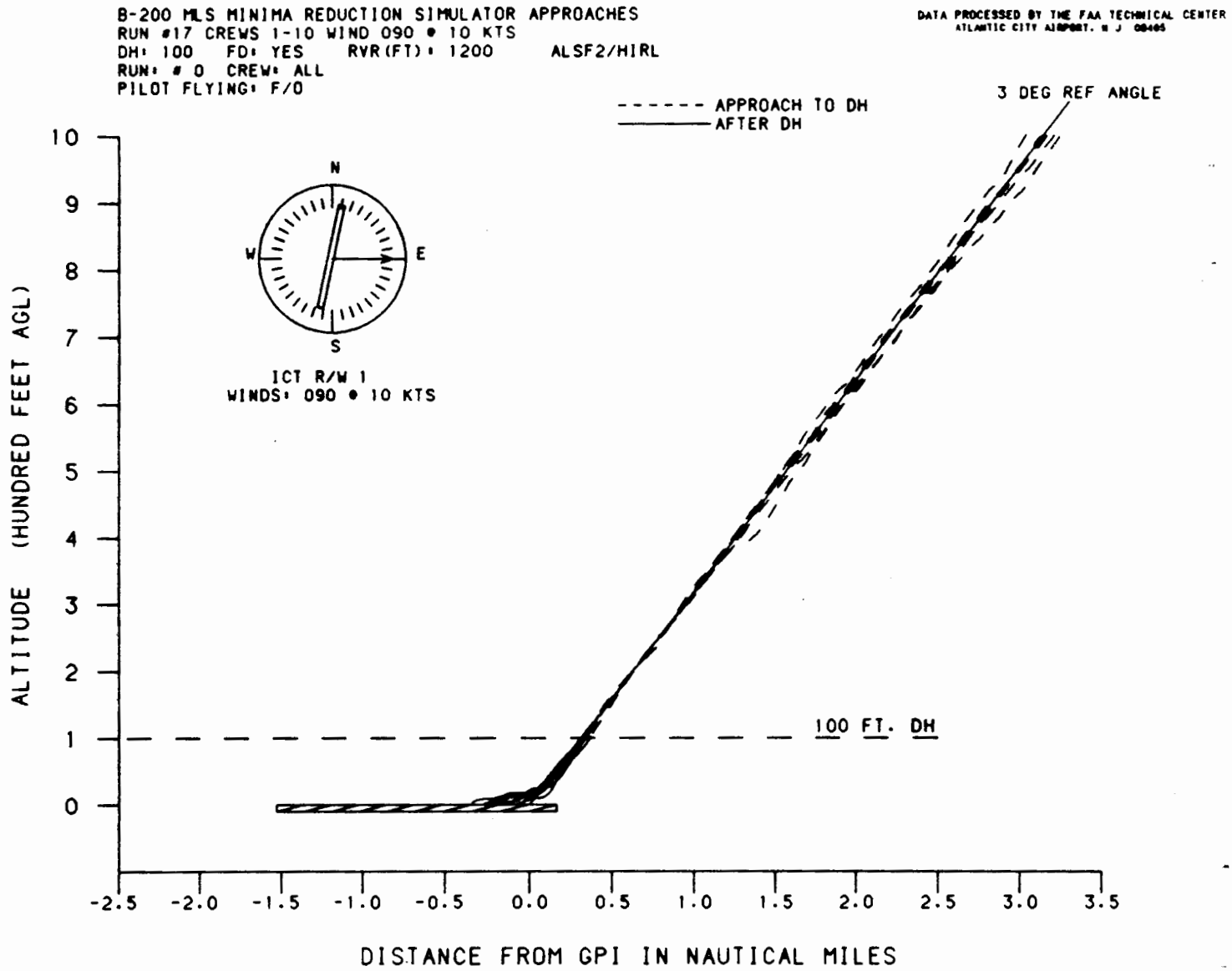


FIGURE 7. VERTICAL TRACKING RESULTS WITH DH=100 FEET, RVR=1200 FEET, AND ALSF-2/HIRL (FO FLYING)

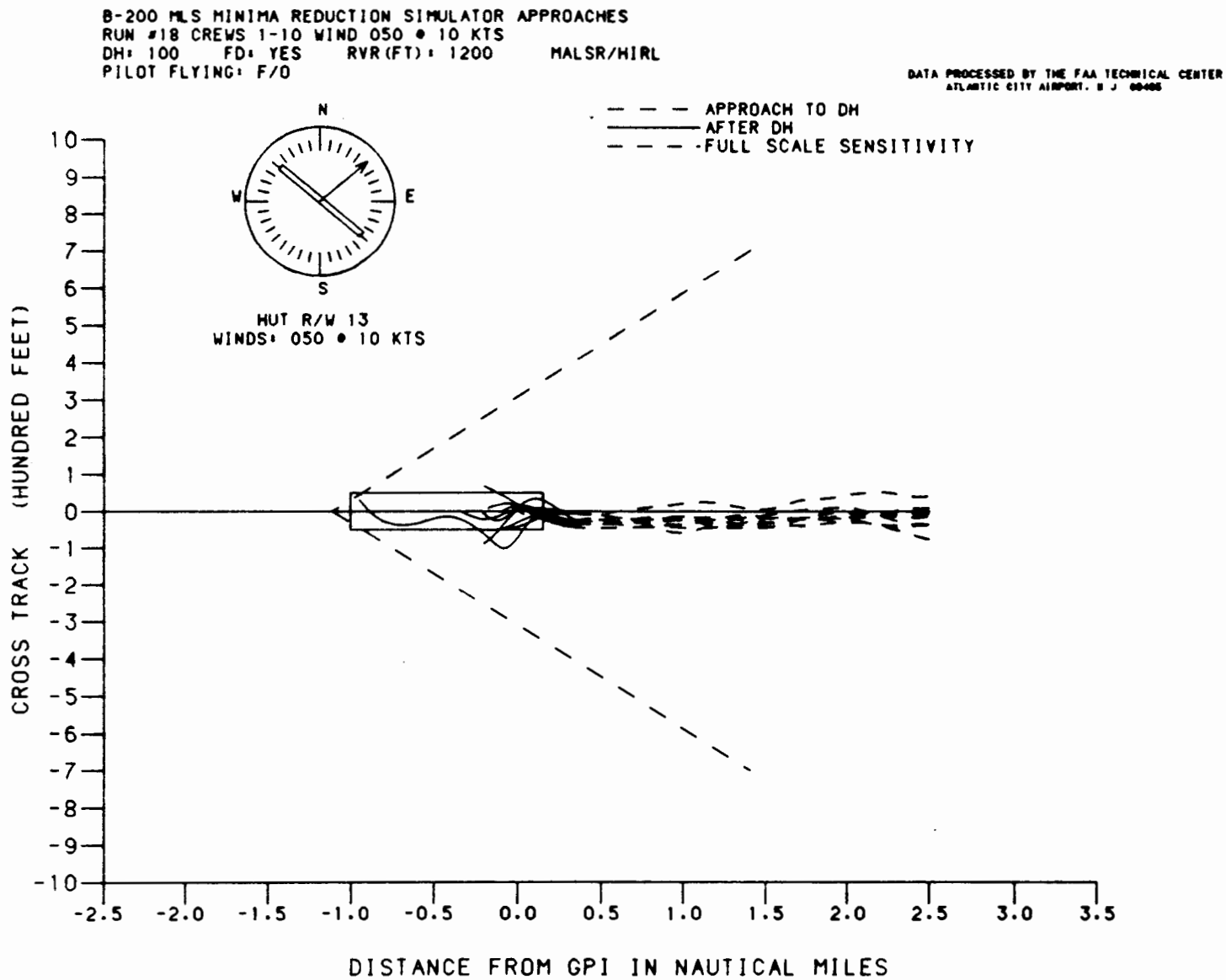


FIGURE 8. LATERAL TRACKING RESULTS WITH DH=100 FEET, RVR=1200 FEET, AND MALSR/HIRL (FO FLYING)

B-200 MINIMA REDUCTION SIMULATOR APPROACHES VERTICAL THRESHOLD WINDOW
RUN: #17 CREWS: 1-10 AIRPORT: ICT PILOT FLYING: F/O
RWY: 1 DH: 100 RVR: 1200 FD: YES WIND: 090 @ 10 KTS ALSF2/HIRL

DATA PROCESSED BY THE FAA TECHNICAL CENTER
ATLANTIC CITY AIRPORT, N J 08405

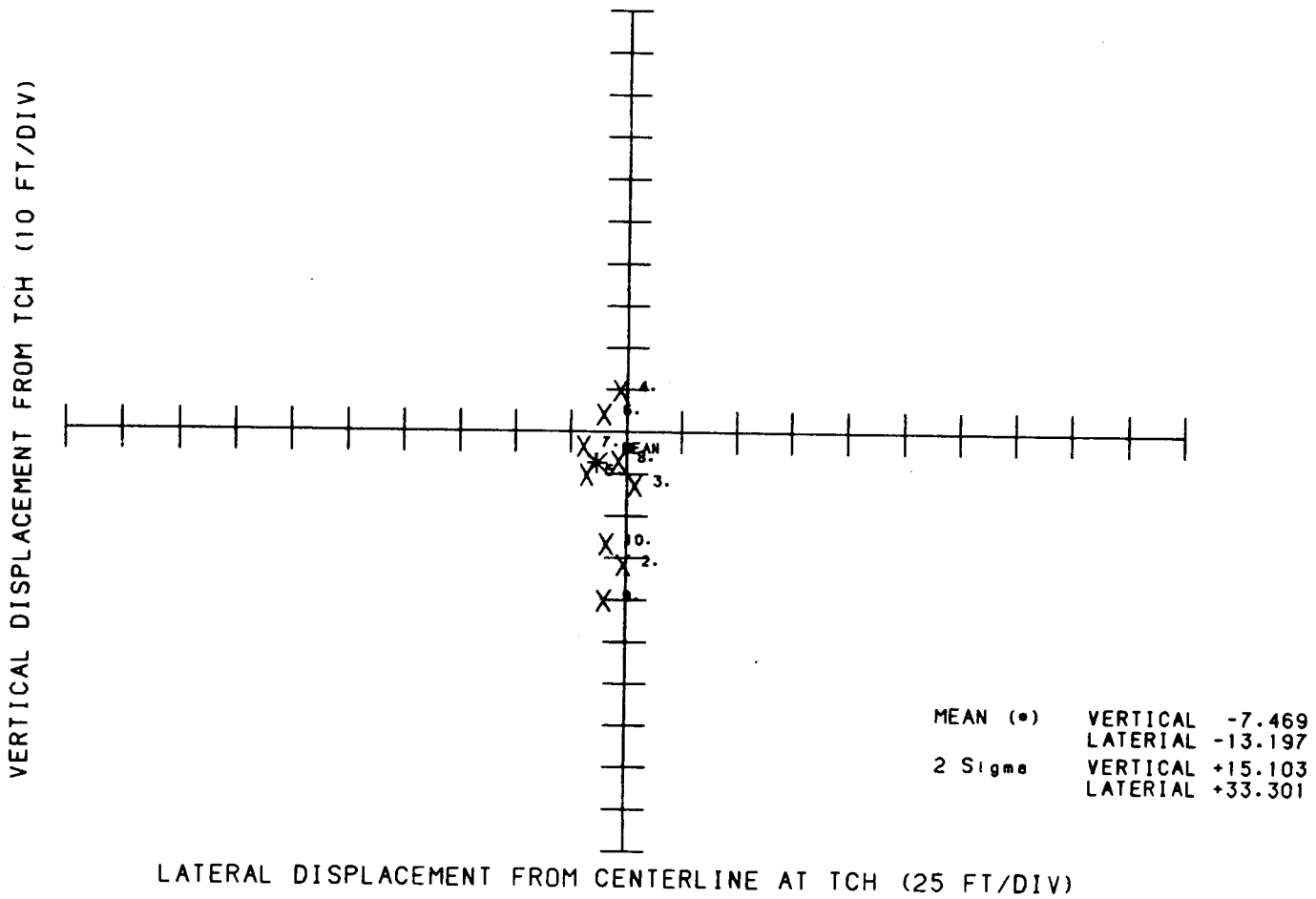


FIGURE 9. THRESHOLD CROSSING POSITION RESULTS WITH DH=100 FEET, RVR=1200 FEET, AND ALSF2/HIRL (FO FLYING)

B-200 MINIMA REDUCTION SIMULATOR APPROACHES VERTICAL THRESHOLD WINDOW
RUN: #18 CREWS: 1-10 AIRPORT: HUT PILOT FLYING: F/O
RWY: 13 DH: 100 RVR: 1200 FD: YES WIND: 050 @ 10 KTS MALSR/HIRL

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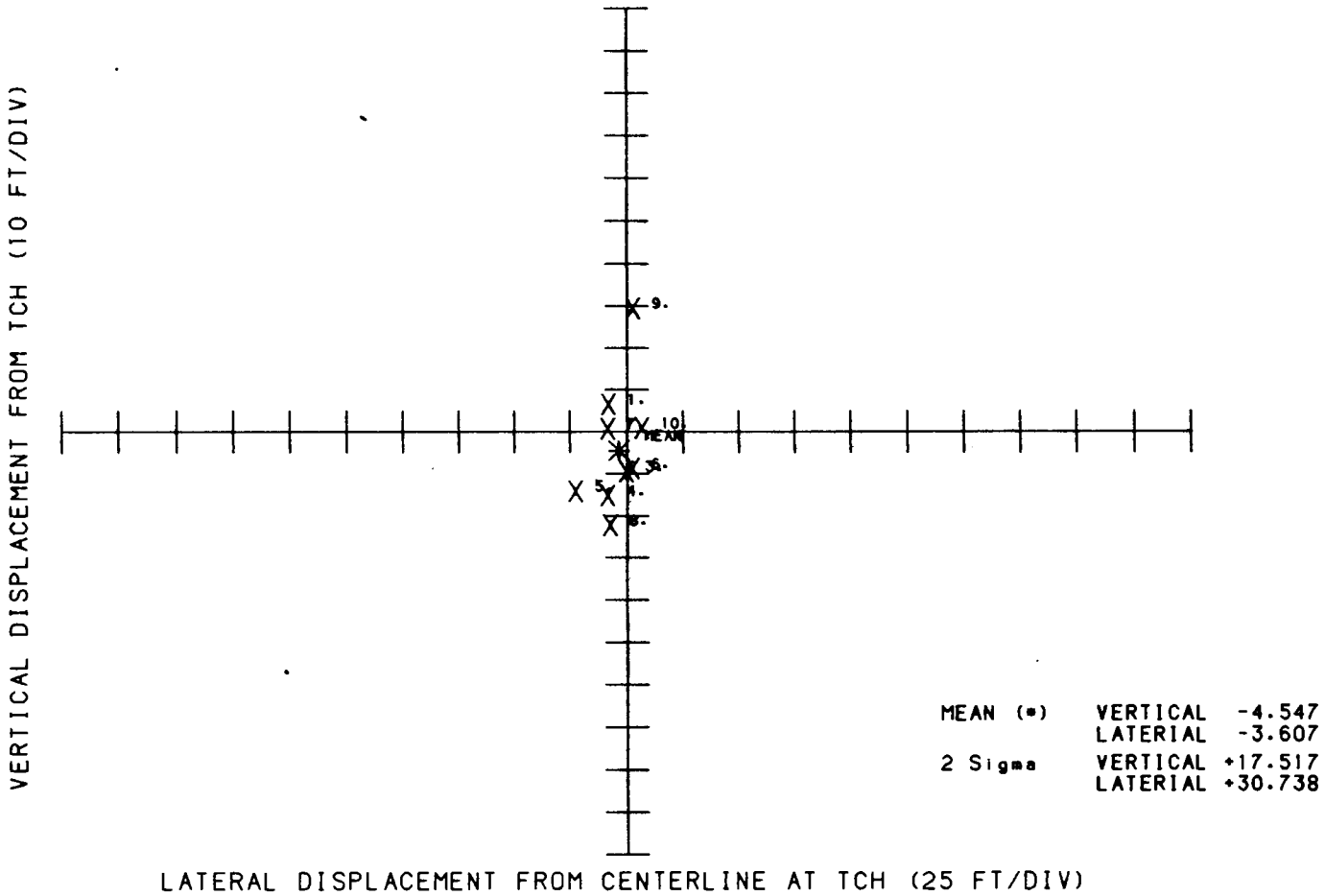

FIGURE 10. THRESHOLD CROSSING POSITION RESULTS WITH DH=100 FEET, RVR=1200 FEET, AND MALSR/HIRL (FO FLYING)

B-200 MINIMA REDUCTION SIMULATOR APPROACHES VERTICAL THRESHOLD WINDOW
RUN: #10 CREWS: 1-10 AIRPORT: HUT PILOT FLYING: CAPTAIN
RWY: 13 DH: 150 RVR: 1600 FD: YES WIND: 130 @ 5 KTS MALSR/HIRL

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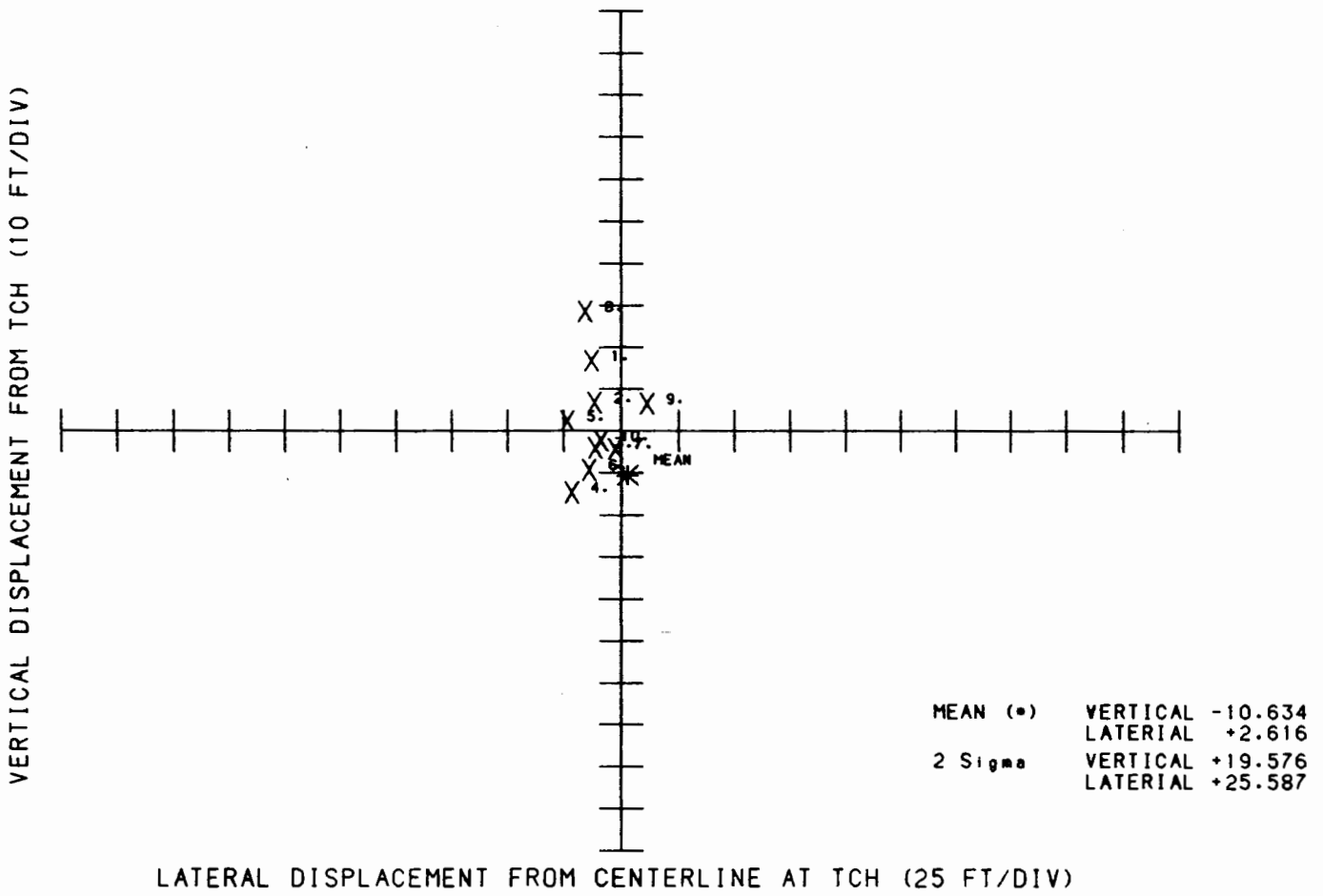

FIGURE 12. THRESHOLD CROSSING POSITION RESULTS WITH DH=150 FEET, RVR=1600 FEET, AND MALSR/HIRL (CAPTAIN FLYING)

B-200 MINIMA REDUCTION SIMULATOR APPROACHES VERTICAL THRESHOLD WINDOW
RUN: # 3 CREWS: 1-10 AIRPORT: ICT PILOT FLYING: CAPTAIN
RWY: 1 DH: 100 RVR: 1200 FD: YES WIND: 270 @ 10 KTS ALSF2/HIRL

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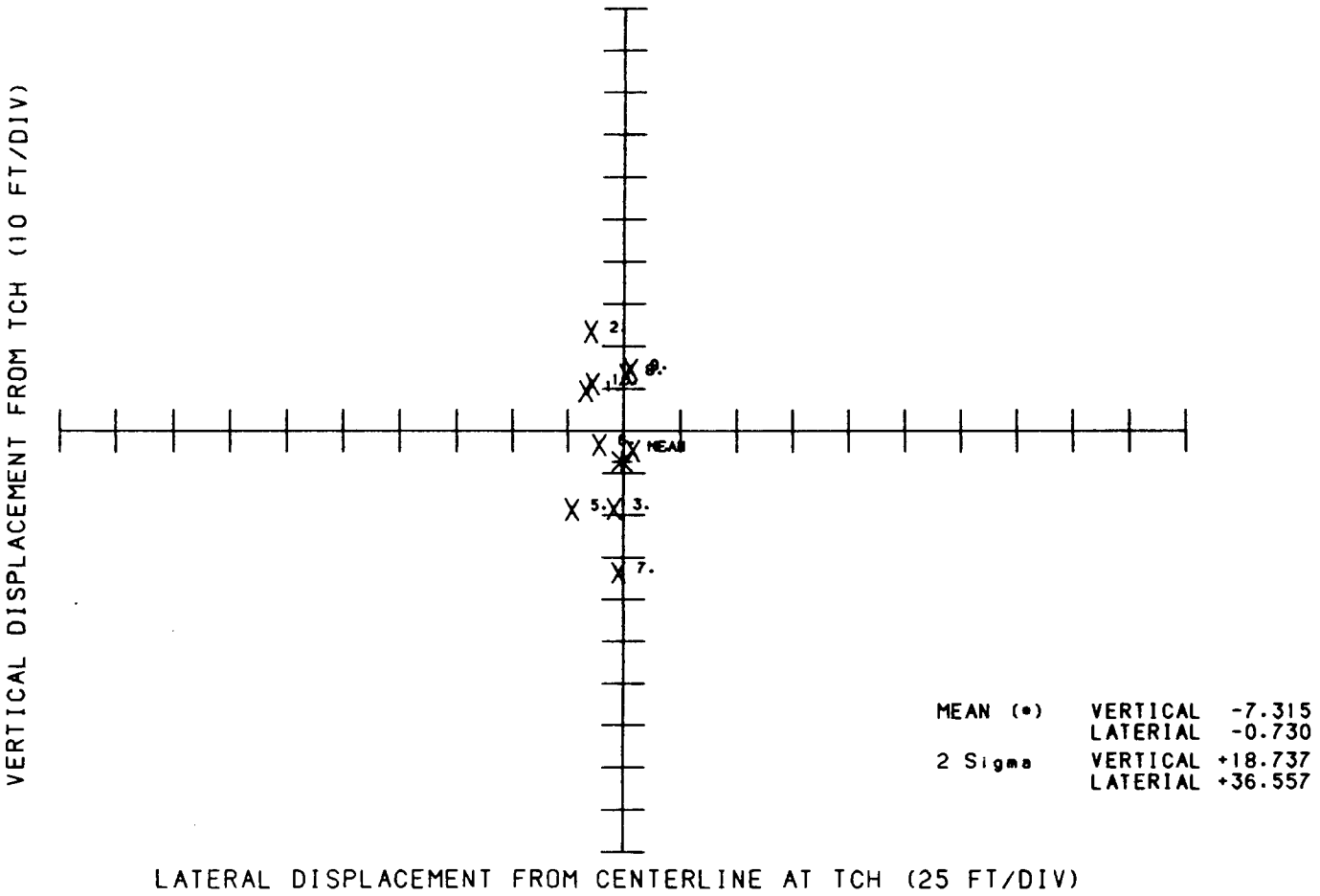

FIGURE 13. THRESHOLD CROSSING POSITION RESULTS WITH DH=100 FEET, RVR=1200 FEET, AND ALSF-2/HIRL (CAPTAIN FLYING)

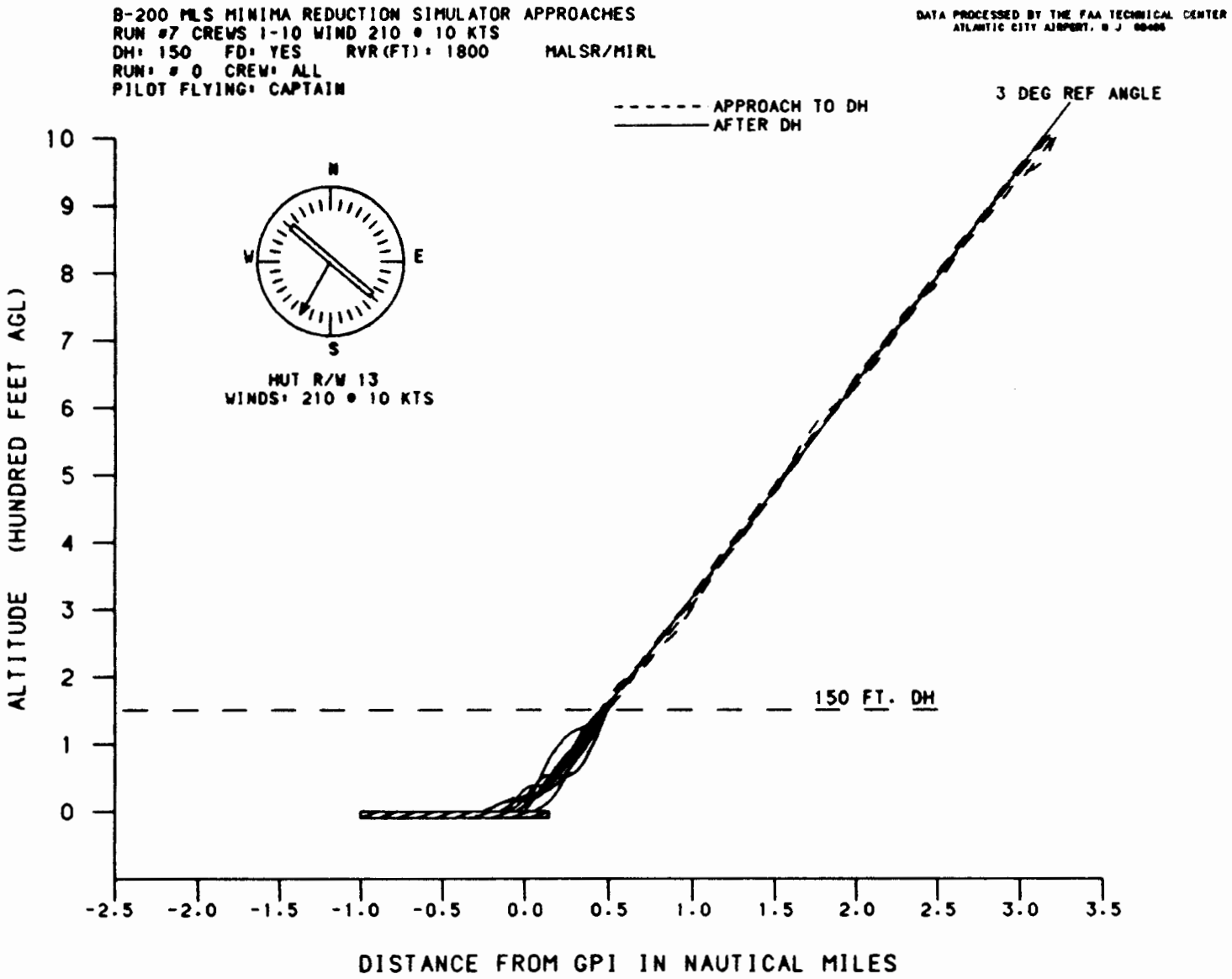

FIGURE 14. VERTICAL TRACKING RESULTS WITH DH=150 FEET, RVR=1800 FEET, AND MALSR/MIRL (CAPTAIN FLYING)

B-200 MINIMA REDUCTION SIMULATOR APPROACHES VERTICAL THRESHOLD WINDOW
RUN: # 7 CREWS: 1-10 AIRPORT: HUT PILOT FLYING: CAPTAIN
RWY: 13 DH: 150 RVR: 1800 FD: YES WIND: 210 @ 10 KTS MALSR/MIRL

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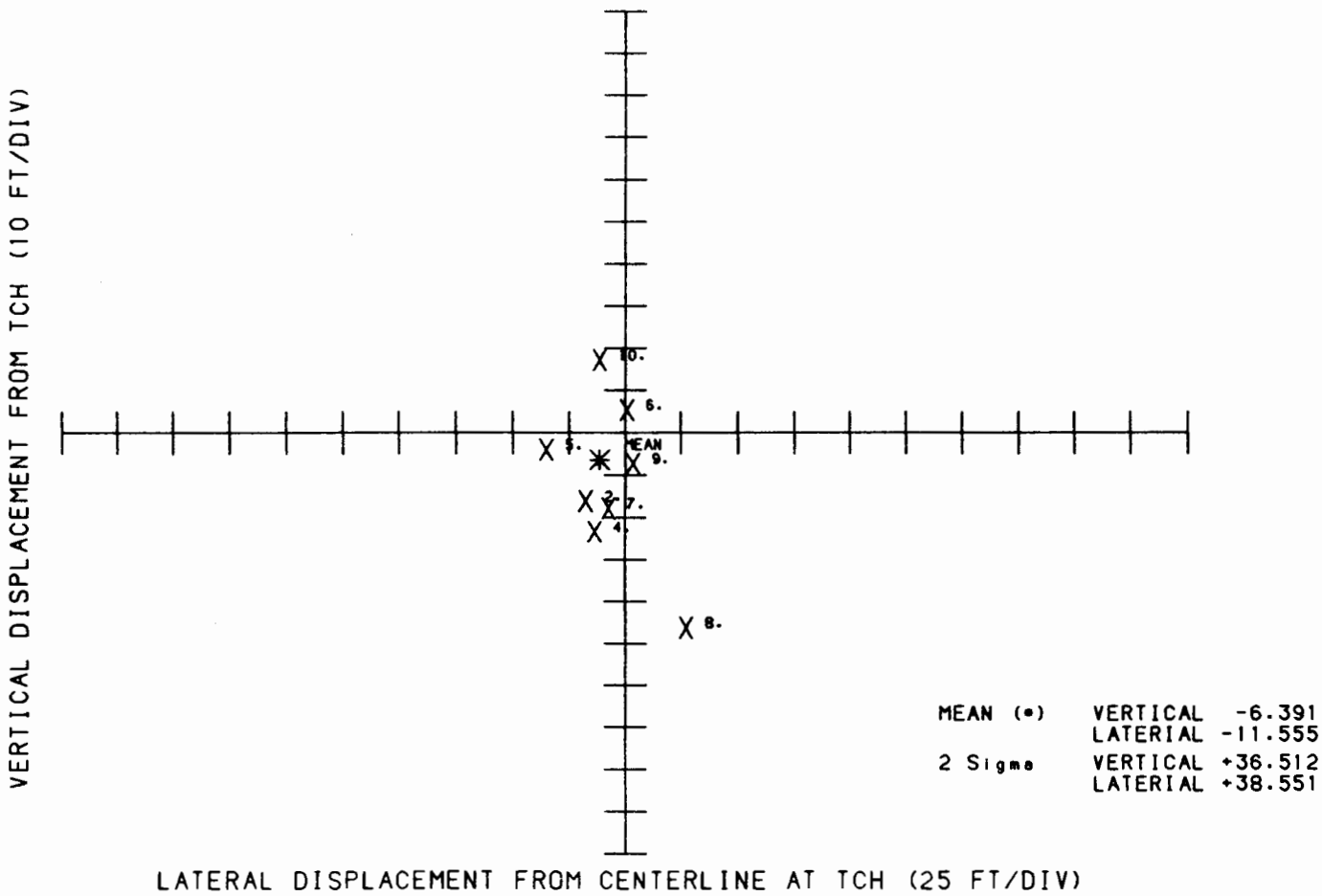

FIGURE 15. THRESHOLD CROSSING POSITION RESULTS WITH DH=150 FEET, RVR=1800 FEET, AND MALSR/MIRL (CAPTAIN FLYING)

The threshold crossing statistics for the second 10 crews are depicted in table 10. Using results from the first 10 crews as a guide, similar analysis was made of the flight director available approaches for the second 10 crews. The analysis focused on approaches 3, 5, 9, 10, 13, 15, 17 and 19.

DH=150 feet and RVR=1800 feet results from approaches 5 (MALSR/HIRL/CL), 9 (ALSF-2/HIRL), and 10 (MALSR/HIRL) can be compared. The best results were obtained with MALSR/HIRL. The mean vertical error of 6.8 feet with MALSR/HIRL was essentially equivalent in magnitude to the ALSF-2/HIRL mean error of -5.4 feet. Both results were 2.5 to 3 times smaller than the MALSR/HIRL/CL mean error result. The observed range in vertical errors were smaller with MALSR/HIRL (27.1 feet) than with either MALSR/HIRL/CL (40.9 feet) or ALSF-2/HIRL (51.0 feet). Figures 17 and 18 depict the vertical tracking performance that resulted with MALSR/HIRL and ALSF-2/HIRL respectively. Figure 19 presents the threshold crossing positions observed with MALSR/HIRL. This pattern can be compared with the threshold crossing positions that resulted with ALSF-2/HIRL depicted in figure 20. It should be noted that position variability increases with ALSF-2/HIRL.

TABLE 10. THRESHOLD CROSSING STATISTICS FOR SECOND 10 CREWS

APP		Pilot		RVR	DH	Vertical Error (Ft)			Lateral Error (Ft)		
#	FD	Fly	Lights	(Ft)	(Ft)	Mean	Min	Max	Mean	Left	Right
1	N	C	MALSR/H	2400	200	13.8	-24.4	41.0	17.5	-26.8	46.7
2	N	F	MALSR/H	2400	200	17.1	-4.9	64.3	1.2	-22.3	8.8
3	Y	C	ALSF2/H	1800	200	-7.4	-32.4	25.4	2.8	-28.1	48.8
4	N	F	ALSF2/H	1800	200	-10.1	-37.1	40.9	-19.0	-35.0	0.9
5	Y	C	MALSR/CL	1800	150	-15.0	-33.8	7.1	5.6	-26.7	70.4
6	N	F	MALSR/CL	1800	150	7.7	-21.6	34.9	10.4	-39.2	65.4
7	Y	C	ALSF2/H	1800	150			(Missed Approach)			
8	N	F	ALSF2/H	1800	150	-9.6	-35.2	4.9	22.8	-0.6	51.9
9	Y	C	ALSF2/H	1800	150	-5.4	-26.1	24.9	-33.3	-68.0	1.1
10	Y	C	MALSR/H	1800	150	6.8	-4.4	22.7	10.1	-9.0	26.4
11	N	F	MALSR/H	1800	150	8.0	-16.0	44.2	1.2	-7.4	23.9
12	N	F	MALSR/CL	1600	150			(Missed Approach)			
13	Y	C	MALSR/CL	1600	150	-18.4	-47.8	33.0	-6.9	-44.1	17.7
14	N	F	MALSR/CL	1600	150	-1.7	-46.5	36.5	8.1	-30.7	33.5
15	Y	C	ALSF2/H	1600	150	-12.0	-36.2	4.5	-22.3	-62.6	1.6
16	N	F	ALSF2/H	1600	150	-13.9	-27.5	4.1	20.1	-11.7	57.2
17	Y	C	MALSR/H	1600	150	-1.5	-30.7	20.5	-24.8	-49.2	1.5
18	N	F	MALSR/H	1600	150	-5.6	-11.7	6.5	8.4	-24.3	35.0
19	Y	C	MALSR/H	1600	150	11.2	0.7	36.6	-16.9	-42.2	7.4

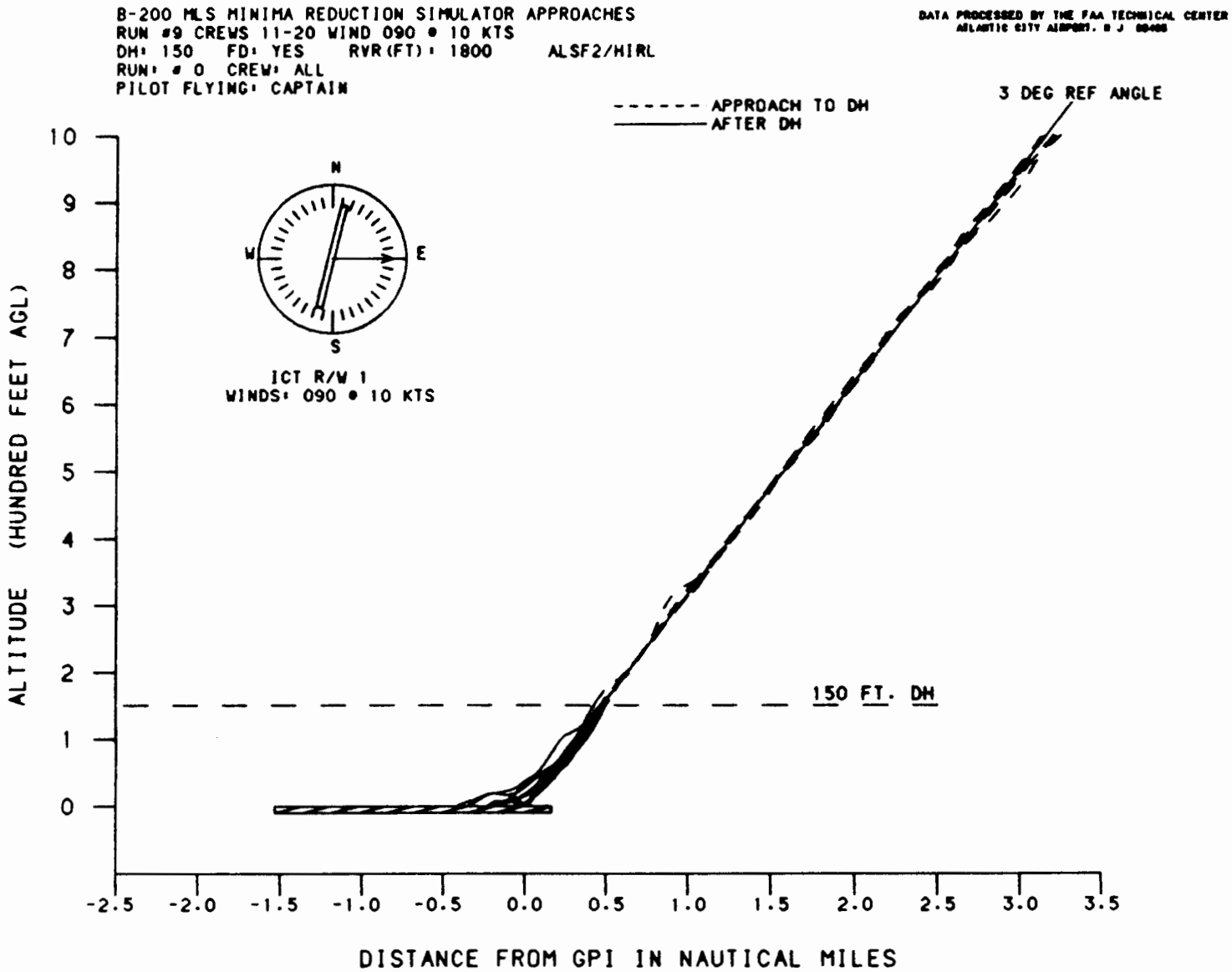

FIGURE 17. VERTICAL TRACKING RESULTS WITH DH=150 FEET, RVR=1800 FEET, AND ALSF-2/HIRL (SECOND 10 CREWS, CAPTAIN FLYING)

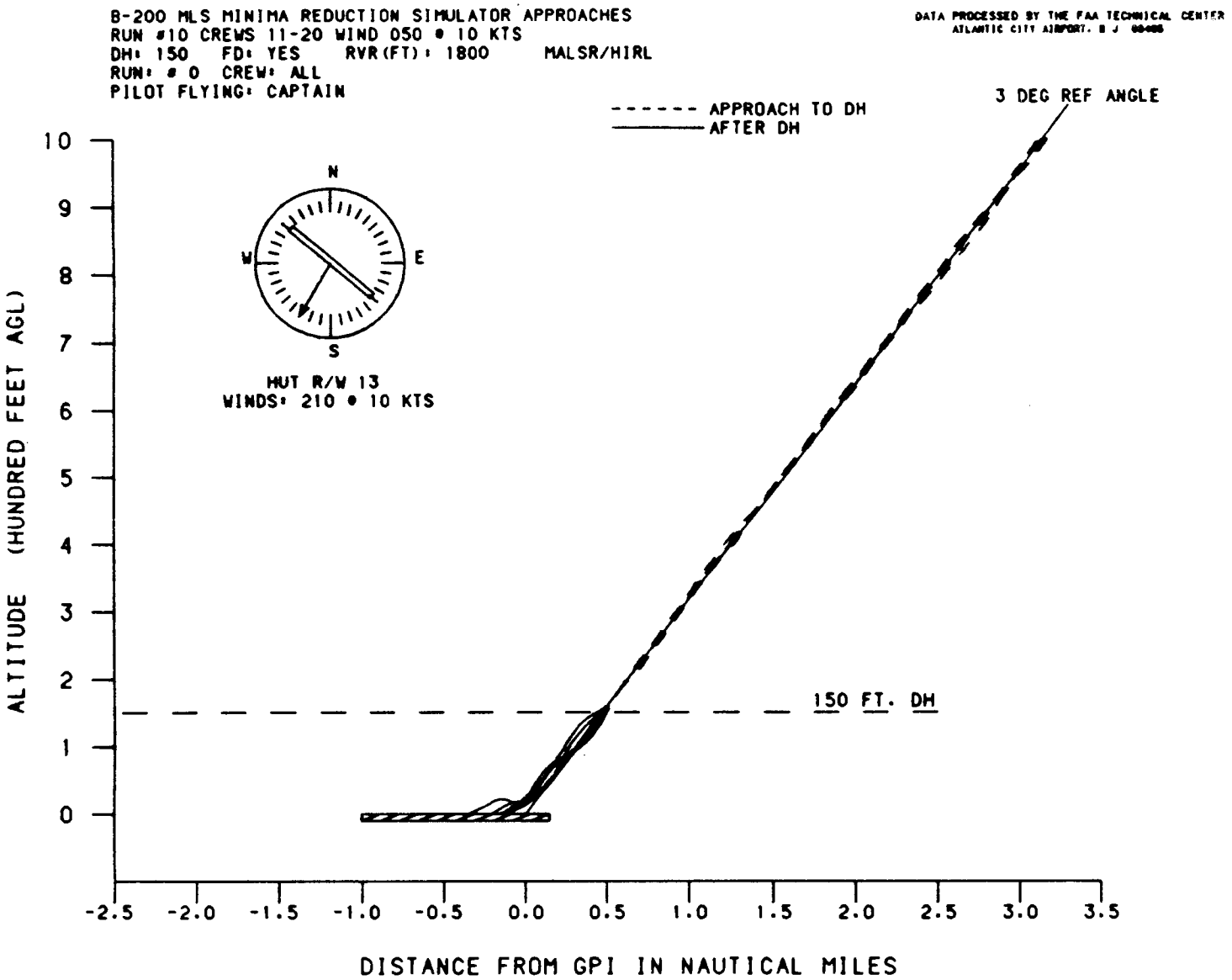

FIGURE 18. VERTICAL TRACKING RESULTS WITH DH=150 FEET, RVR=1800 FEET, AND MALSR/HIRL (SECOND 10 CREWS, CAPTAIN FLYING)

B-200 MINIMA REDUCTION SIMULATOR APPROACHES VERTICAL THRESHOLD WINDOW
RUN: #10 CREWS: 11-20 AIRPORT: HUT PILOT FLYING: CAPTAIN
RWY: 13 DH: 150 RVR: 1800 FD: YES WIND: 050 @ 10 KTS MALSR/HIRL

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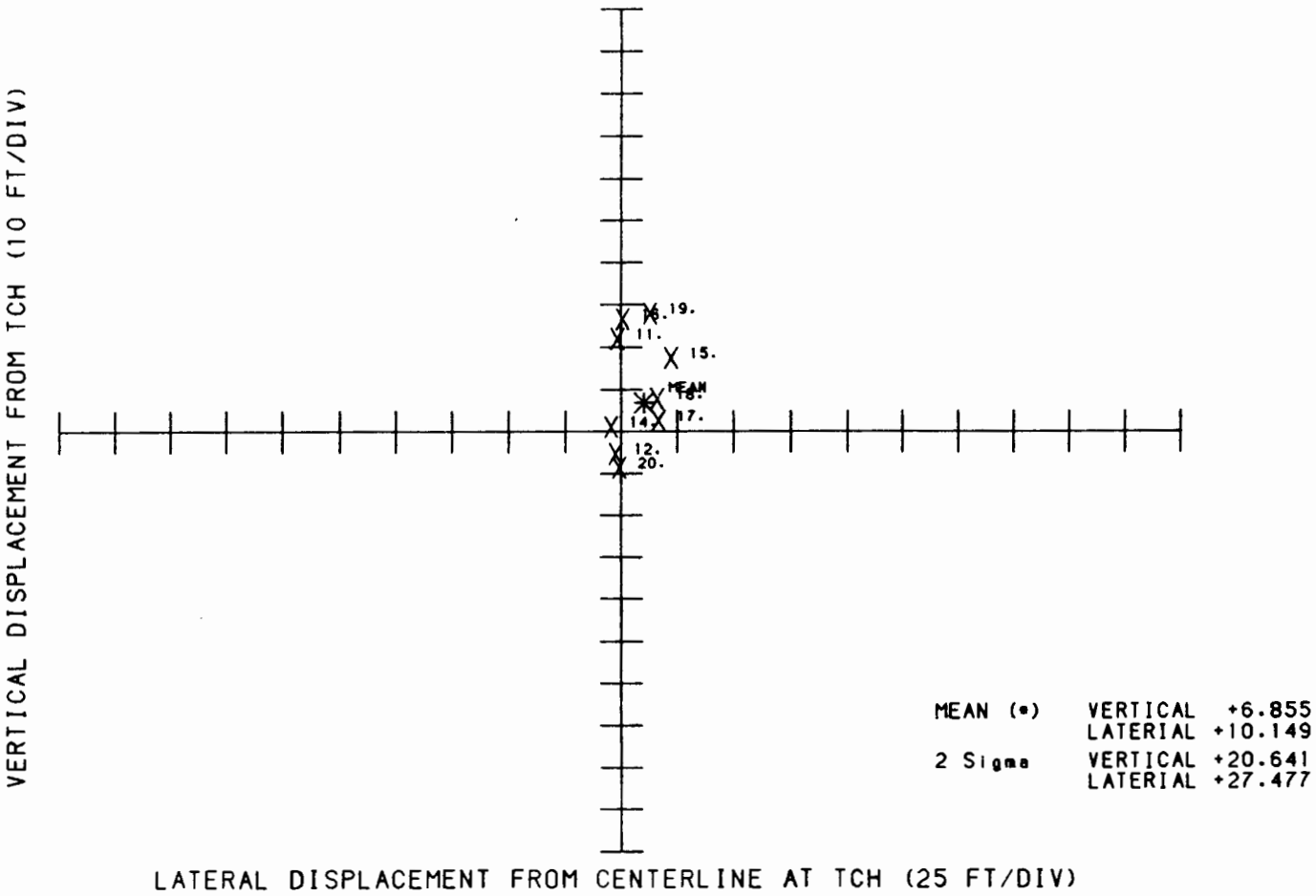

FIGURE 19. THRESHOLD CROSSING POSITION WITH DH=150 FEET, RVR=1800 FEET, AND MALSR/HIRL (SECOND 10 CREWS, CAPTAIN FLYING)

B-200 MINIMA REDUCTION SIMULATOR APPROACHES VERTICAL THRESHOLD WINDOW
RUN: # 9 CREWS: 11-20 AIRPORT: ICT PILOT FLYING: CAPTAIN
RWY: 1 DH: 150 RVR: 1800 FD: YES WIND: 090 @ 10 KTS ALSF2/HIRL

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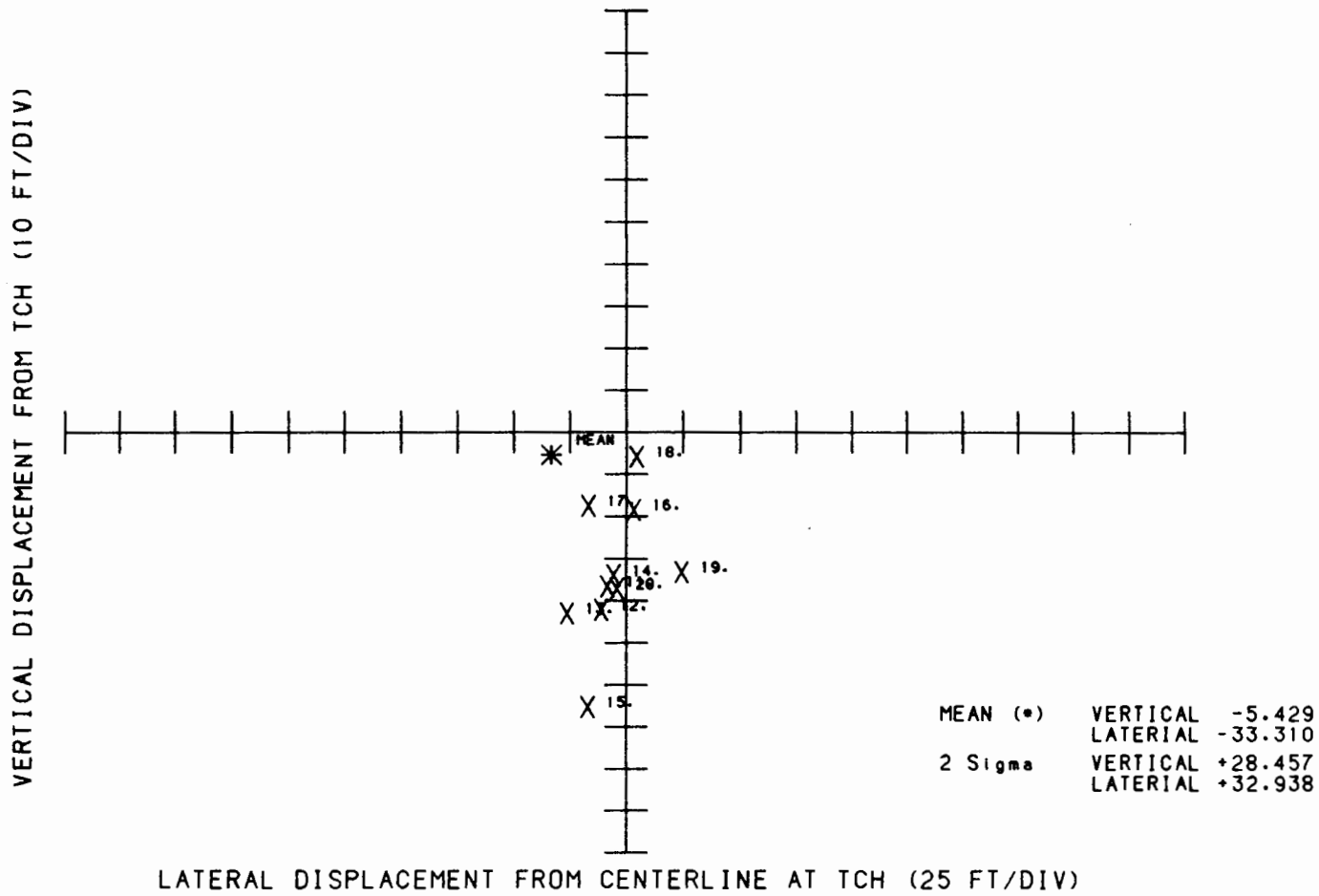

FIGURE 20. THRESHOLD CROSSING POSITION RESULTS WITH DH=150 FEET RVR=1800 FEET, AND ALSF-2/HIRL (SECOND 10 CREWS, CAPTAIN FLYING)

Results under the same test conditions with MALSR/HIRL/CL were considerably poorer than those achieved with MALSR/HIRL. The vertical tracking performance with MALSR/HIRL/CL is shown in figure 21. It appears that the presence of the centerline lights causes an approach under-arcing tendency.

Lateral performance at threshold crossing for DH=150 feet and RVR=1800 feet showed a similar pattern. The mean lateral error of 10.1 feet with MALSR/HIRL was considerably smaller than the -33.3 feet error with ALSF-2/HIRL. The smallest range in observed lateral position error also occurred with MALSR/HIRL, 35.7 feet. This was almost half the value observed with ALSF-2/HIRL, 69.1 feet, and almost a third of the value observed with MALSR/HIRL/CL, 97.1 feet.

Results from approaches 13 (MALSR/HIRL/CL), 15 (ALSF-2/HIRL), and 17 and 19 (MALSR/HIRL) can be compared for the RVR=1600 feet test condition. When the RVR was reduced from 1800 to 1600 feet, the vertical results appear equivalent regardless of the three lighting conditions used. Approaches made with MALSR/HIRL/CL resulted in only slightly greater threshold crossing deviation than with ALSF-2/HIRL or MALSR/HIRL. Laterally, the smallest mean error occurred with MALSR/HIRL/CL. However, the observed range of lateral threshold crossing errors that resulted with MALSR/HIRL/CL were 20 percent larger than the range observed on approaches 17 or 19 with MALSR/HIRL. The largest observed lateral error (62.6 feet) occurred with ALSF-2/HIRL. Figure 22 depicts the better lateral tracking performance that resulted with MALSR/HIRL as compared with the ALSF-2/HIRL results shown in figure 23.

Summary: The analysis of the results from the second 10 crews shows that the best threshold crossing results for the DH=150 feet, RVR=1800 feet condition occurred with MALSR/HIRL. At DH=150 feet RVR=1600 feet, the best vertical results were again obtained with MALSR/HIRL. Lateral performance for the different runway lighting conditions was essentially equivalent.

TOUCHDOWN POINT DISPERSION.

The data thought to be least reliable from the simulation is the touchdown dispersion, owing primarily to the simulator's poor handling qualities in landing configuration with full flaps selected. Based on the recommendations of the FlightSafety International instructors, with their extensive Beech 200 simulator training background, all landings were conducted with approach flaps. Final Approach Speeds (Vref) were, therefore, approximately 13 knots higher than Vref would have been with full flaps extended. The higher approach speed, coupled with reduced drag during the flare, resulted in the aircraft floating and, in most cases, landing well beyond the intended touchdown point. All participants, both subject pilots and instructors, were

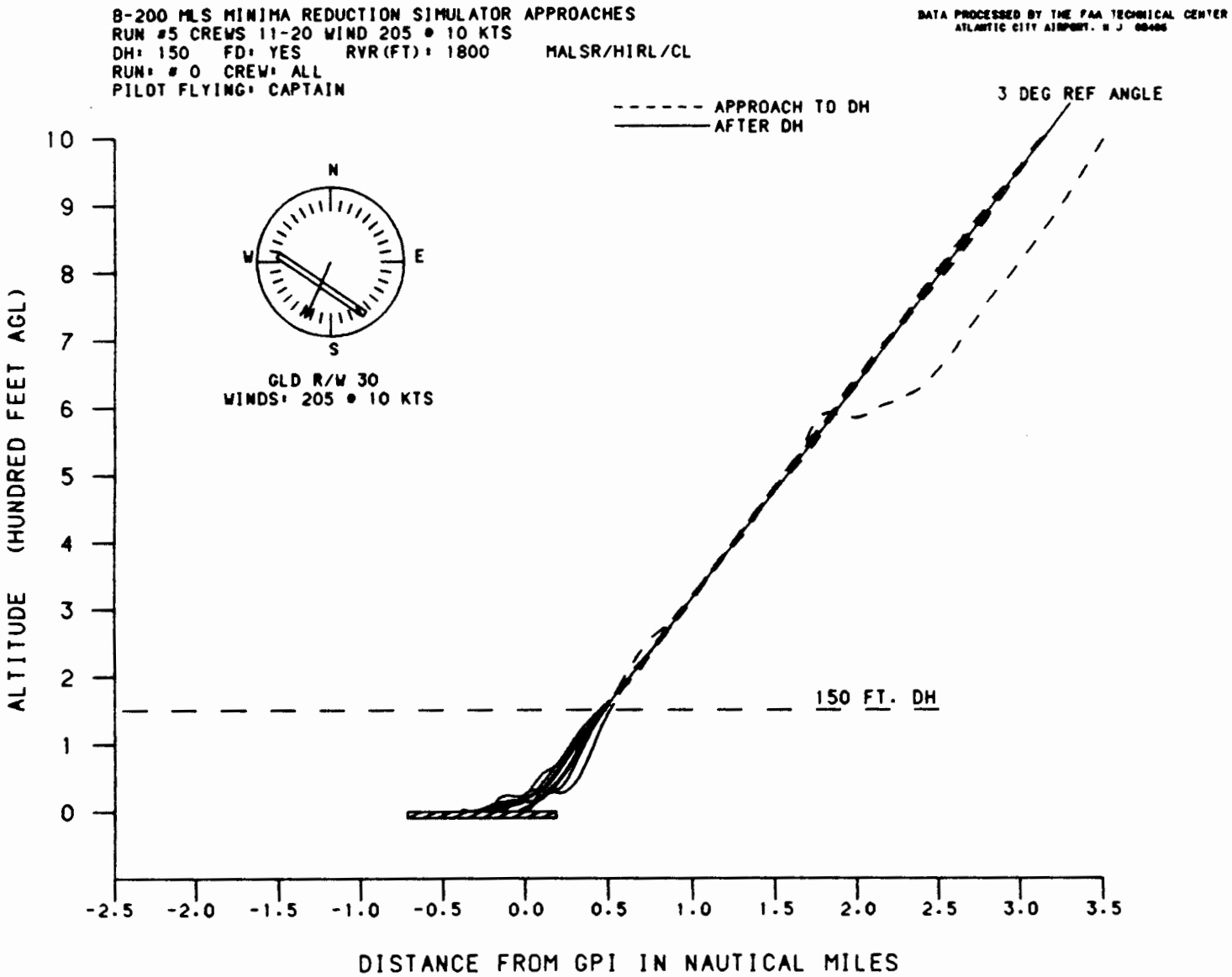

FIGURE 21. VERTICAL TRACKING RESULTS WITH DH=150 FEET, RVR=1800 FEET, AND MALSR/HIRL/CL (SECOND 10 CREWS, CAPTAIN FLYING)

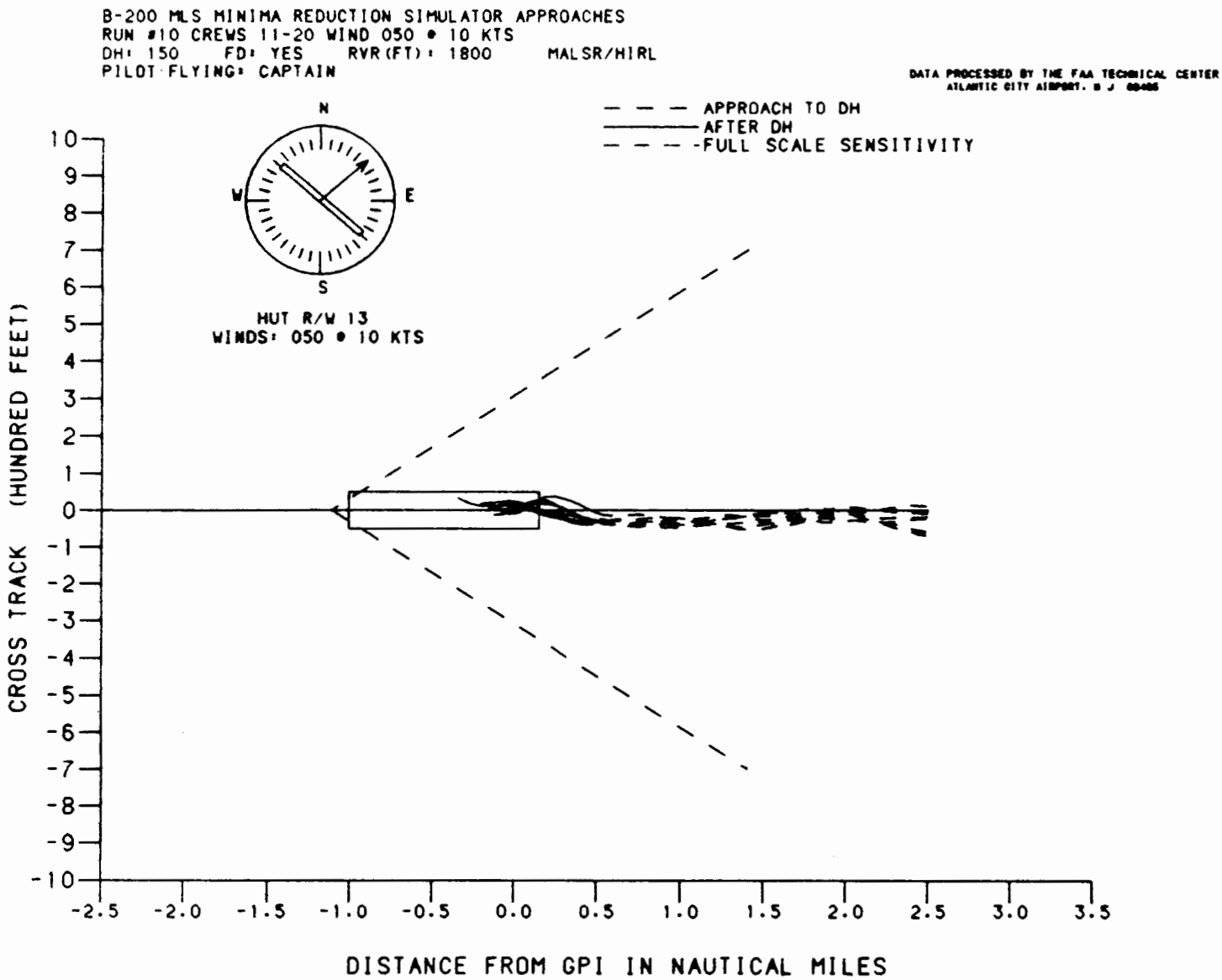

FIGURE 22. LATERAL TRACKING RESULTS WITH DH=150 FEET, RVR=1800 FEET, AND MALSR/HIRL (SECOND 10 CREWS, CAPTAIN FLYING)

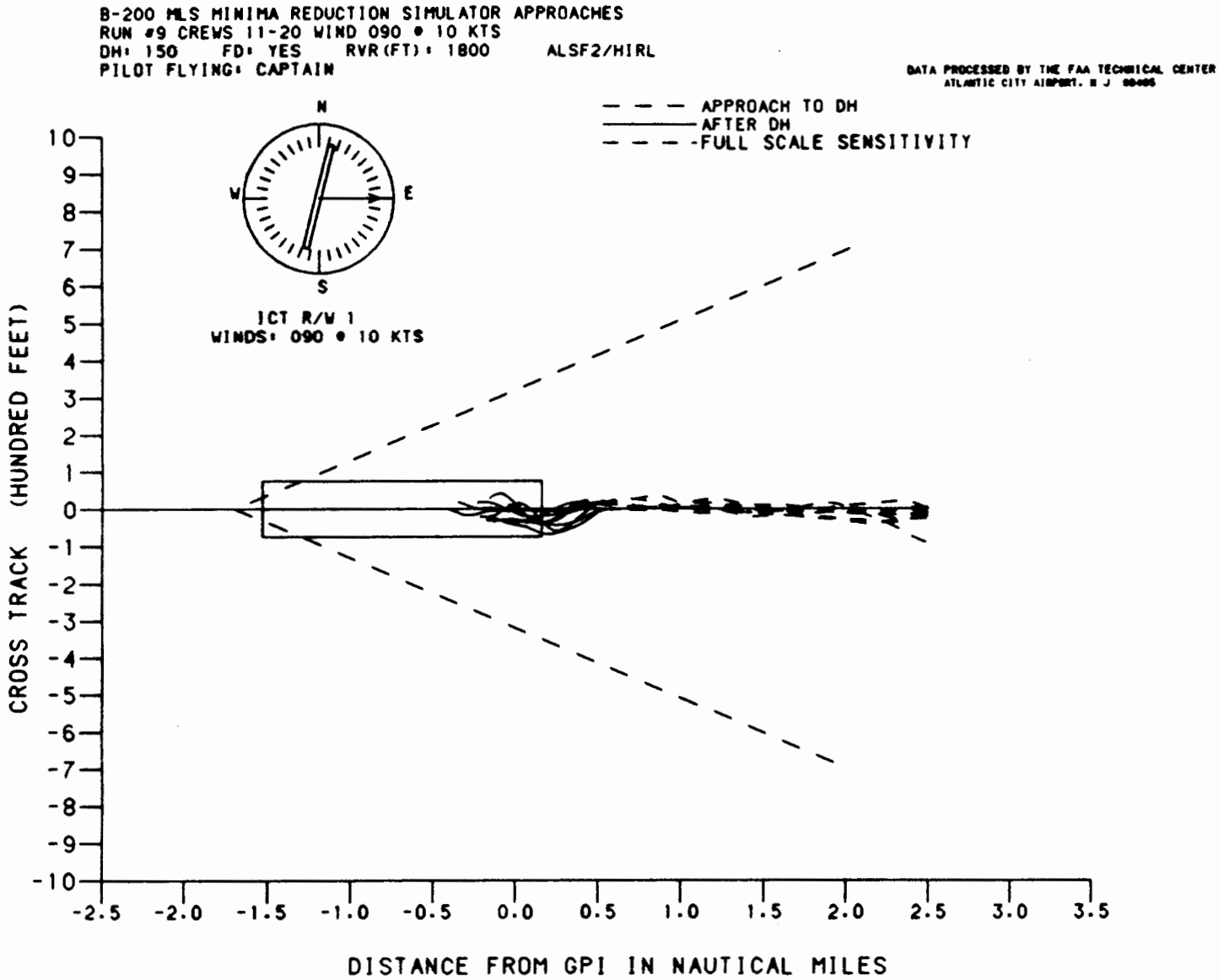

FIGURE 23. LATERAL TRACKING RESULTS WITH DH=150 FEET, RVR-1800 FEET, AND ALSF-2/HIRL (SECOND 10 CREWS, CAPTAIN FLYING)

unanimous in categorizing the behavior of the simulator as unrepresentative of actual Beech 200/1900 landing characteristics.

Comparative plots of touchdown position were analyzed. For the second 10 crews who participated in the evaluation, only the captains used the flight director. Ignoring the planned missed approach runs, the results from approaches 5 (MALSR/HIRL/CL), 9 (ALSF-2/HIRL), and 10 (MALSR/HIRL) can be compared. The results from these three approaches are depicted in figures 24 through 26. Again, for a DH=150 feet and RVR=1800 feet no significant differences in the touchdown dispersion can be detected.

With DH=150 feet and RVR=1600 feet, results from approaches 15 (ALSF-2/HIRL), 13 (MALSR/HIRL/CL), 17 and 19 (MALSR/HIRL) can be compared. The results depicted in figures 27 through 29 do not identify any significant difference associated with a particular lighting system.

QUESTIONNAIRE ANALYSIS

Since the first 10 crews were exposed to different test conditions than the second 10 crews, the questionnaire analysis for each set was done separately. Analysis of pilot responses to three separate questionnaires is presented below. The first questionnaire was administered prior to testing. The second questionnaire consisted of a short series of questions asked of the pilot following each approach. Most of these questions were designed to elicit a numerical response in accordance with the Cooper-Harper rating scheme. The final questionnaire was administered after testing was completed and was designed to collect measures of the overall comparative perceptions of the pilots who participated in the testing.

PRE-EVALUATION QUESTIONNAIRE.

The first question, What approach and runway lighting systems would you want for an approach to a 150-foot DH and RVR of 1800 feet, was designed to establish a perception baseline for the subject pilots. Eighty-five percent of the 20 subject pilots responded with answers that included TDZ and/or CL.

The second question concerned the airborne systems needed to fly to DH's below 200 feet. Eighteen of the subject pilots identified airborne elements required by FAR Part 91, Appendix A. The two most frequent additions were autopilot and large instruments. The need for training and an experienced co-pilot was also mentioned frequently.

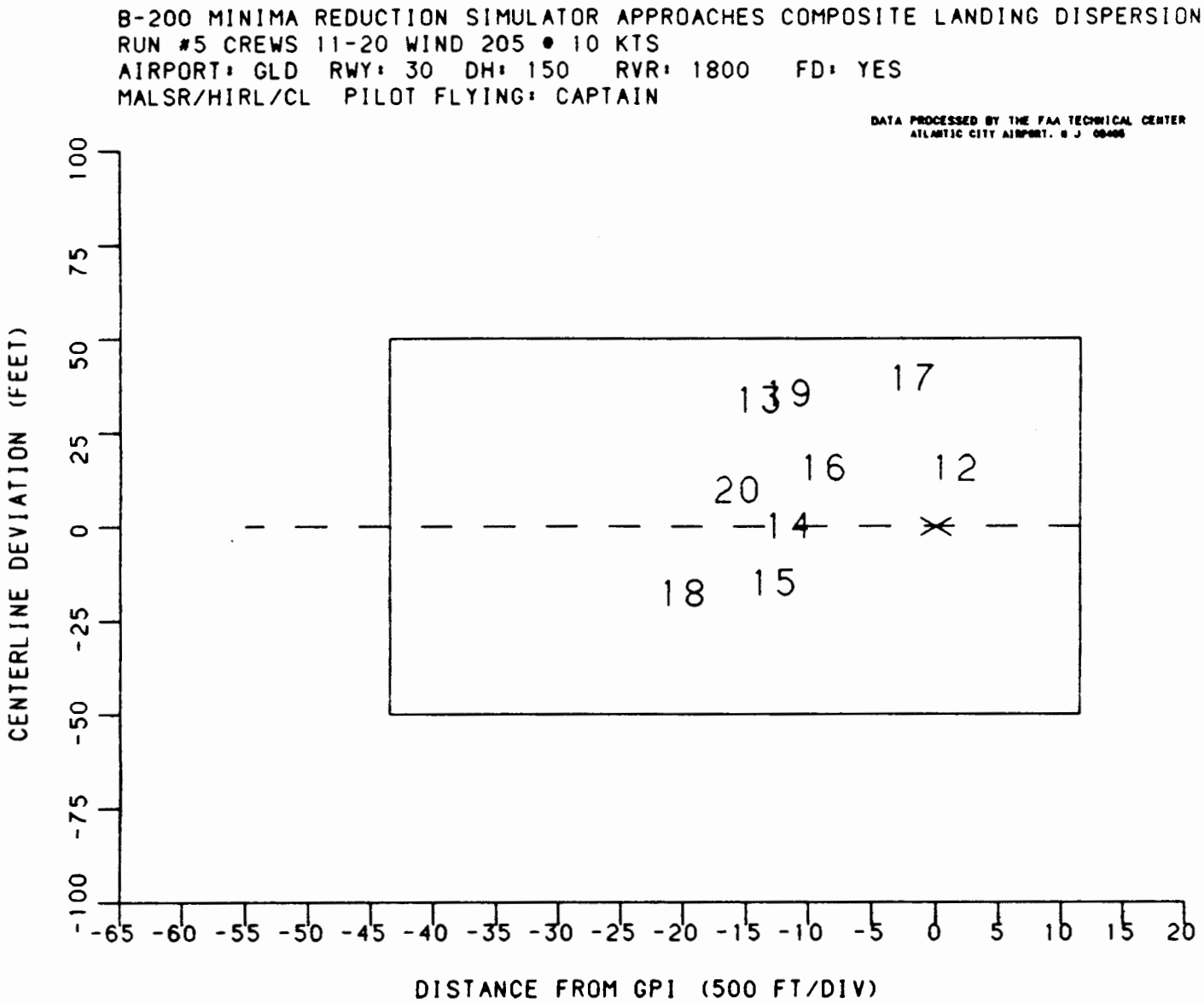

Figure 24. Touchdown Locations with DH=150 Feet, RVR=1800 Feet and MALSR/HIRL/CL

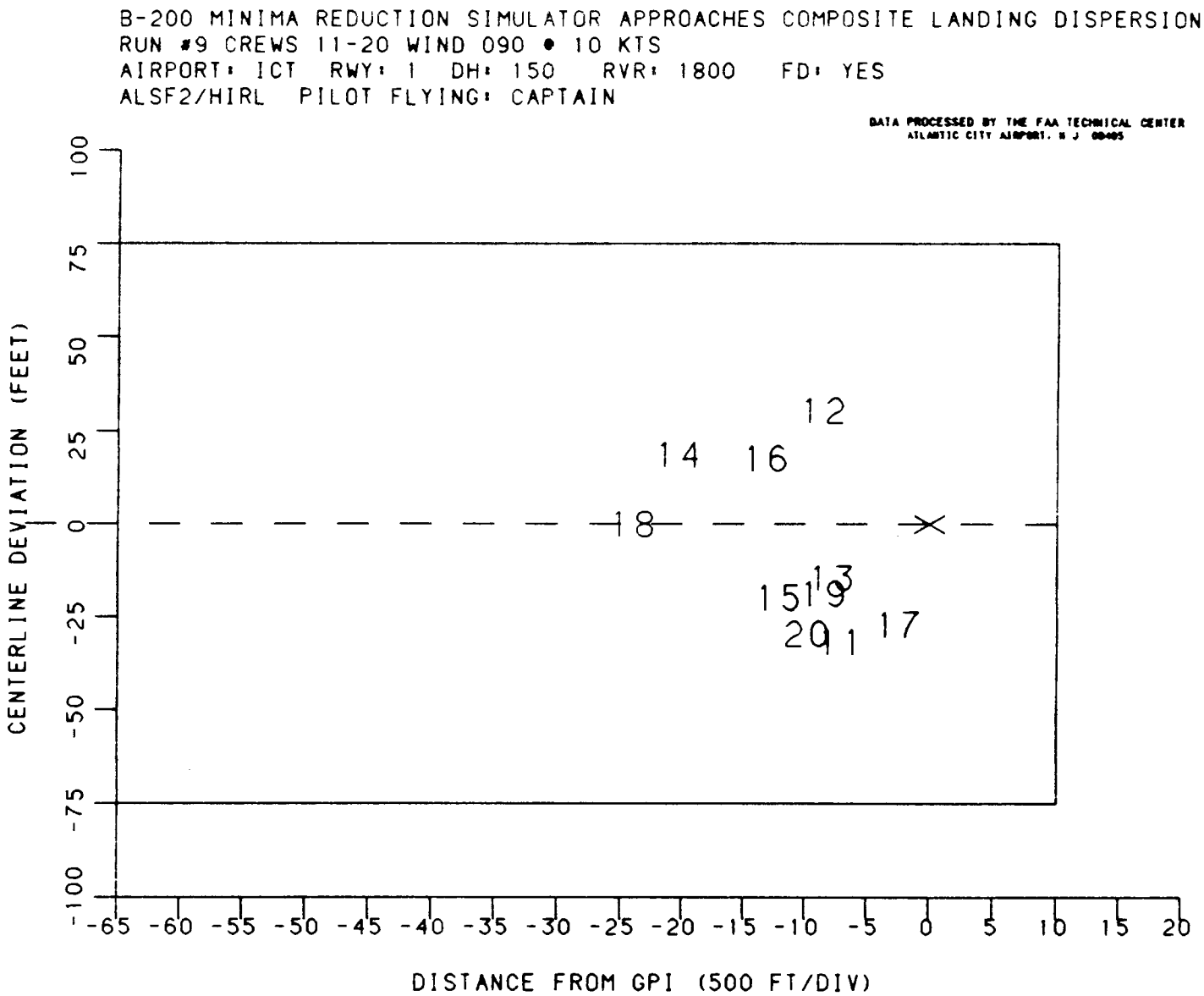

FIGURE 25. TOUCHDOWN LOCATIONS WITH DH=150 FEET, RVR=1800 FEET, AND ALSF-2/HIRL

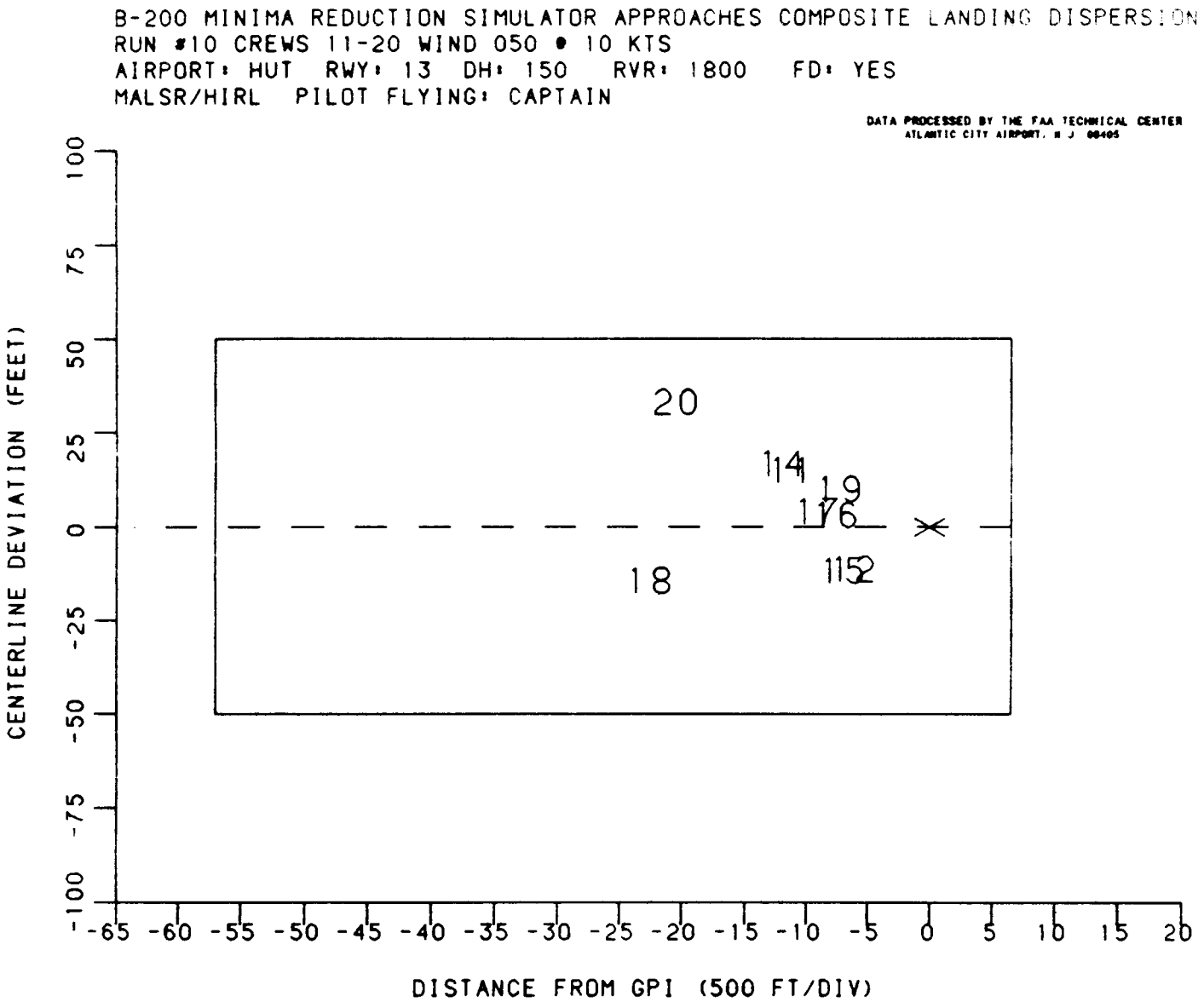

FIGURE 26. TOUCHDOWN LOCATIONS WITH DH=150 FEET, RVR=1800 FEET, AND MALSR/HIRL

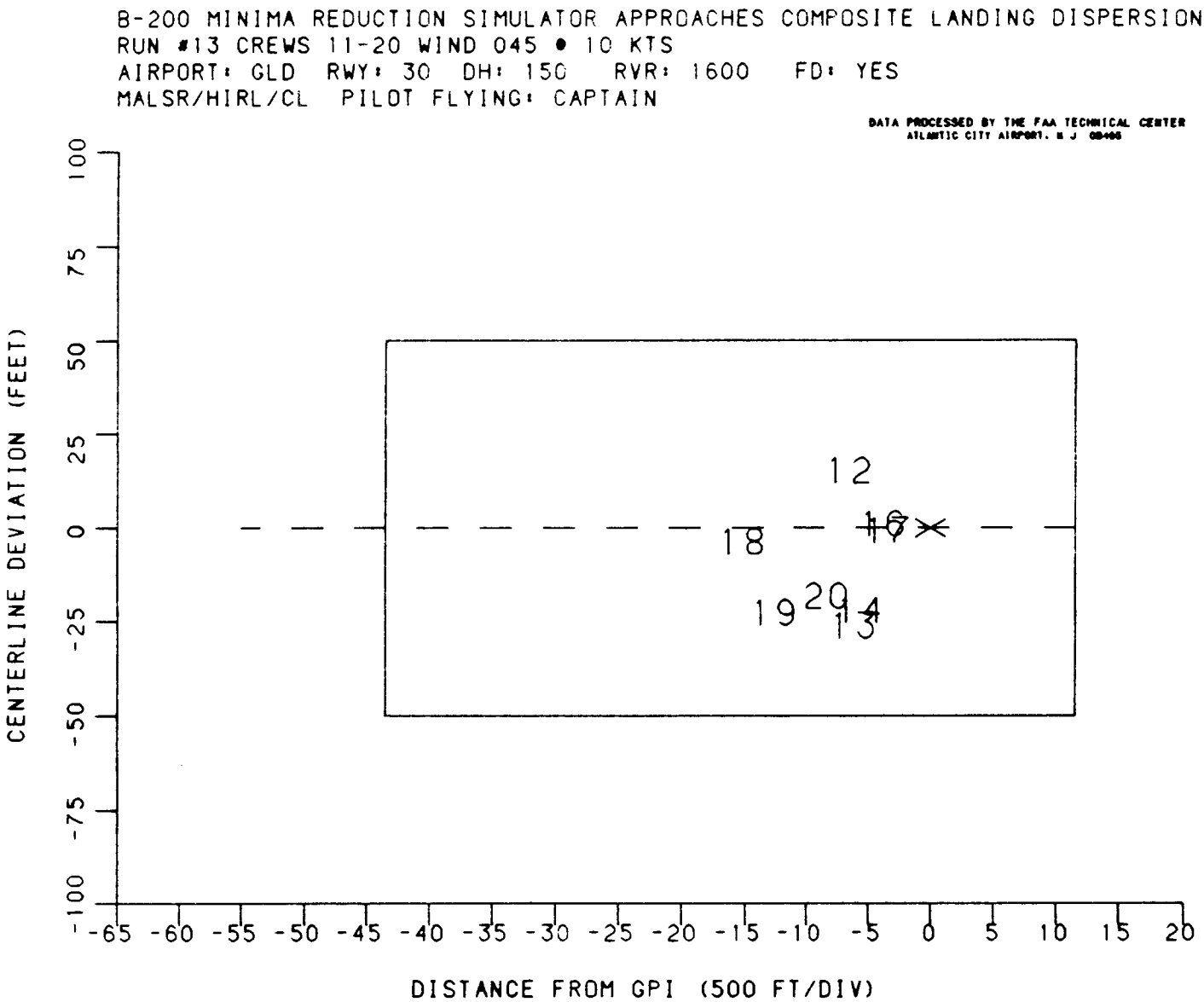

FIGURE 27. TOUCHDOWN LOCATIONS WITH DH=150 FEET, RVR=1600 FEET, AND MALSR/HIRL/CL

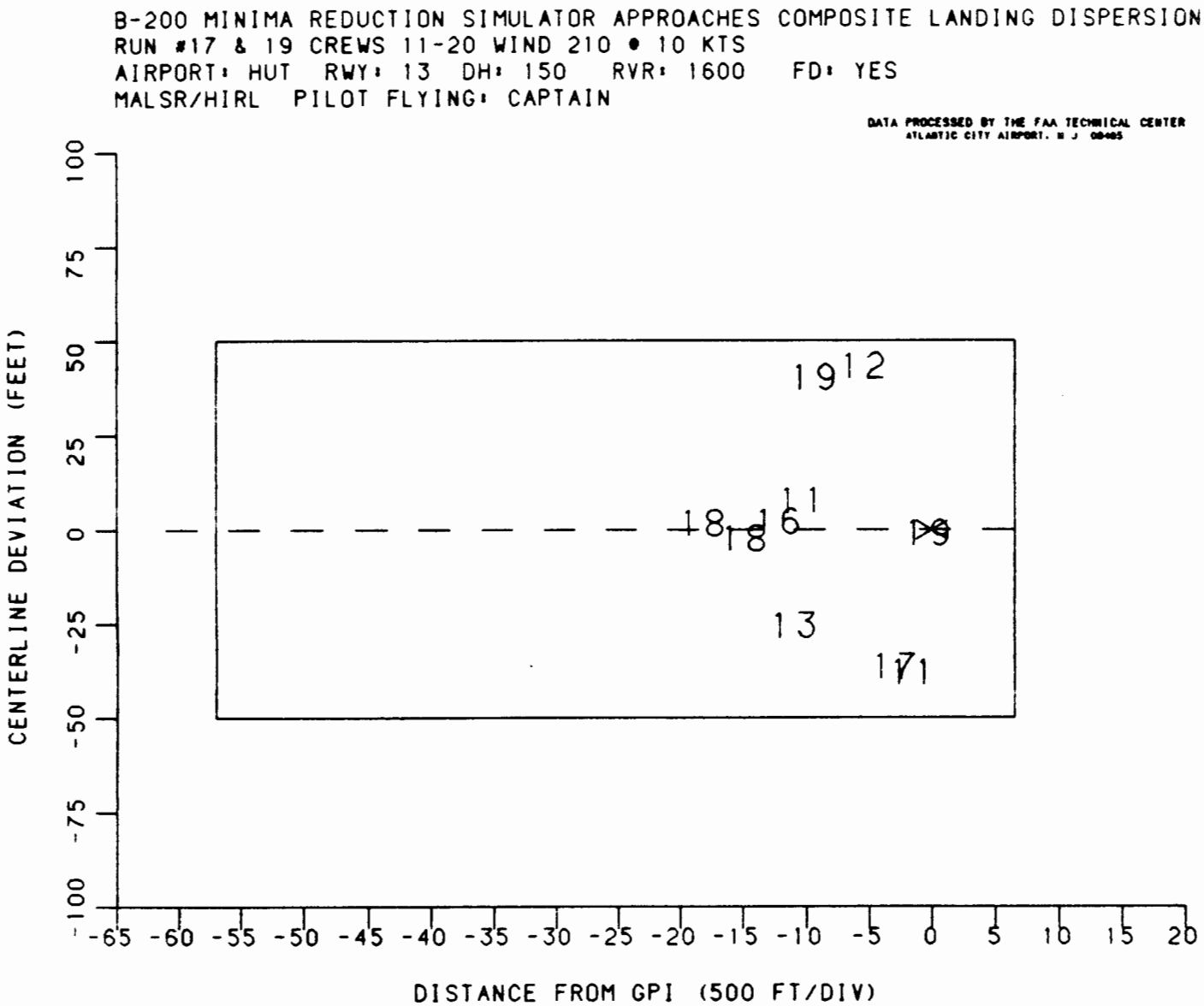

FIGURE 28. TOUCHDOWN LOCATIONS WITH DH=150 FEET, RVR=1600 FEET, AND MALSR/HIRL

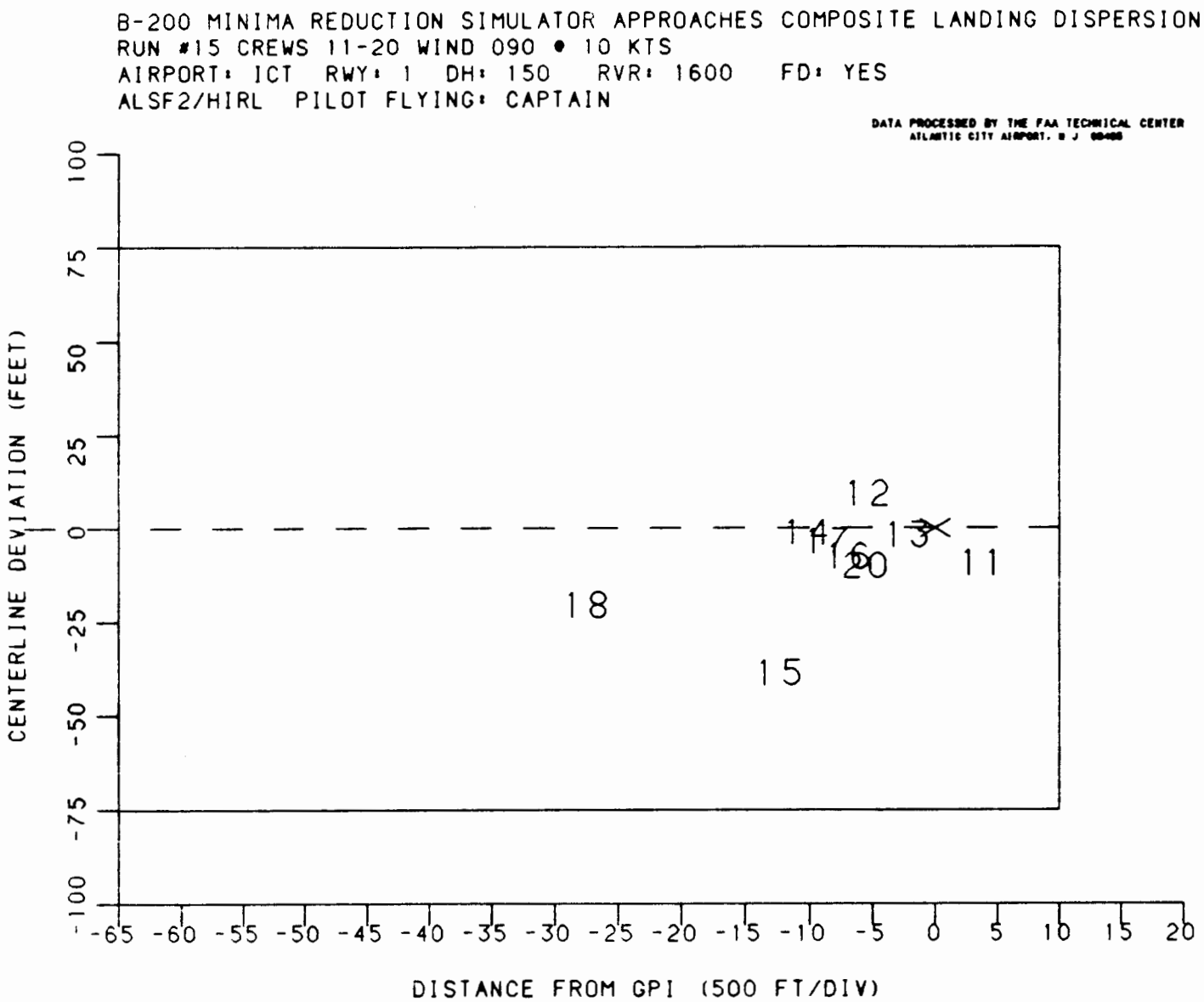

FIGURE 29. TOUCHDOWN LOCATIONS WITH DH=150 FEET, RVR=1600 FEET, AND ALSF-2/HIRL

The third pre-test question was, What is your understanding of the objectives of this evaluation? Responses from 18 of the 20 subject pilots demonstrated that they understood the objectives of the evaluation.

POST PROCEDURE QUESTIONNAIRE.

This questionnaire was designed to measure the subject pilot's immediate perception of the test conditions which he had just been exposed to. It was administered to the pilot who flew the approach immediately after its completion. Since the approaches of interest involved the use of the flight director, the following analysis only considers those approaches for which the flight director was available. For the first 10 crews, the approach set of interest includes approaches 3, 4, 7, 10, and 13.

The crews were requested to respond with a numerical rating, using the Cooper-Harper rating scheme, to the question, For the procedure just flown, how would you rate the lighting system in providing visual guidance to execute a landing? The mean and standard deviation of the responses to this question are presented in table 11.

The captains' ratings of the visual guidance with ALSF-2/HIRL at a 100-foot DH and MALSR/HIRL at a 150-foot DH were not significantly different. The 95 percent upper limit using the Cooper-Harper Rating translates to a "clearly adequate" evaluation of both lighting systems. The captains' responses also indicate that the MALSR/MIRL lighting was inadequate for the test condition (150-foot DH). The 95 percent upper limit response for MALSR/HIRL and a 100-foot DH translates to a "marginal" evaluation.

TABLE 11. CAPTAINS' COOPER-HARPER RATING OF THE LIGHTING ENVIRONMENT FOR THE FIRST 10 CREWS

DH (Feet)	RVR (Feet)	Lighting System	Mean	Standard Deviation	95% Upper Limit
100	1200	ALSF-2/H	2.3	0.44	3.18
150	1800	MALSR/H	2.4	0.54	3.48
150	1800	MALSR/M	4.0	3.24	10.48
150	1600	MALSR/H	2.3	1.00	4.30
100	1200	MALSR/H	3.2	1.56	6.13

(For a review of the Cooper-Harper rating scale, see figure 5)

The second question asked was, From DH to completion of the approach, how would you rate your overall workload for the procedure just completed? A summary of the captains' responses are presented in table 12.

TABLE 12. CAPTAINS' COOPER-HARPER RESPONSE STATISTICS FOR WORKLOAD FOR THE FIRST 10 CREWS

DH (Feet)	RVR (Feet)	Lighting System	Mean	Standard Deviation	95% Upper Limit
100	1200	ALSF-2/H	2.4	1.50	5.40
150	1800	MALSR/H	2.3	0.46	3.22
150	1800	MALSR/M	2.8	0.98	4.76
150	1600	MALSR/H	2.4	1.11	4.62
100	1200	MALSR/H	2.9	1.56	6.02

The best workload ratings occurred with MALSR/HIRL and DH=150 feet. In these cases, the numerical value equates to, "Desired performance requires moderate pilot compensation" or better. All other test conditions, including ALSF-2/HIRL, evoked responses indicating more demanding performance by the pilot was required. For the 49 approaches made by captains under the above test conditions, only one was rated unacceptable. This occurred with MALSR/HIRL and a 100-foot DH.

Similar analysis of first officer responses were made. The approaches of interest are 14 through 18. Table 13 presents the statistics on the first officer's evaluation of the various lighting systems.

TABLE 13. FIRST OFFICERS' COOPER-HARPER RATINGS OF THE LIGHTING ENVIRONMENT FOR THE FIRST 10 CREWS

DH (Feet)	RVR (Feet)	Lighting System	Mean	Standard Deviation	95% Upper Limit
150	1800	MALSR/H	2.5	1.36	5.22
150	1800	MALSR/M	2.8	1.83	6.46
150	1600	MALSR/H	2.6	1.56	5.72
100	1200	ALSF-2/H	1.8	1.54	4.88
100	1200	MALSR/H	3.4	1.56	6.52

The first officer evaluations of the lighting systems reflect somewhat poorer ratings than from the captains. The MALSR/HIRL, DH=150 feet response was only slightly higher than the ALSF-2/HIRL, DH=100 feet response. The 5.22 95 percent upper limit value for MALSR/HIRL translates to an "adequate" rating. The MALSR/MIRL, and MALSR/HIRL with DH=100 feet had significantly poorer ratings. The first officers' response statistics for the question addressing workload are presented in table 14.

TABLE 14. FIRST OFFICERS' COOPER-HARPER RESPONSE STATISTICS FOR WORKLOAD FOR THE FIRST 10 CREWS

DH (Feet)	RVR (Feet)	Lighting System	Mean	Standard Deviation	95% Upper Limit
150	1800	MALSR/H	2.6	2.08	6.76
150	1800	MALSR/M	2.8	1.94	6.69
150	1600	MALSR/H	2.4	1.50	5.40
100	1200	ALSF-2/H	2.0	1.82	5.63
100	1200	MALSR/H	3.0	1.73	6.46

The observations of the test observer indicated a definite learning trend. The ALSF-2/HIRL, DH=100 feet, RVR=1200 feet 95 percent upper limit value of 5.63 was similar to the MALSR/HIRL, DH=150 feet, RVR=1600 feet value of 5.40. Regardless of test condition, the ratings indicate, "adequate performance requires considerable pilot compensation." For each test condition, one or two first officers rated the lighting system unacceptable.

Similar analysis was conducted on the responses of the second 10 crews. Since only the captain used the flight director, only captains' response analyses are presented. Table 15 presents the results of the captains' evaluation of the various lighting systems.

TABLE 15. CAPTAINS RESPONSE STATISTICS ON LIGHTING EVALUATION FOR THE SECOND 10 CREWS

DH (Feet)	RVR (Feet)	Lighting System	Mean	Standard Deviation	95% Upper Limit
200	1800	ALSF-2/H	1.8	0.98	3.76
150	1800	MALSR/H/CL	3.3	1.94	7.18
150	1800	ALSF-2/H	1.9	0.54	2.98
150	1800	MALSR/H	2.5	1.11	4.71
150	1600	MALSR/H/CL	3.8	2.33	8.46
150	1600	ALSF-2/H	3.1	2.38	7.87
150	1600	MALSR/H	2.8	1.39	5.59

With DH=150 feet and RVR=1800 feet, ALSF-2/HIRL ratings were the best. However, the 95 percent upper limit response found MALSR/HIRL "adequate" for DH=150 feet and RVR=1800 feet. Noteworthy are the significantly poorer ratings given to MALSR/HIRL/CL. The 95 percent upper limit response translates to, "Inadequate." It may be that the captains' unfamiliarity with this lighting combination influenced their rating. For DH=150 feet and RVR=1600 feet, MALSR/HIRL was rated better than the ALSF-2/HIRL lighting. An analysis of the captains' responses to the question on workload is presented in table 16.

TABLE 16. CAPTAIN'S RESPONSE STATISTICS TO WORKLOAD PERCEPTION FOR THE SECOND 10 CREWS

DH (Feet)	RVR (Feet)	Lighting System	Mean	Standard Deviation	95% Upper Limit
200	1800	ALSF-2/H	1.8	0.60	3.00
150	1800	MALSR/H/CL	2.6	1.16	4.92
150	1800	ALSF-2/H	2.2	0.87	3.94
150	1800	MALSR/H	2.2	1.00	4.20
150	1600	MALSR/H/CL	3.8	1.97	7.74
150	1600	ALSF-2/H	2.6	2.20	7.00
150	1600	MALSR/H	2.7	1.21	5.12

The best workload rating occurred for the ALSF-2/HIRL, DH=200 feet, RVR=1800 feet test condition. The worst workload rating was given to the MALSR/HIRL/CL, DH=150 feet, RVR=1600 feet test condition. For DH=150 feet and RVR=1800 feet, ALSF-2/HIRL and MALSR/HIRL workload ratings are nearly equivalent, and translate to "desired performance requires moderate pilot compensation." For the RVR=1600 feet condition, the workload rating for MALSR/HIRL (5.12) was better than ALSF-2/HIRL (7.00). However, the 95 percent upper limit response value equates to "adequate performance requires considerable pilot compensation."

POST-EVALUATION QUESTIONNAIRE.

The first question asked following completion of the test was, As a result of your experience during this evaluation, what approach and runway lighting system would you want for an approach to a 150 foot DH with an RVR=1800 feet? Table 17 presents the results for the first 10 crews who participated in the test.

TABLE 17. RESPONSE SUMMARY OF THE FIRST 10 CREWS TO LIGHTING ENVIRONMENT REQUIRED FOR APPROACH TO A 150-FOOT DH WITH RVR=1800 FEET

	Lighting Environment			
Respondent	ALSF-2/H	MALSR/M	MALSR/H	MALSR/CL
Captain	3	2	2	3
First Officer	3	0	5	2

No clear preference exists. Six crew members selected ALSF-2/HIRL and seven crew members selected MALSR/HIRL. It is interesting to note 25 percent (5) asked for MALSR/HIRL/CL even though this combination was not presented to the first 10 crews and, subsequently, received some of the lowest ratings.

The second 10 crews were asked a similar question: As a result of your experiences during this evaluation, what, in your opinion,

are the minimum approach and runway lighting systems necessary to land from an approach to a 150-foot DH with a 1600 foot RVR? The results are presented in table 18.

TABLE 18. RESPONSE SUMMARY OF THE SECOND 10 CREWS TO LIGHTING ENVIRONMENT REQUIRED FOR APPROACH TO A 150-FOOT DH WITH RVR=1600 FEET

	Lighting Environment			
Respondent	ALSF-2	MALSR/M	MALSR/H	MALSR/CL
Captain	3	1	3	3
First Officer	2	0	6	2

Again, 45 percent (9) of the crew members felt MALSR/HIRL was adequate. Several of the ALSF-2/HIRL responses were qualified with a statement such as "less lighting would be required with proper training." Of the 40 crew members who participated in the testing, 90 percent stated they would feel comfortable with the aircraft equipment used in this evaluation when operating to DH's of 150 feet or lower.

CONCLUSIONS

TEST SCENARIO.

Based on the results contained in this report, several conclusions can be drawn:

1. The consistency of test results, including subjective pilot responses to questionnaires, indicate that the Beech 200 simulator provided sufficient fidelity to address the feasibility of minima reduction.

2. The assumed requirements made prior to testing were proven valid. Specialized training and thorough crew coordination are necessary for operations in low visibility conditions. Given very stable and accurate precision approach guidance, pilots with sufficient experience and training can manually fly, with the aid of a flight director, safely to Decision Heights (DH's) below the current Category-I DH of 200 feet. Both lateral and vertical cross track errors are significantly reduced with the aid of a flight director. Pilot performance with the flight director permits arrival at a 150-foot DH with a variability that is entirely contained within the accepted variability without flight director aiding at the current Category-I 200-foot DH.

3. The equipment specified in appendix A to FAR Part 91 is sufficient to support operations to DH's as low as 150 feet. Category-II approach and runway lighting systems may not be required. This conclusion results from the measures of pilot

performance, and from questionnaire responses made by the pilots after testing.

VISUAL SEGMENT PERFORMANCE.

Several conclusions can be drawn concerning pilot performance in the visual segment.

1. Inside DH, having broken out into visual conditions, pilots often continue to utilize the guidance provided by the navigation system. This is increasingly true for the lower DH conditions. This conclusion is based on direct observation of pilot scanning techniques and on statements made by the subject pilots. This conclusion relates to a significant benefit that is provided by the Microwave Landing System (MLS). MLS, when properly sited, will provide accurate guidance to runway threshold. This is not always true with the Instrument Landing System (ILS).

2. Accurate arrival at DH's, regardless of the category of approach, does not assure a landing. On several occasions, with the flight director not available, the pilot arrived at DH in visual conditions, chose to continue the approach beyond DH, and then executed a late missed approach. This is referred to as a balked landing. The flight director provides better attitude cueing which leads to a much lower balked landing rate. When the flight director was available, pilots, with minimal low visibility approach training, were able to complete 149 out of 155 approaches (96 percent). Of the six balked landings that occurred, two of them occurred with Approach Lighting System with Sequenced Flashing Lights (ALSF-2)/High Intensity Runway Lights (HIRL), one occurred with Medium Intensity Approach Light System with Runway Alignment Indicator Lights (MALSR)/Medium Intensity Runway Lights (MIRL), one with MALSR/HIRL/Centerline Lighting (CL), and two with MALSR/HIRL. Both MALSR/HIRL balked landings occurred with DH=100 feet. All flight director aided approaches with MALSR/HIRL to 150-foot DH's were completed successfully.

3. Accurate arrival at threshold crossing is influenced by the runway lighting environment. MALSR/HIRL threshold crossing results for 150-foot DH's were equivalent to or better than results obtained with ALSF-2/HIRL. Test results demonstrated that MALSR/MIRL was inadequate for operation below standard Category-I. Although one would expect that the inclusion of centerline lights with MALSR/HIRL would result in better performance than without centerline lights, that was not the case. With a 150-foot DH, the balked landing rate was higher with MALSR/HIRL/CL. Considerably poorer threshold crossing performance, both laterally and vertically, was also observed with MALSR/HIRL/CL.

TOUCHDOWN LOCATIONS.

Although significant differences in touchdown dispersion were not observed under the conditions tested, no specific conclusions can be drawn. The fidelity of the simulator visual system, coupled with its handling qualities in the landing configuration, prevented a true evaluation of landing dispersion. Accurate touchdown performance measurements can only be taken during actual flight testing.

QUESTIONNAIRE ANALYSIS.

Based on post-evaluation questionnaire responses, it can be concluded that most test subjects felt that MALSR/HIRL was sufficient for operations to DH's of 150 feet. The Cooper-Harper 95 percent upper limit responses provided by test subjects also identified MALSR/HIRL as "adequate" for approaches to 150-foot DH's. In several cases MALSR/HIRL ratings were superior to those for Approach Lighting System with Sequenced Flashing Lights (ALSF-2)/HIRL.

Based on the perceived workload evaluations provided by the test subjects, it is concluded that operation to 150-foot DH's with MALSR/HIRL did not result in an excessively high workload. In fact, MALSR/HIRL ratings were better than those for ALSF-2/HIRL in several cases. The 95 percent upper limit response for MALSR/HIRL workload rating for DH=150 feet translates to "desired performance, requiring only moderate pilot compensation."

RECOMMENDATIONS

Based on the results contained in this report, it is recommended that the flight testing phase of the minima reduction study be initiated. Prior to testing, several issues should be addressed. They are:

1. Development of a thorough training package prior to testing. Testing will require subject pilots to fly with a Federal Aviation Administration (FAA) safety pilot. The crew interaction observed during simulator testing was a result of the captain and first officer coming from the same airline. For the flight testing phase, the crew response repertoire must be developed prior to taking test measures. This may require several practice approaches to gain crew interaction/procedure familiarity.

2. The FAA Beech King Air 200 test aircraft should be used. The Electronic Altitude Director Indicator (EADI) should be modified to display either radar altimeter information or Microwave Landing System (MLS) computed height information.

3. The testing scenario should utilize visibility restricting devices worn by the subject pilot to adequately emulate low

visibility conditions. The devices should be calibrated against the High Intensity Runway Lights (HIRL) system present on the runway to which the approaches will be flown.

4. All testing should be with flight director aiding.

5. The runway lighting environment should include Medium Intensity Approach Light System with Runway Alignment Indicator Lights (MALSR)/HIRL, MALSR/HIRL/Centerline Lighting (CL) and Approach Lighting System with Sequenced Flashing Lights (ALSF-2)/HIRL as test factors.

6. Both on-board data recording and external tracking of the aircraft should be used to collect test measures.

REFERENCES

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3. Hawley, Robert, MLS Reduced Minima Evaluation, Why It Will Work, Booze, Allen & Hamilton, Inc.

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APPENDIX A

SUBJECT PILOT EXPERIENCE

Pilot Experience Responses From
Pre-Evaluation Questionnaire
MLS Minima Reduction Study

CREWS 1-10

Pilot Ratings Held

Crew #	
1C:	Air Transport Pilot, Airplane Single and Multi-Engine Land.
1FO:	Air Transport Pilot, Airplane Multi-Engine Land, Commercial Airplane Single-Engine Land, Rotor-Craft-Helicopter-Instrument, Certified Flight Instructor-Airplane Single-Engine Land.
2C:	DC-3 and BE-1900 Type Ratings, Air Transport Pilot.
2FO:	Air Transport Pilot Multi-Engine Land.
3C:	Air Transport Pilot Multi-Engine, Multi-Engine Certified Flight Instructor Instruments, Metro-III and BE-1900 Type Ratings.
3FO:	Commercial, Multi-Engine Instruments.
4C:	Air Transport Pilot with BE-02/B-300 and DHC-7 Type Ratings, Glider & Multi-Engine Ratings, Certified Flight Instructor Single and Multi-Engine Instruments.
4FO:	Air Transport Pilot Single Engine, Multi-Engine Commercial, Instruments, Lear Jet, L-300.
5C:	Air Transport Pilot, Multi-Engine Land.
5FO:	Single and Multi-Engine Land, Commercial, Instruments, Flight Engineer.
6C:	Air Transport Pilot, BE-1900/300 and BV-234 (Commercial Chinook) Type Ratings, Commercial/Instrument Rotorcraft.
6FO:	Commercial, Instruments, Multi and Single Engine Land.
7C:	Air Transport Pilot, Commercial, Multi-Engine Land.
7FO:	Commercial Single and Multi-Engine Land, Instrument Airplane.
8C:	Air Transport Pilot, Flight Engineer, Turbo Jet.
8FO:	Instrument, Multi-Engine, Commercial.
9C:	Air Transport Pilot, Multi-Engine Land, Commercial Privileges, C-500 Type Rating, Turbo-Jet Flight Engineer.
9FO:	Commercial, Instrument, Multi-Engine Land.
10C:	Air Transport Pilot/Commercial, Single Engine Land and Single Engine Seaplane Flight Instructor, Multi-Engine Land and Instrument, BE300/900 Type Ratings.
10FO:	Commercial/Instruments, Multi-Engine Land, Multi-Engine I0nstruments.

Crew #	Total Flight Time Hours	B-200/1900 Flight Hours	B-200/1900 Flight Hrs (Last 6 Months)
1C	5,600	1,000	500
1FO	2,250	100	80
2C	7,900	2,000	500
2FO	2,400	650	500
3C	5,000	400	400
3FO	2,350	280	280
4C	4,200	1,050	95
4FO	4,300	50	50
5C	7,000 +	2,000	480
5FO	650	150	150
6C	4,100	1,100	550
6FO	1,300	200	200
7C	3,000	1,000	600
7FO	1,300	100	100
8C	3,000	500	450
8FO	1,400	400	400
9C	7,000	950	500
9FO	575	300	300
10C	4,700	2,200	200
10FO	1,300	450	450

Pilot Experience Responses From
Pre-Evaluation Questionnaire
MLS Minima Reduction Study
CREWS 11-21

Pilot Ratings Held

Crew #	
11C:	Air Transport Pilot, Commercial Single Engine Land and Rotorcraft, Instrument Helicopter.
11FO:	Commercial, Instrument, Multi-Engine, Flight Engineer.
12C:	Air Transport Pilot Multi-Engine, Commercial Single-Engine, Flight Instructor.
12FO:	Commercial, Multi and Single Engine Instruments.
13C:	Air Transport Pilot-Multi-Engine Land, Commercial Privileges, Airplane Single Engine Land, BE-1900 and BE-300 Type Ratings, Certified Flight Instructor Instruments Multi-Engine.
13FO:	Commercial, Instrument, Certified Flight Instructor, Certified Flight Instructor Instruments, Multi-Engine, Multi-Engine Ground Instructor.
14C:	Air Transport Pilot, BE-1900 Type Rating.
14FO:	Air Transport Pilot.
15C:	Air Transport Pilot, Certified Flight Instructor, Multi-Engine Helicopter Instruments, Commercial Helicopter.
15FO:	Air Transport Pilot Multi-Engine Land, Commercial, Instrument, Single Engine Land, Certified Flight Instructor Instruments and Multi-Engine.
16C:	Flight Engineer (727), Certified Flight Instructor, Certified Flight Instructor Instruments, Glider, Air Transport Pilot, Single and Multi-Engine, SA227, CV-240, 340, 440, Lear Jet, BE-1900 Type Ratings.
16FO:	Air Transport Pilot, Commercial.
17C:	Air Transport Pilot-Multi-Engine Land, DA-10 and BE-1900/BE-300 Type Ratings, Commercial-Single Engine Land, Single Engine Seaplane, Multi-Engine Seaplane, Glider.
17FO:	Air Transport Pilot, Certified Flight Instructor Instruments/Multi-Engine, Ground Instructor.
18C:	Air Transport Pilot, BE-200/300 Type rating, Certified Flight Instructor Instruments.
18FO:	Commercial, Multi-Engine Land, Certified Flight Instructor Instruments.
19C:	Air Transport Pilot, Commercial/Instruments, Single and Multi-Engine.
19FO:	Commercial Single Engine Land, Multi-Engine Land, Instruments, Flight Instructor Single and Multi-Engine Land.
20C:	Air Transport Pilot, BE-1900 Type Rating, Flight Engineer, Air Transport Pilot.
20FO:	Commercial, Airplane Single and Multi-Engine Land, Glider, Certified Flight Instructor.

Crew #	Total Flight Time Hours	B-200/1900 Flight Hours	B-200/1900 Flight Hrs (Last 6 Months)
11C	5,000 +	2,000	4
11FO	3,200	25	25
12C	7,500	800	65
12FO	1,900	10	10
13C	3,000	800	450
13FO	1,900	350	350
14C	5,000	600	550
14FO	5,000 +	300	300
15C	11,000	600	400
15FO	1,910	21	21
16C	9,000	1,000	2
16FO	5,100	10	10
17C	7,000	800	600
17FO	2,600	50	50
18C	2,600	500	450
18FO	2,500	100	100
19C	3,800	200	200
19FO	1,600	60	60
20C	5,100	200	200
20FO	4,200	120	120

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