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C-141 MICROWAVE LANDING SYSTEM (MLS) FLIGHT TEST REPORT

Project AVN-210-85-5

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EXECUTIVE SUMMARY

The Aviation Standards' Program Plan "Microwave Landing System Flight Inspection and Terminal Instrument Procedures Criteria Development (MLS FI/TERPS)" developed in July 1982 provides the test objectives, data requirements, operational approach scenarios, and technical coordination of flight analysis for both flight inspection and TERPS development. Presently, TERPS criteria (paragraph 936) state that all Instrument Landing System (ILS) facilities will be commissioned with a 3.0° glide slope angle. However, criteria in TERPS do not exist for MLS. Criteria are provided under a separate FAA Order 8260.36, Civil Utilization of Microwave Landing System (MLS). The problem of developing MLS criteria will be solved by developing a data base through the MLS data collection program which will include Conventional Takeoff and Landing (CTOL) aircraft and Vertical Takeoff and Landing (VTOL) aircraft, primarily helicopters. The C-141 test project was one portion of the MLS FI/TERPS test and evaluation program. The objectives of this project were:

a. To evaluate the system parameters of a "full capability" airborne microwave landing system.

b. To acquire a data base to establish standards and criteria from which procedures specialists will determine obstacle clearance requirements and design MLS approach procedures.

AVN-540 (formerly AVN-210) was given the management responsibility for this program and to develop the obstruction clearance and procedure design criteria. The Aeronautical System Division, ASD/ENAC, and the 4950th Test Wing performed the data collection flights in a Lockheed C-141A and provided comprehensive computer processed statistical and graphical data to AVN-540. The data collection flights were conducted at Wallops Flight Center, Virginia.

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LOCKHEED C-141A MICROWAVE LANDING SYSTEM
FLIGHT TEST PROGRAM REPORT

1.0 INTRODUCTION.

In 1986, the Lockheed C-141A Microwave Landing System (MLS) Flight Test was conducted by the Federal Aviation Administration (FAA) and the United States Air Force (USAF) in accordance with the Flight Inspection/United States Standard for Terminal Instrument Procedures (FI/TERPS) program developed in July 1982. FI/TERPS provides the test objectives, data requirements, operational approach scenarios, and technical coordination for both flight inspection and TERPS development. The FAA focal point for this program was APM-430, Cockpit Technology Program Office. The Standards Development Branch, AVN-540, provided the overall management responsibilities for the TERPS activities. The Aeronautical System Division, ASD/ENACT, and the 4950th Test Wing (TW), located at Wright-Patterson Air Force Base, Ohio, provided aircraft and essential personnel to maintain the aircraft and perform data reduction for the flight test. Lear Siegler, Inc., (LSI) developed steering command algorithms and the airborne data acquisition system.

2.0 PURPOSE.

This document provides test procedures and analyses of the 3° (CAT II) and 3.5° (CAT I) intermediate, final, and missed approach segments.

3.0 BACKGROUND.

MLS provides a wide proportional guidance coverage area allowing terminal area navigation concepts to be optimized. The MLS approaches, using area navigation (MLS/RNAV) defined paths, allow for a variety of maneuvers to be performed within the nominal limits of the MLS azimuth (AZ), elevation (EL), and precision distance measuring equipment (DME/P) signal coverage.

The Radio Technical Commission for Aeronautics (RTCA) Special Committee (SC) -151, charged with developing the Minimum Operational Performance Standards (MOPS) for airborne MLS/RNAV equipment, has defined three levels of performance for the systems: Level I, single-segment straight path 3-dimensional (3-D) capability; Level II, multi-segment 3-D paths without positive guidance throughout turns; and Level III, full curved path 3-D capability providing positive turn guidance. These operational levels are described in table 1. The C-141 was equipped with a sophisticated MLS/RNAV computer system capable of performing each of these levels. [1]

4.0 TEST LOCATION.

The simulator test was conducted at National Aeronautics and Space Administration (NASA) Langley Research Center, Hampton, Virginia, and the flight test was done at NASA Wallops Flight Center in Chincoteague, Virginia.

5.0 TEST DESCRIPTION.

5.1 General.

The operational characteristics, test procedures, and profile definitions were first evaluated in the simulator. The performance data acquired from the simulator test were extensively assessed to assist in finalizing the profile definitions, cockpit instrumentation displays, and establishing flight procedures. These results were further examined in the aircraft during the shakedown phase. Once this task was completed, the flight test data collection phase began.

5.2 Simulator Test.

a. Objectives.

(1) To allow LSI to examine the performance of their flight management system using waypoints to generate the test profiles by providing feedback to their bench simulations.

(2) To develop the cockpit instrument displays that were used in the complex path approaches and to develop parameters such as turn radii, turn alert conditions, and elevation path intercept alert.

(3) To verify the algorithm used to drive the flight director (FD) and other flight instruments that would satisfy the MLS/RNAV path guidance requirements.

(4) To establish flight procedures for the subject pilot, safety pilot, and test director/observer.

(5) To eliminate approaches having parameters that were not feasible to fly.

(6) To verify and modify the approach profiles selected for flight testing.

b. Method. The simulation tests were conducted by a team formed of representatives from AVN-540 and the Instrument Flight Center (IFC). The profiles developed by the simulator team were programmed into the L-1011 simulator at the NASA/Langley Research Facility and the instrument displays were programmed to respond in accordance with test requirements. The profiles were flown by IFC test pilots and refined by the test team as required. The candidate profiles were flown by six subject pilots while data were recorded for analysis. A debriefing was held after each simulation session for additional feedback. After evaluation of the simulator test results, the profiles were formed into the final set and submitted to the C-141 project manager for inclusion in the test plan along with profiles generated to fulfill test requirements submitted from other sources.

c. Simulator. The simulator was a general purpose Visual Motion Simulator (VMS) consisting of a two-man cockpit, configured with a mounted

generic jet transport cockpit, on a six-degree-of-freedom synergistic motion base. The control laws adopted in the simulator were from the Lockheed L-1011 model. This simulator was selected because it was a good representative of wide-body Category D aircraft and could be configured to perform guidance functions required for MLS complex profiles.

The cockpit guidance displays consisted of both position information, comprising lateral and vertical path deviations, and command information, presented respectively on a Horizontal Situation Indicator (HSI) and a dual cue FD. A significant addition to the HSI-FD system used for this test was the incorporation of a course arrow on the HSI, which was automatically slewed to the desired course heading by the guidance computer indicating a turn. Also, secondary situation information, consisting of bearing and distance to the azimuth station serving the runway, was displayed independently to aid in pilot orientation during the execution of complex maneuvers. Similar cockpit guidance procedures were used in the flight test.

The MLS software consisted of the parameters needed for airborne derivation of AZ, EL, and distance. The actual simulation model generated "pure" MLS signals and subsequently corrupted them, using the Hazeltine error model, giving the characteristics of signals actually received by an aircraft. The operational scan for AZ and EL was the same as Wallops Flight Center, ± 60° laterally and 0 to 15° vertically. [2]

The visual landing display system (VLDS) supports the VMS by generating a realistic landing scene for the pilots. To simulate instrument meteorological conditions (IMC), an adjustable skyplate was incorporated with predetermined ceiling heights and variable visual conditions. Flight technical error (FTE) and airborne system parameter data were collected, reduced, and analyzed to measure how close the pilots were able to follow the flight path using the guidance algorithm that was implemented for the flight test.

d. Subject Pilots. The subject pilots were pilots from FAA, NASA, USAF, Airline Pilot Association (ALPA), and Air Transport Association (ATA). A post-flight briefing was conducted at the conclusion of each simulator session.

e. Profile Description. The simulator team evaluated 2 to 5° approach angles, various decision heights (DH's), segmented and curved path procedures, offset approaches, and terminal maneuvers. The profiles selected for the flight test are described in section 5.3(h). The selected profiles were flown in the aircraft during the "pretest" profile evaluation phase to confirm their validity in flight prior to the actual data collection phase of the test.

5.3 Flight Test.

a. Objectives.

(1) To evaluate the system parameters of an MLS/RNAV system using inertial inputs to a conventional FD and HSI display.

(2) To provide data and operational procedures for establishing MLS/RNAV standards and criteria for Category D large jet transport aircraft.

(3) To determine the maximum operational elevation angle (MOEA) for the C-141.

(4) To evaluate the guidance presentation to the pilot for flying a computed centerline approach and traversing turns using segmented and curved path definitions.

(5) To establish the acceptability of utilizing the MLS computed path and segmented techniques for procedures in the terminal area including departures and shuttle patterns.

(6) To evaluate various offset azimuth transitions to centerline using elevation guidance during the entire straight-in approach.

(7) To evaluate proposed MLS curved path and segmented instrument approach charting requirements.

(8) To provide feasibility testing regarding airspace requirements, pilot workload, and pilot response to cockpit displays on open and closed loop segment approaches.

b. Method. To simulate instrument flight rules (IFR) weather conditions, a special view limiting device was used during this test identified as the Instrument Meteorological Conditions (IMC) Simulator series 1020, which permitted clouding goggles on the top and side to limit pilot view to the cockpit instruments. At DH, the instructor pilot cleared the goggles for landing or left the goggles clouded for a missed approach. On departure, the instructor pilot clouded the goggles at 200 feet above ground level (AGL). USAF test personnel recorded flight-test parameters and navigation errors using an airborne data acquisition system and logged information pertinent for data reduction. The aircraft position was recorded using a ground-based radar/laser tracking and data acquisition facility located near the runway. Digital tape recordings and plots of these data were provided for postflight analysis. To assist in checking the validity of each data run, the test directors/observers, who were personnel from AVN-540 and IFC, used observer logs to record event marks, equipment problems, instructor and safety pilot comments, pilot comments, weather conditions, and specific instrument display information.

c. Test Aircraft and Systems. Flight tests were conducted using a Lockheed C-141A Starlifter, N61-2779, operated by the 4950th TW at WPAFB, Ohio. The aircraft was powered by four Pratt and Whitney TF33-P-7 turbofan jet engines. The normal landing weight was 257,500 pounds and the maximum landing weight was 323,100 pounds. To maintain approach airspeed in the upper range limit of Category D with speed 141 knots (kts) or more but less than 166 kts, the aircraft was loaded with ballast.

The aircraft was equipped with a fuel savings and advisory system (FSAS). The FSAS is a flight management system for military transport aircraft, which includes fuel savings computer (FSC), control/display unit (CDU), display

interface unit (DIU), and display interface control unit (DICU). In order to collect flight test data, LSI supplied a Class II modification to interface with the FSAS and MLS.

For the flight test, two FSAS systems were used, thereby requiring modifications to the aircraft's FSAS and to allow communication with the FSAS located in the cargo bay.

The second FSAS had a CDU and an FSC modified to be dedicated to MLS functions. This MLS computer, designed by LSI, was called the microwave interface computer (MIC) and interfaced to the MLS, PDME, FSAS, and aircraft FD. The MIC provided the interface to the aircraft instruments that were not a part of the normal USAF FSAS installation. It was located on a Wheaton table in the cargo bay. The MIC had capabilities to drive the attitude direction indicator (ADI), HSI, and bearing distance heading indicator (BDHI) used in the MLS. The aircraft inputs, usually monitored by FSAS, were available to the MIC. The MIC was dedicated to performing MLS functions.

The MLS/RNAV profiles used waypoints in predetermined x, y, and z positions to compute route guidance. These profiles were programmed into the MIC as "canned" or "programmable." The CDU was used to select and activate profiles for each flight test. Once the profiles were activated, the navigational guidance system was switched to the MLS/RNAV mode.

The airborne MLS used the new "cabin class" angle receivers manufactured by Bendix. These receivers were designed to meet the requirements of a 20-mile system with a coverage intercept angle of 70° to the selected AZ. The MLS control display (CD) panel provided the operator interface to the MLS angle receiver and allowed the selection and display of channel, AZ, and EL data. The CDU provided the interface between the Wheaton table in the cargo bay where the MLS control and airborne data acquisition system (DAS) was located. The MICU provided switches and lights for the pilots to arm and monitor the MLS. The PDME provided continuous range information used by the MIC and provided a display of PDME system parameters.

Antenna switching was provided for both angle and range functions to prevent loss of coverage on some profiles. PDME switching was controlled by the same logic that controls the angle receiver antenna switch. The MLS antennas were mounted on top of the cockpit and under the aft portion of the fuselage.

No filtering of the MLS signal was performed beyond that done in the airborne receiver. Receiver outputs were sampled at a 20 hertz (Hz) rate and angle and range data were transformed into the x, y, and z coordinate system used by the MIC.

Deviation and command outputs to the cockpit instruments were filtered using conventional, i.e., lag filters.

An FD algorithm, written by LSI and resident in the navigation computer, was used during MLS operations for the MLS/RNAV approaches. Displays were driven by commands and deviations generated by MIC. Non-MLS modes, such as heading, altitude hold, and go-around, used the existing C-141A flight director.

The deviation sensitivities were the normal MLS AZ and EL outputs for 3° glide slope, until the specified course width was reached, at which point linear deviations were used. For the Wallops MLS, AZ sensitivity was ± 1.85°, and for a 3° glide slope, EL sensitivity was ± 0.75° full scale. [3]

d. Ground System. The MLS ground system installed on Runway 22 was a Bendix (BN) MLS consisting of three functional elements: (a) EL; (b) AZ; and (c) PDME. The system radiates a time reference scanning beam (TRSB) format consisting of a preamble and a TO-FRO scanning beam. The operating scan was ± 60° laterally and 0 to 15° vertically.

e. Ground Tracking System. The tracking facility consisted of a laser tracking system (LTS) collocated with the FPS-16 radar and sharing a common mount. The laser and radar were capable of tracking the same target; each system developing its own range information. The angle data were derived from sensors on the mount. Each system developed angle error signals to control rotation of the mount. The radar operator could switch mount rotation to either system or allow the system to automatically switch control with the laser signal being preferred. Range data from both systems as well as angle data were recorded. Radar was used for long-range tracking down to 3 NM from GPI, where laser tracking began. Tracking of the aircraft was done using a laser retro-reflector mounted on the jack pad on the nose of the C-141A.

f. Airborne Data Acquisition System (ADAS). The ADAS developed by LSI operated in real time to acquire and record data pertinent to the given test conditions. The MIC in the MLS recorder mode enabled the panel operator, through the use of the CDU, to input special identifiers for each mission. All instrumentation data were recorded on cassette tape using a cassette data recorder. Data were recorded at 5 Hz and time tagged using a time code generator that was synchronized with the tracker time for merge processing. A list of selected parameters and definitions for this project is in tables 3 and 3A. During post tests, the tapes were scanned using the onboard recorder and MIC that provided a dependable quick-look. Afterwards, the instrumentation tapes were sent to the 4950th TW/FFTA, WPAFB, for data reduction.

g. Subject Pilots. The 12 subject pilots participating in this test were 2 4950th TW pilots and 10 airline pilots who were current C-141 rated through reserve duty. The selection of subject pilots was also based on diverse instrument experience and availability. Each pilot completed and returned a pilot experience form; the results are presented in table 1. The table depicts a range of flying time from 2,490 to 11,800 hours with a mean of 6882.5 hours. When the pilots arrived for the test, they were given a preflight briefing and were provided a cockpit orientation. Practice MLS approaches were also conducted prior to data collection flights. A post-flight briefing was conducted upon conclusion of the test flights. Each subject pilot was issued pilot questionnaires to provide comments and rate the overall maneuverability of the profiles, approach plate documentations, and cockpit display information.

h. Profile Description.

The SC-151 committee established operational capability levels with minimum equipment requirements to fly MLS/RNAV approaches. The FAA and USAF incorporated these procedures for designing profile definitions and path construction.

Prior to the flight tests, an investigation was conducted to eliminate, modify, and verify approach and departure profiles. The FAA and USAF/IFC project team evaluated EL angles ranging from 2 to 5° during the simulation and pre-flight test phases. The EL angles selected and subsequently flown were 3° Cat II, DH providing 100-foot HAT, straight-in and complex approaches and the 3.5° Cat I, DH providing 200-foot HAT, straight-in approach. (The MOEA was not tested because FAA policy limits the designed approach angle of a procedure to that angle requiring a mean descent rate of not more than 900 fpm for the aircraft category.) The offset approaches were flown with a 3° glidepath to varying DH values.

All profiles were defined with x, y, and z waypoints. The approach airspeed was between 160-165 kts. The intermediate segment was flown using computed vertical guidance and barometric altimetry. During the latter portion of the flight test, vertical guidance was flown using barometric altimetry only. This change reflected the consensus from the SC-151 committee and air traffic that vertical separation of aircraft in a terminal environment area will be done using barometric altimetry unless otherwise specified.

(1) Straight-In. The 3° (CAT II) and 3.5° (CAT I) EL angles were flown similar to the conventional ILS straight-in approach using MLS raw data inputs to the HSI. The procedure called for a 45° intercept to the extended runway centerline (ERCL) using the initial waypoint as a "locator" of the profile. See figures 1 and 2.

(2) Offsets. Level I generated a computed single straight line path that provided both lateral and vertical guidance for the entire approach. Profiles flown with this capability were the parallel and angle offsets.

(a) Parallel Offset Approach. This profile route definition was compatible to a straight-in approach procedure. Using MLS computer generated course guidance, the approach was flown to a phantom runway located 3,000 feet from and parallel to the MLS instrumented runway. The DH was 350 feet. See figure 9.

(b) Offset Azimuth Approach. This profile was designed to simulate a straight-in approach to an offset azimuth where the final approach course intercepts the ERCL. During the pre-test phases, an evaluation was made to determine the maximum offset angle and the least amount of distance between the offset angle and runway threshold for allowing the pilot to safely land. The offset angles evaluated were 5, 8, 10, and 12° and the distances from threshold and DH values were 3,000 feet at DH providing 250-foot HAT and 4,000 feet at DH providing 350-foot HAT. The profiles selected and flown were 5, 8, and 10° offset angles with a 250-foot DH at a distance of 3,000 feet from threshold. See figures 3, 4, 5, and 6.

(3) Segmented Approaches. Level II generates a series of waypoints connected with straight-line segments. The segmented procedure, not having the capability to produce track guidance in the turn, resulted in discontinuity among flight paths when transitioning from segment to segment. Course deviations and guidance were only relative to the straight segments. These profiles included a fixed turn point (TP) or turn anticipation point and rollout point (RP), both having equivalent distances from the segment intersection waypoint as the radius of turn. To inform the subject pilots of a course change, the turn anticipation light flashed 10 seconds prior to TP. Once the aircraft reached the TP, the CDI slewed to the next segment where course guidance was then referenced to that segment. Once the flightpath angle changed, indicating the aircraft was in a turn, LSI applied an algorithm for generating steering control laws to the FD that assisted the subject pilot in capturing the heading of the next segment. The turn rate varied on the capture because its computation was based on groundspeed and wind velocity at the start of the turn. While in the turn, the turn anticipation light remained steady until the aircraft reached the RP where the light went out indicating the aircraft had intercepted the next segment. An idealized arc was constructed adjoining the connecting segments at the TP and RP to measure the flightpath dispersion about the arc for evaluating the airspace required for segmented or open-loop maneuvers.

The subject pilots were provided additional guidance information. Prior to capturing the glidepath intercept point, the vertical deviation indicator (VDI) went positive full-scale when the aircraft was positioned 500 feet below the extended glidepath. When the VDI was centered, the aircraft had reached glidepath intercept point. This provided familiar indications similar to those encountered during a normal glide slope intercept on ILS.

The segmented profile flown in the test was a three-segment 180° approach with a non-centerline segment (NCLS) between the inbound segment and the centerline approach segment. This profile incorporated a descending turn where the precision final approach fix (PFAF) was located prior to the final turn to centerline. See figure 7.

(4) Curved Path Profile. Level III constructs a ground track path consisting of straight line segment connected to a curved segment. The straight segment prior to the curved segment was tangent to the curve at the start of the curved segment, which was located at the TP. The straight line segment at the end of the curved segment was tangent to the curve at the RP. The magnitude of the curved segment compensated for speed and bank angle for Category D operations. Lateral and vertical course deviation and guidance were provided for the straight and curved segments. The curved path flight procedures were the same as the segmented procedures used for informing the subject pilots of a pending course change and capturing glidepath. All profiles were designed with the PFAF prior to the first turn to evaluate the subject pilots' ability to maneuver during a descending turn. Below is a description of the profiles:

(a) CP902: 90° turn to intercept to the FCLS. Figure 15.

(b) CP131: 120° turn to an NCLS, then a 30° turn to FCLS. The NCLS length was 0.9 NM. Figure 16.

(c) CPS01: Parallel sidestep offset having two 90° opposing turns. The NCLS length was 0.9 NM. Figure 14.

(d) Same profile as described in "3" but in a curved path mode. Figure 8.

(5) Shuttle Pattern. There were two shuttle patterns designed for this test. Two AZ radials, 0 and 20°, formed the first shuttle pattern. The procedure was accomplished after a departure using the HSI. The segment length between the DME fixes was 3.5 NM with the holding airspeed at 230 kts in a no-wind condition. The inside turn bank angle was 20° and the outside turn bank angle was 16° in a no-wind condition. See figure 12. This shuttle pattern was flown only in the pre-test phase.

The second shuttle pattern was a segment version of a rectangular RNAV shuttle pattern with waypoints based on a turn radius for 180 kt airspeed at a 1.6 second turn rate. The distance of the NCLS was 3.5 NM. The inbound/outbound segments had a distance of 6.5 NM. Guidance, based on Level II system, was provided on straight path segments having a turn anticipation light illuminating 10 seconds prior to the TP. This profile maintained an altitude of 5,000 feet to insure that airspace required for the shuttle pattern was within MLS coverage. See figure 13.

(6) Departure Profiles. There were two departure procedures flown during this test. The first procedure, illustrated in figure 10, was to fly outbound on a heading of 41° on the computed course to intercept the 20° offset radial, then climb to 5,000 feet or as assigned. This procedure was only flown in the "pre-test" phase of the test. The second departure procedure was 180° course change using MLS/RNAV course guidance. The method used was to depart runway heading of 41° and fly outbound on centerline AZ to a fixed DME on the computed curved path course continuing to climb through a 180° turn to 5,000 feet or as assigned. See figure 11.

(7) Missed Approach Profiles. By test design, approximately three-fourths of the approaches flown ended in a missed approach. When the instructor pilot informed the pilot, by leaving the goggles clouded and announcing that the runway was not in sight, to make a go-around, the pilot executed a missed approach. The back AZ signal, PDME, or the HSI were not used to provide guidance during missed approach. The task was to maintain a heading and climb to an altitude of 2,000 feet Mean Sea Level (MSL) before executing a turn. (The missed approach procedure is found on all approach profiles.)

6.0 DATA ANALYSES.

This report provides statistical analyses for the 3° (CAT II) and 3.5° (CAT I) intermediate, final, and missed approach segments. Terminal area maneuvering, complex approaches, and aircraft performance will be analyzed in a separate report. All probability lines are referenced to the center of the aircraft on

ERCL. Adjustments for aircraft fuselage and wingspan will be made for obstruction collision consideration.

6.1 Pilot Acceptability Ratings. During the preflight briefing, pilots were advised that they would be requested to rate the overall workload and IFR characteristics of each procedure. Each pilot was briefed on the rating system and advised of the beginning and ending points for each segment of flight. The pilot questionnaire ratings and comments are in Report No. FAA-AVN-500-39, C-141 Microwave Landing System (MLS) Pilot Questionnaire Summary, Project AVN-210-85-5.

a. Departure. The ratings indicated that the pilots experienced no difficulty maintaining the specified course. Eight pilots encountered minimal problems relating to position orientation. Six pilots responded to "sensitivity of the AZ course" as being the most difficult aspect in the departure procedure. Pilots also commented that the turns were too steep.

b. Shuttle Pattern. According to pilots' ratings, the inbound/outbound leg distances (6.5 NM) and the distance between the inbound/outbound courses (3.5 NM) were adequate. Pilot comments also reflect a "higher than normal" cockpit workload.

c. Offset Angle. The pilots ratings indicated that the workload involved in this approach increased when the offset angle was greater than 5°. As the angle increased, turning onto centerline became more difficult without causing an excessive overshoot which could attribute to an aborted landing regardless of the suggested distances between runway threshold and point of interception. Pilots indicated that the HSI and RMI provided the best guidance information and position orientation.

No improvement to the basic construction of the offset procedure was indicated, since the pilots believed that the intermediate and straight segment lengths allowed enough time to reconfigure the aircraft prior to landing.

When comparing, the pilots found the MLS/RNAV offset approach to an ILS offset approach in terms of tracking, workload, and airspeed control factors were similar.

d. Straight-In Approaches.

(1) 3° (CAT II): The pilots indicated that the workload involved in this MLS/RNAV approach was minimal. They rated the HSI higher than the RMI or FD for providing guidance information. They expressed the need for more "lead time" prior to intercepting the ERCL. Overall, the pilots stated that this procedure was very similar to flying a 3° ILS straight-in approach.

(2) 3.5° (CAT I): The subject pilots commented that the overall workload involved in this straight-in approach was acceptable provided the airspeed be reduced to maintain an adequate descent rate. A suggestion of an increase in DH should accommodate the lower power setting. Additional comments and observations suggested that for Category D operations, complex

approaches developed with EL angles greater than 3° would cause a substantial increase in pilot workload, especially for profiles having descending turns.

e. Complex Approaches.

The subject pilots commented that segmented approaches were easier to fly than the computed curved path approach. The segmented approach required minimal workload since the pilot had no prescribed ground track to maintain in the turns. The curved path approach had a more consistent ground track where course guidance was provided throughout the entire approach. This increased the pilot workload because the bank steering bars were more demanding in the turns.

The pilots commented that the overall workload for these approaches was satisfactory. Although a "high degree of concentration" was needed to fly the approach, they believe that with experience, pilots could learn how to follow the flight instrumentation presentation especially prior to any course change.

6.2 Intermediate Segment. This segment joins the final approach segment at the glidepath intercept point. During this segment as in an ILS, the pilot establishes the aircraft on the AZ course in preparation for a descent to land or to execute a missed approach. The start and stop points and segment length, where the distance is measured from Ground Point Intercept (GPI), are listed in table 2.

The intermediate segment length for the various complex profiles ranged from 5 to 9 NM. For Category D operations, flying an airspeed of 166 kts, 16,810 ft/min, allows for a segment length of 2.77 NM before the PFAF for the recommended 60 seconds time and a segment length of 4.16 NM for the recommended 90 seconds time.

6.3 Final Approach Segment. This segment commences at the GSI and terminates at DH. Table 3 reflects the start of the segment (GSI) and the segment length from the GSI to DH.

a. Lateral. The accepted cumulative risk for an approach has a probability level of 10^{-7}, or 1 in 10 million. Considering the small sample size of the test, a normal distribution was used to initially screen the data. In a normal distribution, 10^{-7} corresponds to 5.3267 standard deviations (SD) from the mean. For the obstacle clearance screening, ± 6.0 SD were utilized having a probability level of 10^{-9} for the normal distributions to achieve approximately 10^{-7} cumulative risk for the approach. (At a later date, these data will be combined with other data to develop appropriate probability density functions.)

The AZ full-scale angular sensitivity was ± 1.85°. Figures 27 and 28 depict statistical plots for the 3.0° CAT II and 3.5° CAT I approach angles showing the ± 6.0 SD screening contour lines exceeding the AZ full-scale limiting lines during portions of the final approach segment. The composite plots (the overlying of single similar profiles) are shown in figures 17 through 19. The comparison of the 3.0° and 3.5° approach angles' SD's is illustrated in figure 31.

b. Vertical. The full-scale vertical deviation indicator (VDI) was set at ± 0.75 for 3.0° CAT II EL angle and ± 0.88° for 3.5° CAT I EL angle. This corresponds to the agreed standard of setting full-scale vertical sensitivity to EL/4. The 3.0° CAT II and 3.5° CAT I ± 6.0 SD screening contour lines exceeded full scale deflection. See figures 29 and 30. The composite plots are shown in figures 20 through 22. The comparison of the 3.0 and 3.5° approach angles SD's is illustrated in figure 32.

6.4 Missed Approach Segment. Missed approach maneuvers were executed at a predetermined distance from glidepath intercept point (distance based on EL angle and DH) for all profiles. At DH, the instructor pilot informed the pilot to make a missed approach or land. When a missed approach was executed, the HSI was no longer used to monitor lateral or vertical deviation. The missed approaches were conducted outside the MLS coverage area under dead reckoning (DR). The task was to maintain a heading and climb to an altitude that was safe to make the go-around.

a. Lateral. The ± 6.0 SD screening contour lines were chosen for screening lateral dispersion in the missed approach. The ± 6.0 SD screening contour lines did not exceed the present ILS CAT I and II missed approach area. See figures 33 and 34.

b. Vertical. An assumption of normality for the initial screening represents a situation where ± 6.0 SD below the mean describes a contour beneath the ground. The ± 2.0 SD screening contour lines penetrated the existing TERPS CAT I missed approach surface (40:1 slope) criteria and the AC 120-29 CAT II missed approach surface. See figures 35 and 36.

7.0 DECISION HEIGHT ANALYSES.

One of the objectives of the test was to evaluate the 200-foot DH for this type of aircraft flying 3.5° EL angle. Another objective was to evaluate the effect of CAT II 100-foot DH minimums using this type of aircraft.

Two important parameters of a missed approach are: (1) how close to the ground (low point) the aircraft gets while executing a missed approach; and (2) how much distance is required to execute a missed approach once the decision to execute one is made (height loss).

7.1 Low Point. The low point is the lowest altitude reached during the execution of a missed approach. Table 4 lists mean low point values and where they occurred. The missed approach profile flown at an EL angle of 3° (CAT II) had a mean low point of 61.68 with a SD of 16.23 feet. The ground level was 3.8 SD from the mean low.

The missed approach profile flown at an EL angle of 3.5° (CAT I) had a mean low point of 148.74 with a SD of 27.43 feet. The ground level was 5.42 SD from the mean low.

7.2 Height Loss. Height loss is the vertical distance the aircraft travels downward after the decision to execute a go-around is made. Height loss = DH - low z.

The mean height loss value for 3° CAT II and 3.5° CAT I EL were 38.32 and 51.26 feet, respectively.

8.0 CONCLUSIONS.

The following conclusions were made as a result of an analysis of pilot ratings and aircraft tracking data.

a. Based on AC 120-29 criteria for ILS CAT II obstacle clearance and approach surface, the results from the test are listed below.

(1) The 3° approach and missed approach lateral dispersion remained inside the ILS CAT II trapezoids.

(2) The ILS CAT II final approach surface demonstrated inadequate obstacle clearance due to a penetration of the 29.5:1 slope.

(3) The ± 2.0 SD vertical screening contour lines did penetrate the missed approach 40:1 slope.

b. The present trapezoids for ILS CAT I approaches contained the lateral dispersion contours for 3.5° EL angle flown under the test conditions.

c. The present ILS CAT I TERPS (34:1) surfaces provide adequate obstacle clearance for the 3.5° EL angle data.

d. The 3.5° lateral dispersions did not penetrate the present TERPS ILS CAT I missed approach area.

e. The 3.5° vertical ± 2.0 SD screening contour lines penetrated the existing TERPS CAT I missed approach surface.

f. The 3° CAT II and the 3.5° ± 6.0 SD screening contour lines remained inside the AZ limit.

g. The 3° CAT II and the 3.5° ± 6.0 SD screening contour lines exceeded the vertical full-scale deflection.

h. Pilots rated the MLS/RNAV departure procedure as adequate.

i. Pilots rated the shuttle pattern more difficult to maneuver than the conventional holding pattern because of the increased cockpit workload.

j. Based on pilot opinion, 5° offset angle should be the maximum used when developing CAT D angle offset procedures.

k. The pilots indicated that the 45° intercept to the ERCL was too narrow for Category D operations.

l. Based on pilot opinion, the 3.5° straight-in approach would be acceptable provided the airspeed be comparable to maintaining an adequate descent rate.

m. The general consensus from pilot comments was that segmented approaches were easier to fly than the computed curved path approaches.

n. The pilots indicated that the sensitiveness of the bank steering bars influenced the excessive roll rates incurred during each approach.

o. The MOEA was not tested because FAA policy limits the designed approach angle of a procedure to that angle requiring a mean descent rate of not more than 900 fpm for the aircraft category.

p. The pilots indicated that the approach plates used in this test did not have enough information in some cases and too much in other cases.

GLOSSARY OF TERMS

Definitions shown in this glossary apply to the Joint FAA/USAF C-141A FI/TERPS Tests of the Time Reference Scanning Beam, Microwave Landing System. The special terms and abbreviations are listed to explain their meaning and application to procedures and criteria used in this test program and are not necessarily accepted terminology.

ADAS - Airborne Data Acquisition System.

ATD - Along Track Distance. The distance to go to Ground Point of Intercept (GPI) as measured along the datum flight path.

AZ - MLS Azimuth Beam. Directional Computer Input.

Closed Loop - A turning technique in which the navigation system provides, to the guidance system, continuous feedback, throughout the turn of the aircraft position relative to a specified arc along which the turn is to be conducted.

CP - Curved Path. An MLS complex maneuver approach utilizing a curved segment joined to straight segments.

DH - Decision Height. The decision height value, measured in feet above MSL.

DP - Descent Point. Glidepath intercept point.

EL - MLS Elevation Beam. Glidepath computer point.

ERCL - Extended Runway Centerline.

FAS - Final Approach Segment. The segment from the final configuration point to DH.

FCP - Final Configuration Point. (gear down, landing flaps)

FI/TERPS - Flight Inspection/Terminal Instrument Approach Procedures Standards

FLIGHT - A flight consists of several runs during the time period from initial takeoff to the termination landing.

FMS - Flight Management System.

FSAS - Fuel Savings and Advisory System.

FTE - Flight Technical Error. The difference between the center of the display depicting the MLS displayed course line and the deviation indicator position. This difference is displayed by the cockpit instrument providing MLS course guidance to the pilot. FTE measures how closely the pilot follows the MLS guidance provided, and is exclusive of any other system.

GPI - Ground Point of Intercept. A point in the vertical plane on the runway centerline at which the straight line extension of the elevation angle intercepts an imaginary plane drawn horizontally at the runway threshold elevation.

HAT - Height Above Touchdown.

Initial Approach Segment - The segment from the initial approach fix (IAF) to the intermediate approach fix or point. In the initial segment, the aircraft has transitioned to an MLS approach either from the en route phase of flight by radar vector or from other terminal area facilities (VOR, TACAN), and is maneuvering to enter the intermediate segment. There can be multiple initial segments.

Intermediate Approach Segment - This segment begins at the intermediate fix (IF) or point and ends at the final approach fix (FAF). It is this segment where aircraft configuration, speed, and positioning adjustments are made.

IP - Intersection Point. Point at which the offset course intersects the centerline.

LTS - Laser Tracking System. Primary tracking facility at Wallops.

MCLS - Minimum Centerline Segment. The minimum operational straight line segment length from DH outward to the rollout point of the final turn along the extended runway centerline that may be used in designing a segmented or curve path MLS approach.

MLS DEVIATION - The difference between aircraft position as derived from the MLS A and B angle data and DME/P and the position recorded from the ground tracker.

NCLS - Non-Centerline Segment. The minimum operational straight line segment length between turns that may be used in designing a segmented or curved path MLS approach.

NSE - Navigational System Error. This is the value difference between TSE and FTE.

OCLS - Optimum Centerline Segment. The most practical operational straight line segment length from DH outward to the rollout point of the final turn along the extended runway centerline to be used in the design of a segmented or curved path MLS approach.

Open Loop - A turning technique in which no feedback is provided to the guidance system about the aircraft position relative to any specific turn point.

PDME - The Precision DME distance (slant) from the GPI to the aircraft, in nautical miles.

RNAV - Area navigation. A method of navigation that permits aircraft operations on any desired course within the coverage of station referenced navigation signals or within the limits of self-contained system capability without having to overfly ground-based navigation facilities. RNAV, which provides navigation and guidance capabilities in the horizontal plane only, is two-dimensional (2-D), while RNAV, which also incorporates vertical guidance, is three-dimensional (3-D).

RP - Rollout Point. The completion point of a turn with positive course guidance.

RUN - Flying one complete profile for a data record.

SP - Segmented Path. Any MLS approach utilizing one or more straight segments with positive course guidance.

TERPS - U.S. Standard for Terminal Instrument Procedures.

TP - Turn Point. Points within the intermediate and/or final segment where transitions occur in the horizontal plane (azimuth).

TSE - Total System Error. The deviation of actual aircraft position from a computed flight path reference (FPR).

WP - Waypoint. A predetermined geographical position used for route definition and is the basis for construction of RNAV path.

TABLE 1 - PILOT BACKGROUND

Pilot	C-141 Hours	Total Hours
1	4000	8400
2	4200	9200
3	2300	2500
4	3200	9400
5	3700	7700
6	5600	6750
7	4300	7100
8	5800	11800
9	3700	6100
10	3700	7550
11	2300	2490
12	400	3600
AVERAGE	3600	6882.50

INTERMEDIATE SEGMENT

Profile	START Feet From GPI	STOP Feet From GPI	Length of Segment Feet	NM
Straight-In				
3.0° (CAT II	64576	34196	30380	5.00
3.5°	64576	34196	30380	5.00
Angle Offset				
5.0°	64344	34080	30264	4.98
8.0°	63983	33899	30084	4.95
10.0°	63653	33734	29919	4.92
Parallel Offset				
3000 feet	64576	34196	30380	5.00
Segment				
SGF230	123407	68838	54569	8.98
Curved Path				
CP181	97604	75692	21912	3.61
CP902	68349	44045	24304	4.00
CP131	95120	70310	24812	4.08
CPS01	81243	63015	18228	3.00
CPF230	123407	68838	54569	8.98

TABLE 2

ON CENTERLINE SEGMENT

Profile	Length of Segment Feet	NM
Straight-In		
3.0° (CAT II)	32288	5.31
3.5°	30926	5.09
Angle Offset 3.0°		
5.0°	29313	4.82
8.0°	29139	4.80
10.0°	28979	4.77
Parallel Offset 3.0°		
3000 feet	27518	4.53
Segment 3.0°		
SCF230	48608	8.00
Curved Path 3.0°		
CP181	38483	6.33
CP902	23174	3.81
CP131	34901	5.74
CPS01	23174	3.81
CPF230	48608	8.00

TABLE 3

C-141 MLS PROJECT
LOW POINT STATISTICS

Profile	Mean	Standard Deviation	Skewness	Kurtosis	Maximum	Minimum
Straight-In						
3.0° CAT II						
Low Z (Ft)	61.68	16.23	- 0.60	4.00	89.90	10.10
Ht Loss (Ft)	38.32	16.23	0.60	4.00	89.90	10.10
Ft from GPI	674.97	467.07	- 0.07	3.71	1647.50	- 659.80
Crosstrack (Ft)	- 3.68	28.47	- 0.01	2.21	44.70	- 59.00
3.5° CAT I						
Low Z (Ft)	148.74	27.43	- 0.41	1.89	182.80	100.90
Ht Loss (Ft)	51.26	27.43	0.41	1.89	99.10	17.20
Ft from GPI	1898.36	538.85	- 0.12	1.94	2673.70	1007.40
Crosstrack (Ft)	- 10.58	29.24	0.33	1.91	42.30	- 44.80
Angle Offsets 250 Feet DH						
5.0°						
Low Z (Ft)	193.97	18.37	0.14	2.08	227.10	164.80
Ht Loss (Ft)	56.03	18.37	- 0.14	2.08	85.20	22.90
Ft from GPI	3353.83	430.32	- 0.30	2.31	3960.60	2482.20
Crosstrack (Ft)	- 8.07	26.17	- 0.53	2.77	33.70	- 67.40
8.0°						
Low Z (Ft)	207.30	24.44	- 0.11	1.66	237.00	171.00
Ht Loss (Ft)	42.70	24.44	0.11	1.66	79.00	13.00
Ft from GPI	3537.78	395.35	- 0.75	2.78	3947.10	2797.90
Crosstrack (Ft)	- 0.70	22.96	0.60	2.09	40.20	- 28.10
10.0°						
Low Z (Ft)	206.95	20.29	0.03	1.72	235.30	182.80
Ht Loss (Ft)	43.05	20.29	- 0.03	1.72	67.20	14.70
Ft from GPI	3441.52	343.28	0.13	1.38	3844.80	3079.40
Crosstrack (Ft)	8.20	45.80	0.76	2.56	- 37.80	87.50

TABLE 4

C-141 MLS PROJECT
LOW POINT STATISTICS

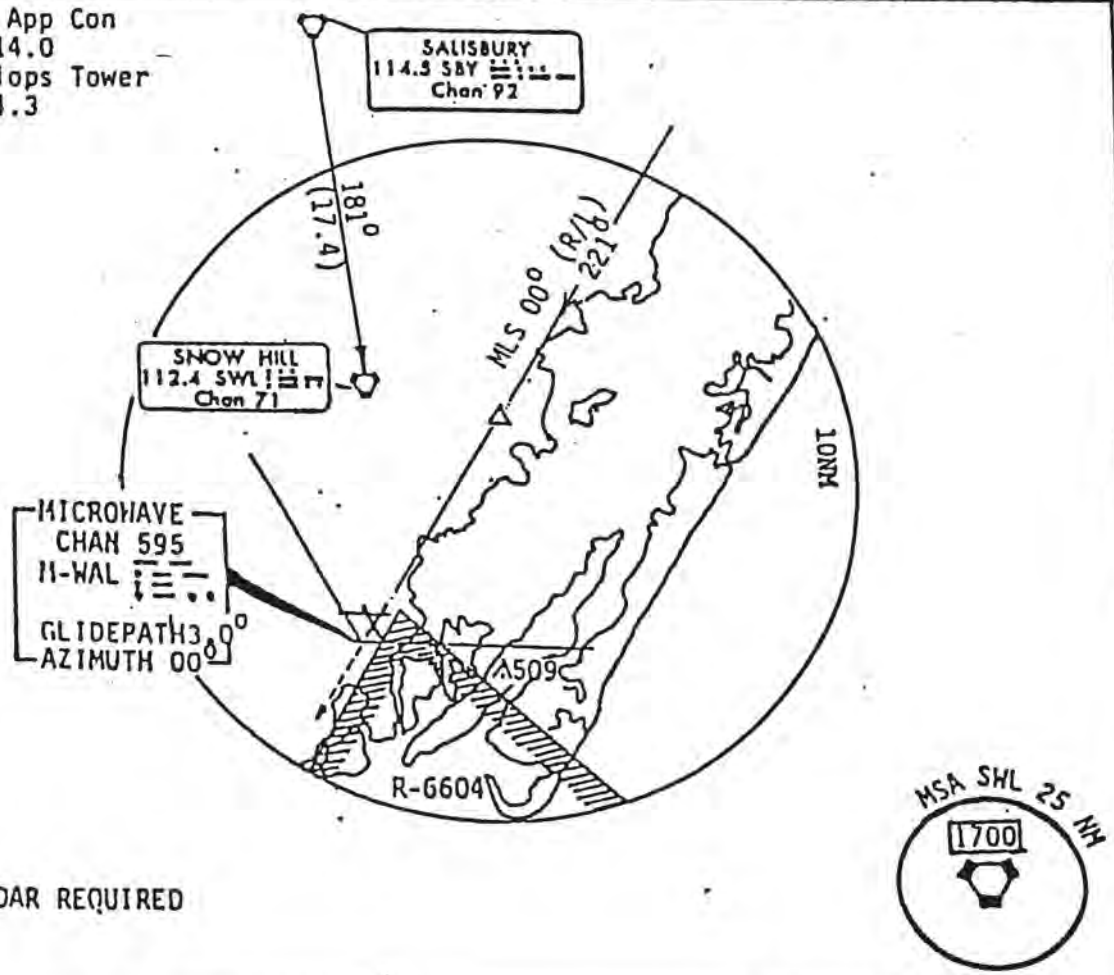
Profile	Mean	Standard Deviation	Skewness	Kurtosis	Maximum	Minimum
3000 Ft Parallel Offset						
Low Z (Ft)	287.77	23.69	0.27	2.40	339.10	243.70
Ht Loss (Ft)	62.23	23.69	- 0.27	2.40	106.30	10.90
Ft from GPI	5159.06	439.09	0.44	2.33	6079.40	4377.00
Crosstrack (Ft)	- 18.99	35.68	2.11	10.16	- 70.90	143.60
Segment 3.0° CAT II						
Low Z (Ft)	58.64	12.70	0.47	2.77	84.40	38.60
Ht Loss (Ft)	41.36	12.70	- 0.47	2.77	61.40	15.60
Ft from GPI	662.03	369.75	0.55	3.34	1500.30	72.60
Crosstrack (Ft)	- 7.72	26.49	- 0.12	2.23	42.60	- 54.40
Curved Path 3.0° CAT II						
CPF230						
Low Z (Ft)	49.55	13.90	0.41	3.63	85.60	24.40
Ht Loss (Ft)	50.45	13.90	- 0.41	3.63	75.60	14.40
Ft from GPI	551.89	381.83	0.56	3.76	1600.60	- 50.10
Crosstrack (Ft)	- 7.36	23.27	- 0.50	2.59	28.30	- 63.30
CP902						
Low Z (Ft)	54.29	14.69	- 0.68	3.79	83.70	16.90
Ht Loss (Ft)	45.71	14.69	0.68	3.79	83.10	16.30
Ft from GPI	491.81	506.21	- 1.02	4.45	1393.00	-1003.70
Crosstrack (Ft)	- 8.55	25.69	- 0.23	3.87	53.60	- 68.50
CP131						
Low Z (Ft)	55.49	18.53	- 0.46	3.45	85.40	12.40
Ht Loss (Ft)	44.51	18.53	- 0.46	3.45	87.60	14.60
Ft from GPI	609.42	562.96	- 1.32	6.55	1669.20	-1269.90
Crosstrack (Ft)	- 2.03	27.43	1.01	5.57	- 57.50	84.50
CPS01						
Low Z (Ft)	54.50	10.10	0.09	2.42	73.90	34.50
Ht Loss (Ft)	45.50	10.10	- 0.09	2.42	65.50	26.10
Ft from GPI	667.05	254.03	- 0.06	2.23	1091.20	173.90
Crosstrack (Ft)	- 8.90	29.25	0.85	3.77	71.70	- 51.10

TABLE 4 (Continued)

CHINCOTEAGUE ISLAND/NASA WALLOPS FLIGHT CENTER,(WAL)

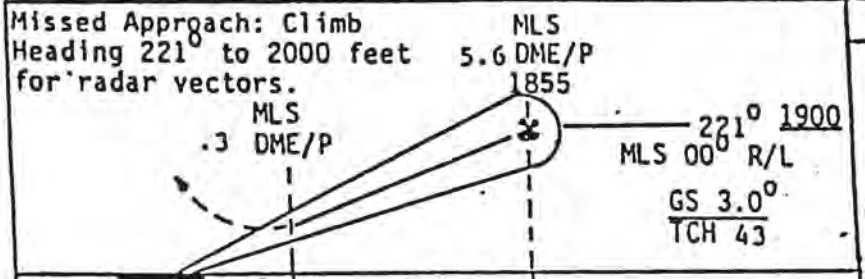
MLS RWY 22 (CAT II) CHINCOTEAGUE ISLAND,VIRGINIA

Patuxent App Con
127.95 314.0
NASA Wallops Tower
126.5 394.3



RADAR REQUIRED

Missed Approach: Climb Heading 221° to 2000 feet for radar vectors.



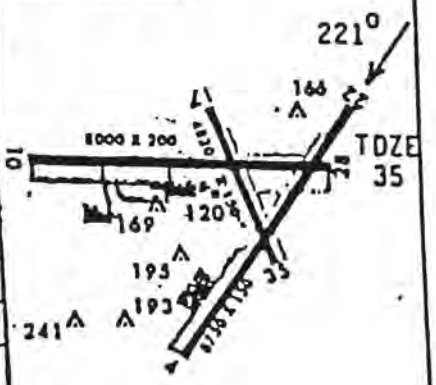
CATEGORY	A	B	C	D	E
S-MLS-22	135/24	100	RA100		

MLS TEST VFR ONLY

Category II MLS Special Aircrew and Aircraft Certification Required

STAA30

ELEV. 41



HIRL Rwys 4-22 and 10-28.
REIL Rwys 4 and 22.

MLS RWY 22 (CAT II) 37°56'N-75°28'W CHINCOTEAGUE ISLAND,VIRGINIA

CHINCOTEAGUE ISLAND/NASA WALLOPS FLIGHT CENTER (WAL)

Figure 1

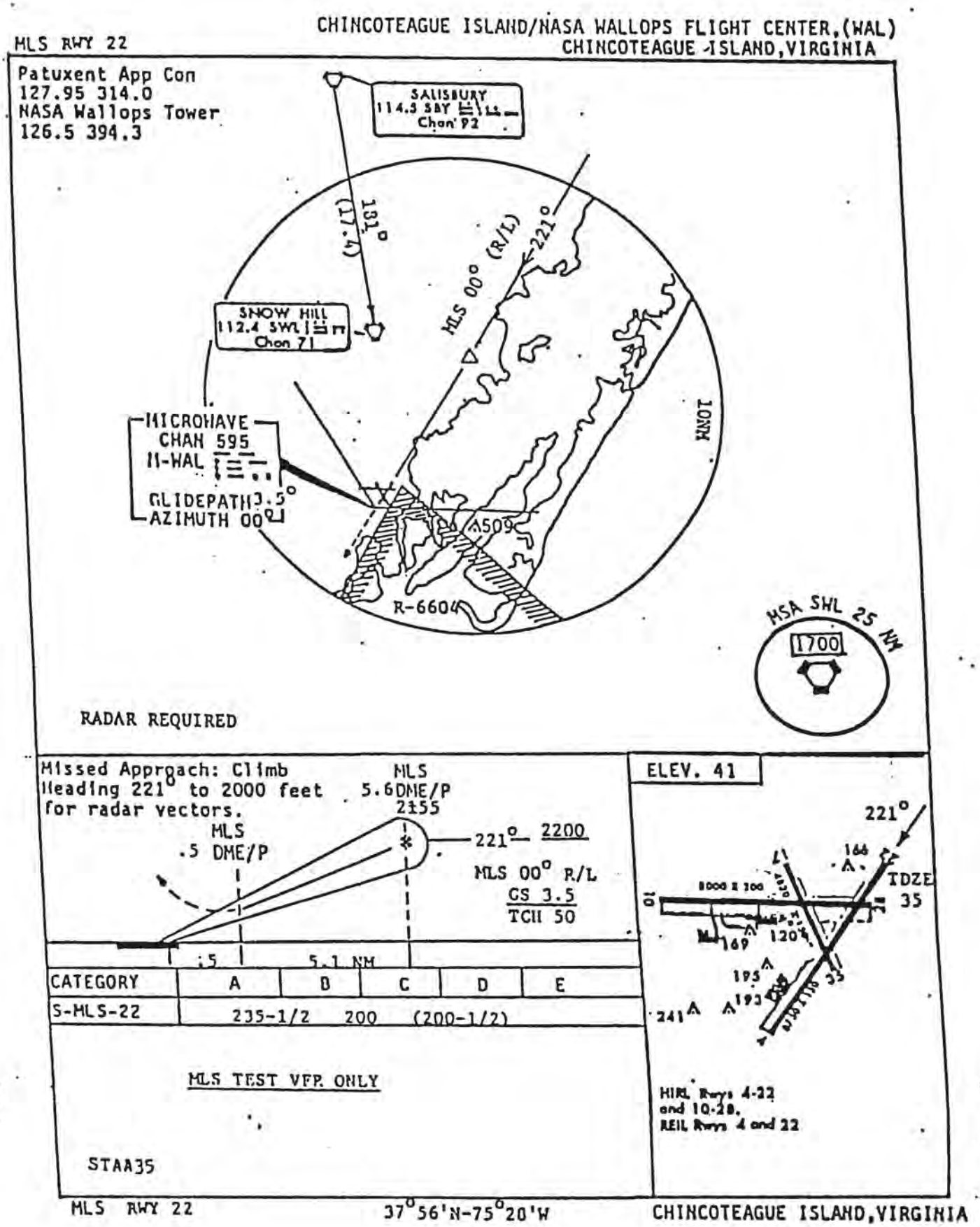

CHINCOTEAGUE ISLAND/NASA WALLOPS FLIGHT CENTER,(WAL)
CHINCOTEAGUE ISLAND,VIRGINIA
MLS RWY 22
Patuxent App Con
127.95 314.0
NASA Wallops Tower
126.5 394.3
SALISBURY
114.5 SBY
Chan 92
181°
(17.4)
MLS 00° (R/L)
221°
SNOW HILL
112.4 SWL
Chan 71
MICROWAVE
CHAN 595
M-WAL
GLIDEPATH 3.5°
AZIMUTH 00°
509
R-6604
10NM
MSA SWL 25 NM
1700
RADAR REQUIRED
Missed Approach: Climb
Heading 221° to 2000 feet
for radar vectors.
MLS
5.6DME/P
2±55
MLS
.5 DME/P
221° 2200
MLS 00° R/L
GS 3.5
TCH 50
.5
5.1 NM
CATEGORY
A
B
C
D
E
S-MLS-22
235-1/2 200 (200-1/2)
MLS TEST VFR ONLY
STAA35
ELEV. 41
221°
166
TDZE
35
169
120
195
193
241
HIRL Rwys 4-22
and 10-28.
REIL Rwys 4 and 22
MLS RWY 22
37°56'N-75°20'W
CHINCOTEAGUE ISLAND,VIRGINIA

Figure 2

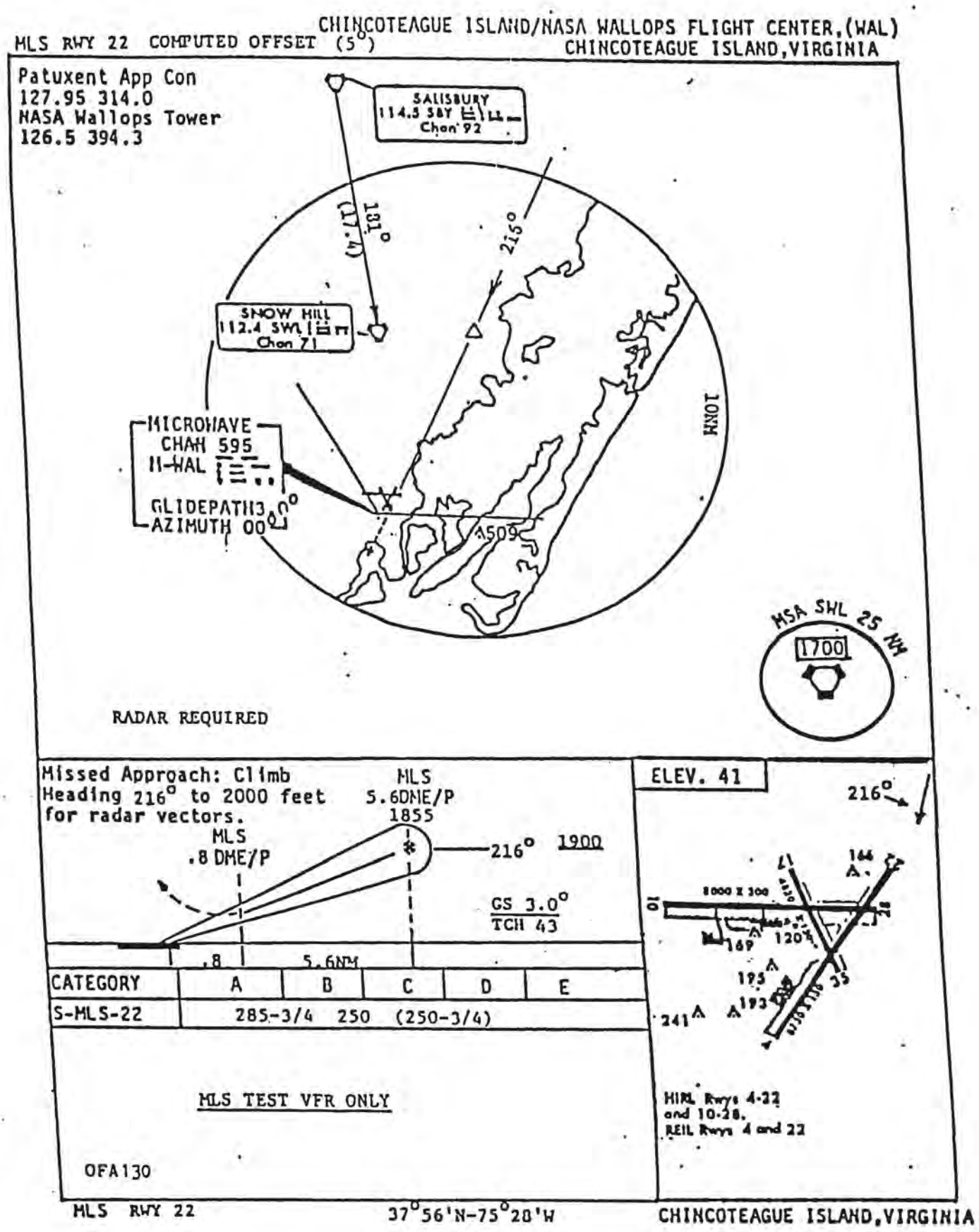

CHINCOTEAGUE ISLAND/NASA WALLOPS FLIGHT CENTER,(WAL)
MLS RWY 22 COMPUTED OFFSET (5°)
CHINCOTEAGUE ISLAND,VIRGINIA
Patuxent App Con
127.95 314.0
NASA Wallops Tower
126.5 394.3
SALISBURY
114.3 SBY
Chan 92
SNOW HILL
112.4 SWL
Chan 71
181°
(17.4)
215°
10NM
MICROWAVE
CHAN 595
N-WAL
GLIDEPATH 3.0°
AZIMUTH 00
1509
MSA SWL 25 NM
1700
RADAR REQUIRED
Missed Approach: Climb
Heading 216° to 2000 feet
for radar vectors.
MLS
5.6DME/P
1855
MLS
.8 DME/P
216° 1900
GS 3.0°
TCH 43
.8
5.6NM
CATEGORY A B C D E
S-MLS-22 285-3/4 250 (250-3/4)
MLS TEST VFR ONLY
OFA130
ELEV. 41
216°
8000 X 300
169
120
195
193
241
HIRL Rwys 4-22
and 10-28.
REIL Rwys 4 and 22
MLS RWY 22
37°56'N-75°28'W
CHINCOTEAGUE ISLAND,VIRGINIA

Figure 3

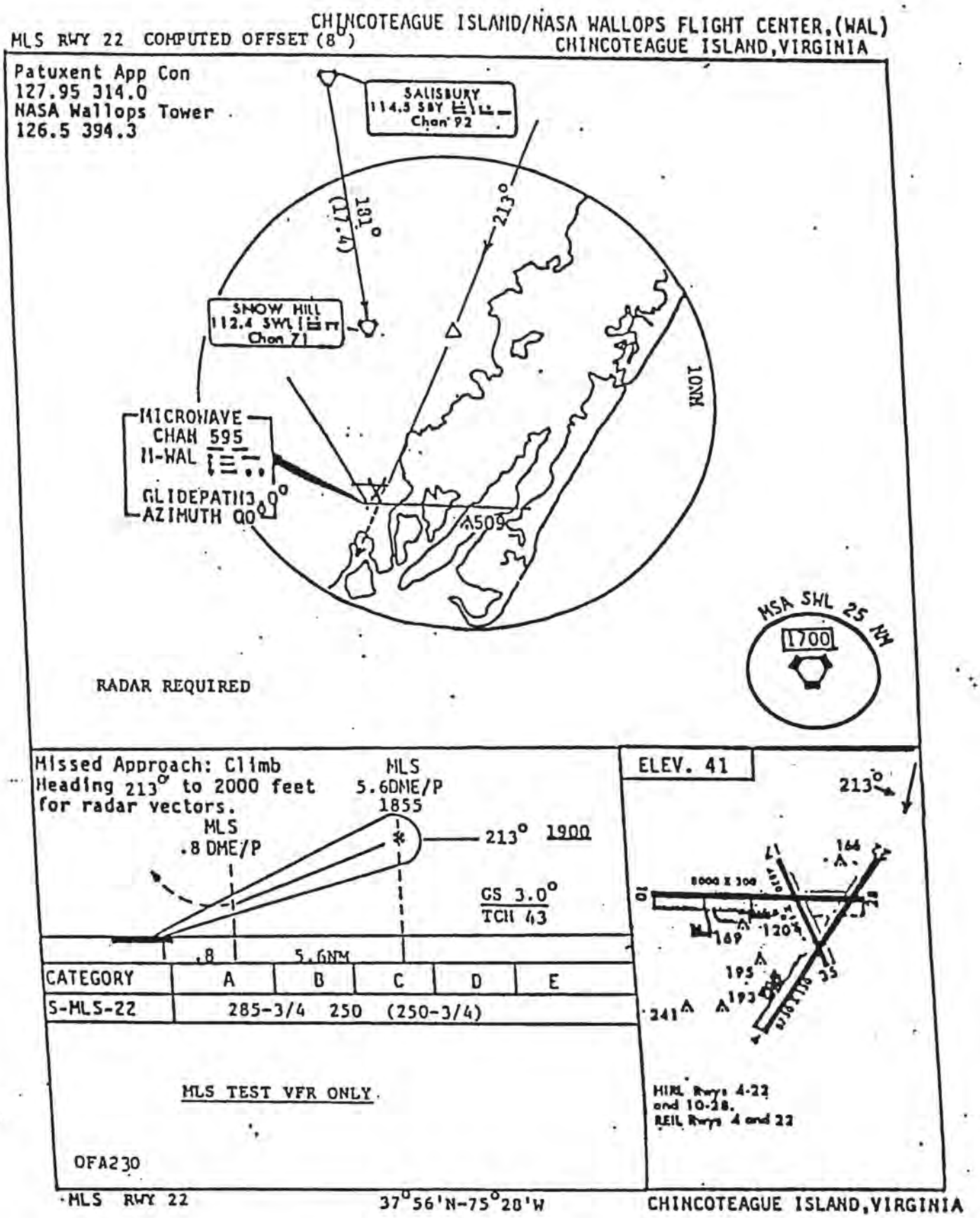

CHINCOTEAGUE ISLAND/NASA WALLOPS FLIGHT CENTER,(WAL)
MLS RWY 22 COMPUTED OFFSET (8°)
CHINCOTEAGUE ISLAND,VIRGINIA
Patuxent App Con
127.95 314.0
NASA Wallops Tower
126.5 394.3
SALISBURY
114.5 SBY
Chan 92
181°
(17.4)
213°
SNOW HILL
112.4 SWL
Chan 71
MICROWAVE
CHAN 595
N-WAL
GLIDEPATH 3.0°
AZIMUTH 00°
A509
10NM
MSA SWL 25 NM
1700
RADAR REQUIRED
Missed Approach: Climb
Heading 213° to 2000 feet
for radar vectors.
MLS
5.6DME/P
1855
MLS
.8 DME/P
213° 1900
GS 3.0°
TCH 43
.8
5.6NM
CATEGORY
A
B
C
D
E
S-MLS-22
285-3/4 250 (250-3/4)
MLS TEST VFR ONLY
OFA230
ELEV. 41
213°
8000 X 300
166
169
120
195
193
241
35
HIRL Rwys 4-22
and 10-28.
REIL Rwys 4 and 22
MLS RWY 22
37°56'N-75°28'W
CHINCOTEAGUE ISLAND,VIRGINIA

Figure 4

MLS RWY 22 COMPUTED OFFSET (10°)

CHINCOTEAGUE ISLAND/NASA WALLOPS FLIGHT CENTER,(WAL)
CHINCOTEAGUE ISLAND,VIRGINIA

Patuxent App Con
127.95 314.0
NASA Wallops Tower
126.5 394.3

SALISBURY
114.3 SBY
Chan 92

181°
211°

SNOW HILL
112.4 SWL
Chan 71

10NM

MICROWAVE
CHAN 595
N-WAL

GLIDEPATH 3.0°
AZIMUTH 00°

A509

MSA SWL 25 NM
1700

RADAR REQUIRED

Missed Approach: Climb
Heading 211° to 2000 feet
for radar vectors.

MLS
5.6DME/P
1855

MLS
.8 DME/P

211° 1900

GS 3.0°
TCH 43

.8 5.6NM

CATEGORY	A	B	C	D	E
S-MLS-22	285-3/4 250 (250-3/4)				

MLS TEST VFR ONLY

OFA330

ELEV. 41

211°

8000 X 200

HIRL Rwys 4-22
and 10-28.
REIL Rwys 4 and 22

MLS RWY 22 37°56'N-75°20'W CHINCOTEAGUE ISLAND,VIRGINIA

Figure 5

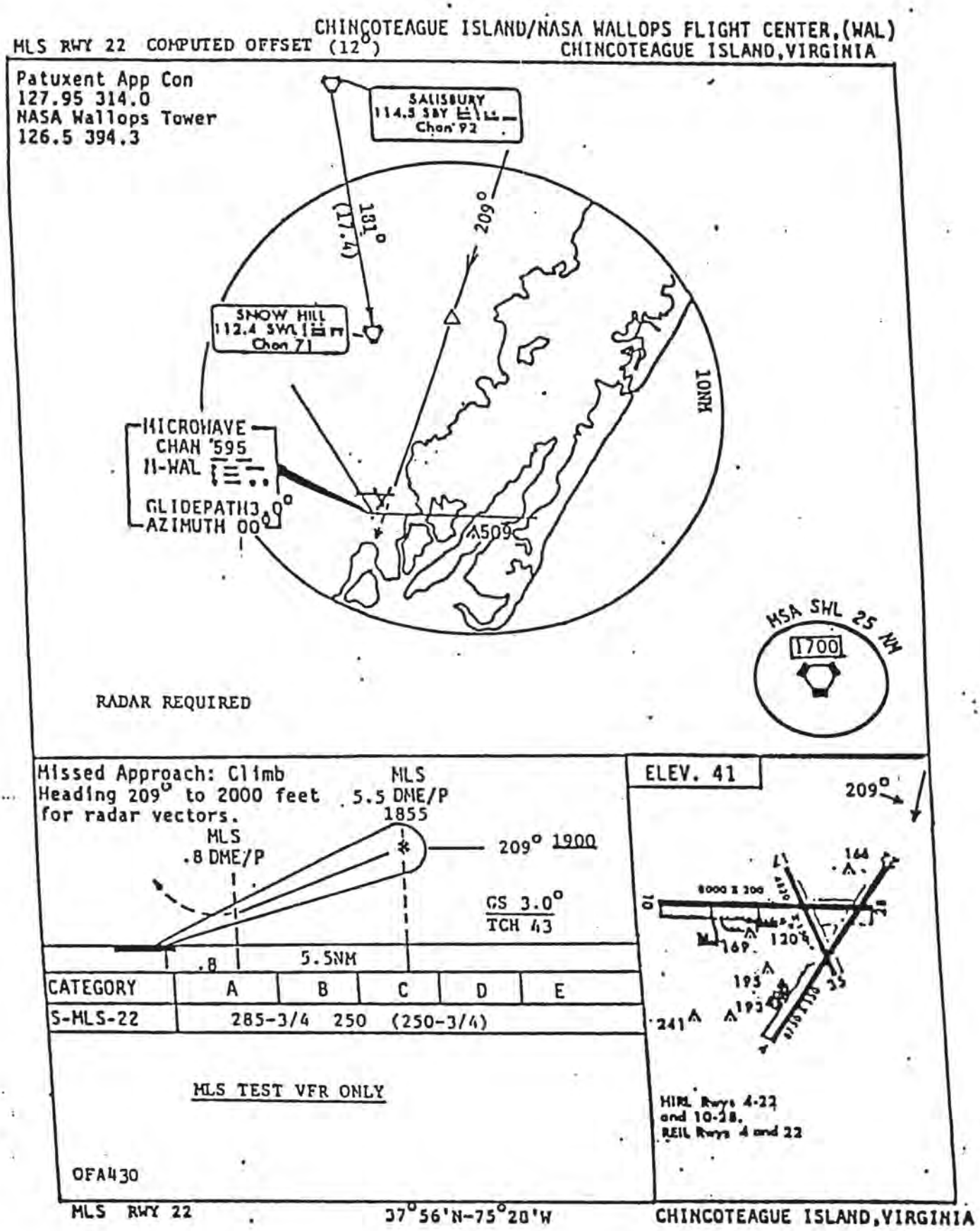
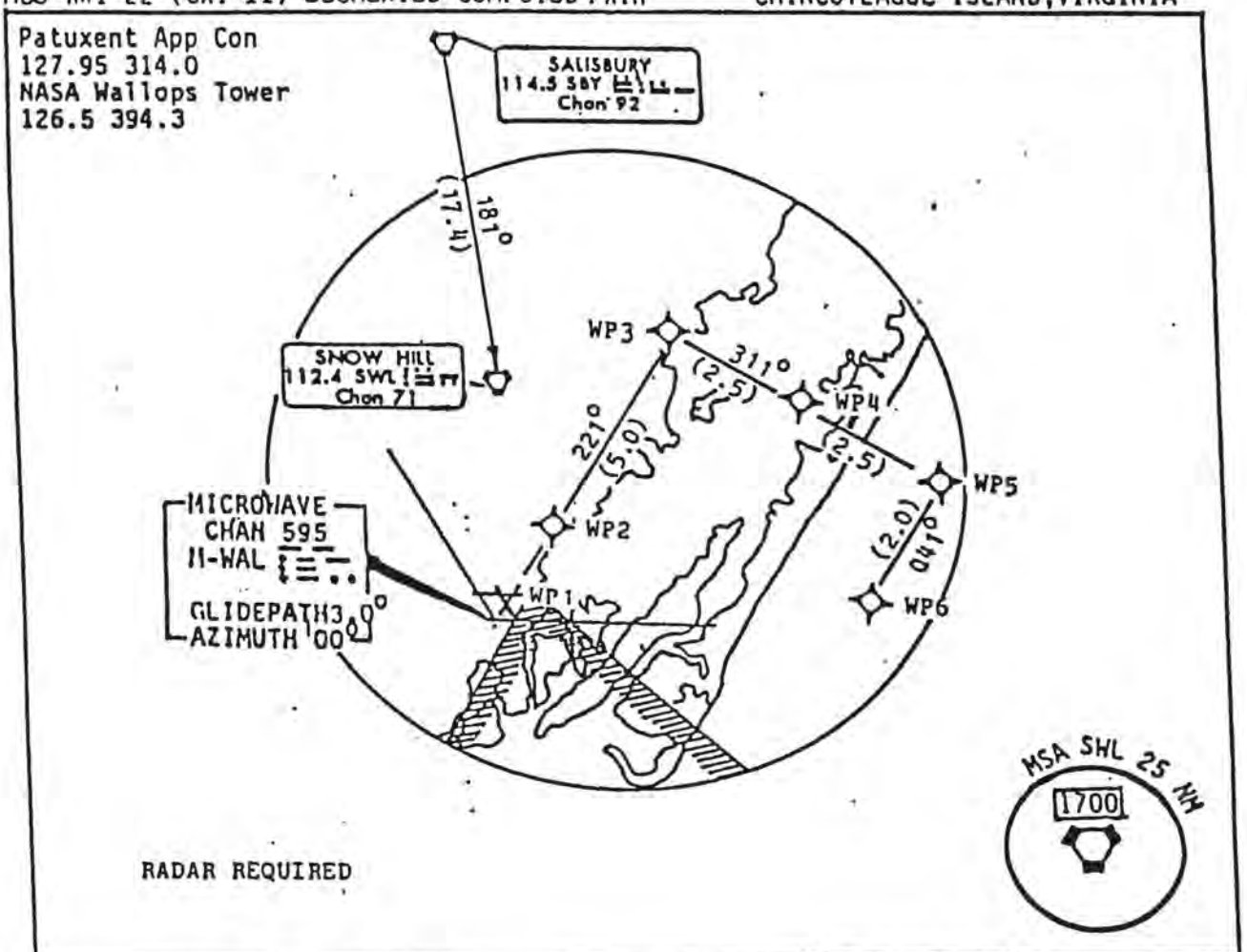
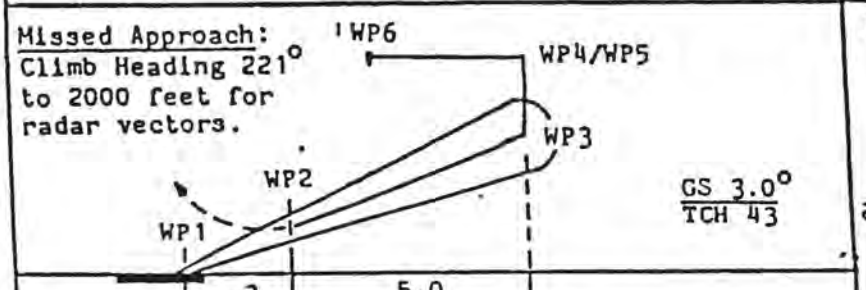

CHINCOTEAGUE ISLAND/NASA WALLOPS FLIGHT CENTER,(WAL)
MLS RWY 22 COMPUTED OFFSET (12°)
CHINCOTEAGUE ISLAND,VIRGINIA
Patuxent App Con
127.95 314.0
NASA Wallops Tower
126.5 394.3
SALISBURY
114.5 SBY
Chan 92
181° (17.4)
209°
SNOW HILL
112.4 SWL
Chan 71
MICROWAVE
CHAN 595
N-WAL
GLIDEPATH 3.0°
AZIMUTH 00
A509
10NM
MSA SWL 25 NM
1700
RADAR REQUIRED
Missed Approach: Climb
Heading 209° to 2000 feet
for radar vectors.
MLS
5.5 DME/P
1855
MLS
.8 DME/P
209° 1900
GS 3.0°
TCH 43
.8
5.5NM
CATEGORY
A
B
C
D
E
S-MLS-22
285-3/4 250 (250-3/4)
MLS TEST VFR ONLY
OFA430
ELEV. 41
209°
8000 X 200
164
169
120
193
241
HIRL Rwys 4-22
and 10-28.
REIL Rwys 4 and 22
MLS RWY 22
37°56'N-75°20'W
CHINCOTEAGUE ISLAND,VIRGINIA

Figure 6

CHINCOTEAGUE ISLAND/NASA WALLOPS FLIGHT CENTER,(WAL)

MLS RWY 22 (CAT II) SEGMENTED COMPUTED PATH CHINCOTEAGUE ISLAND,VIRGINIA



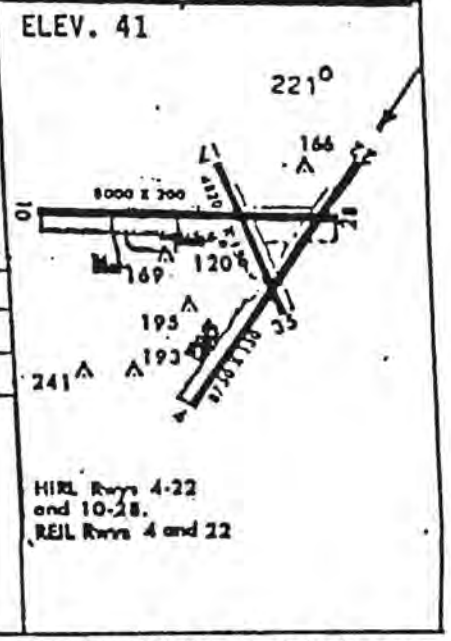


CATEGORY	A	B	C	D	E
S-MLS-22	135/24 100 RA 100				

MLS TEST VFR ONLY

Category II MLS Special Aircrew and Aircraft Certification Required

SGF230

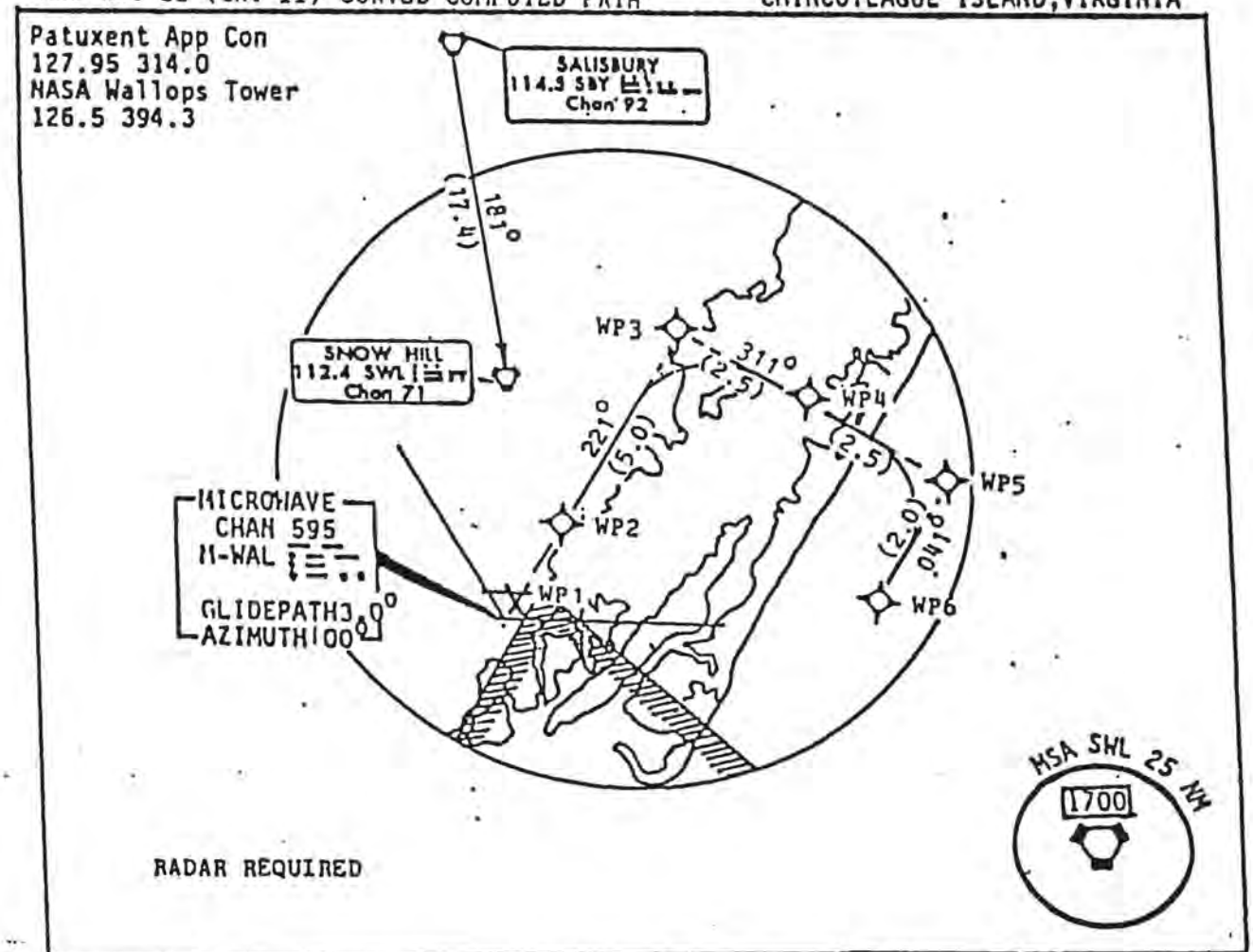


MLS CHINCOTEAGUE ISLAND,VIRGINIA

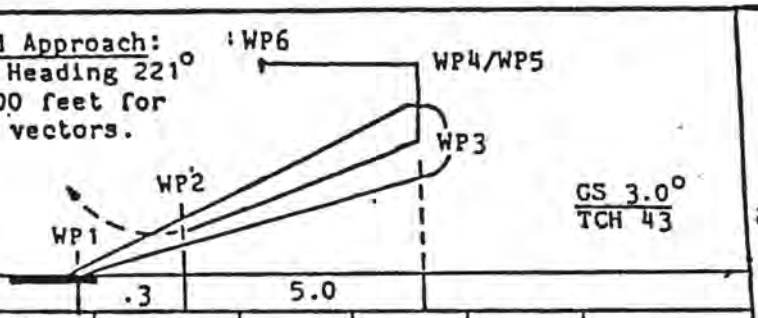
Figure 7

CHINCOTEAGUE ISLAND/NASA WALLOPS FLIGHT CENTER,(WAL)

MLS RWY 22 (CAT II) CURVED COMPUTED PATH — CHINCOTEAGUE ISLAND,VIRGINIA



Missed Approach:
Climb Heading 221° to 2000 feet for radar vectors.



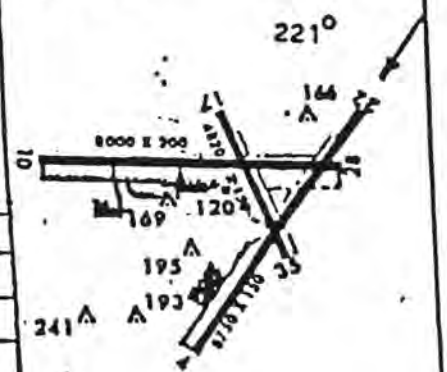
CATEGORY	A	B	C	D	E
S-MLS-22	135/24 100 RA 100				

MLS TEST VFR ONLY

Category II MLS Special Aircrew and Aircraft Certification Required

CPF230

ELEV. 41



HIRL Rwys 4-22 and 10-28.
REIL Rwys 4 and 22

MLS — CHINCOTEAGUE ISLAND,VIRGINIA

Figure 8

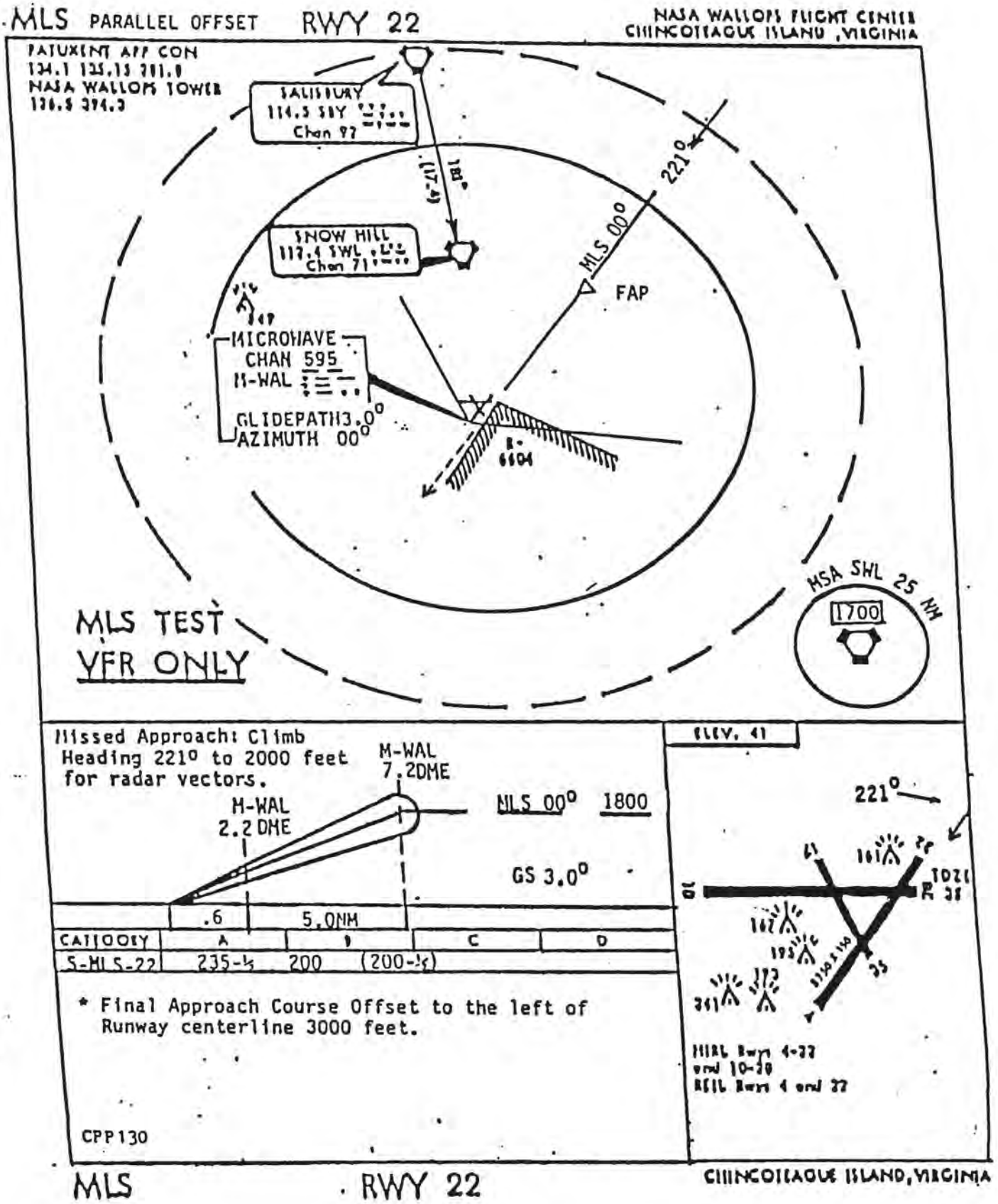
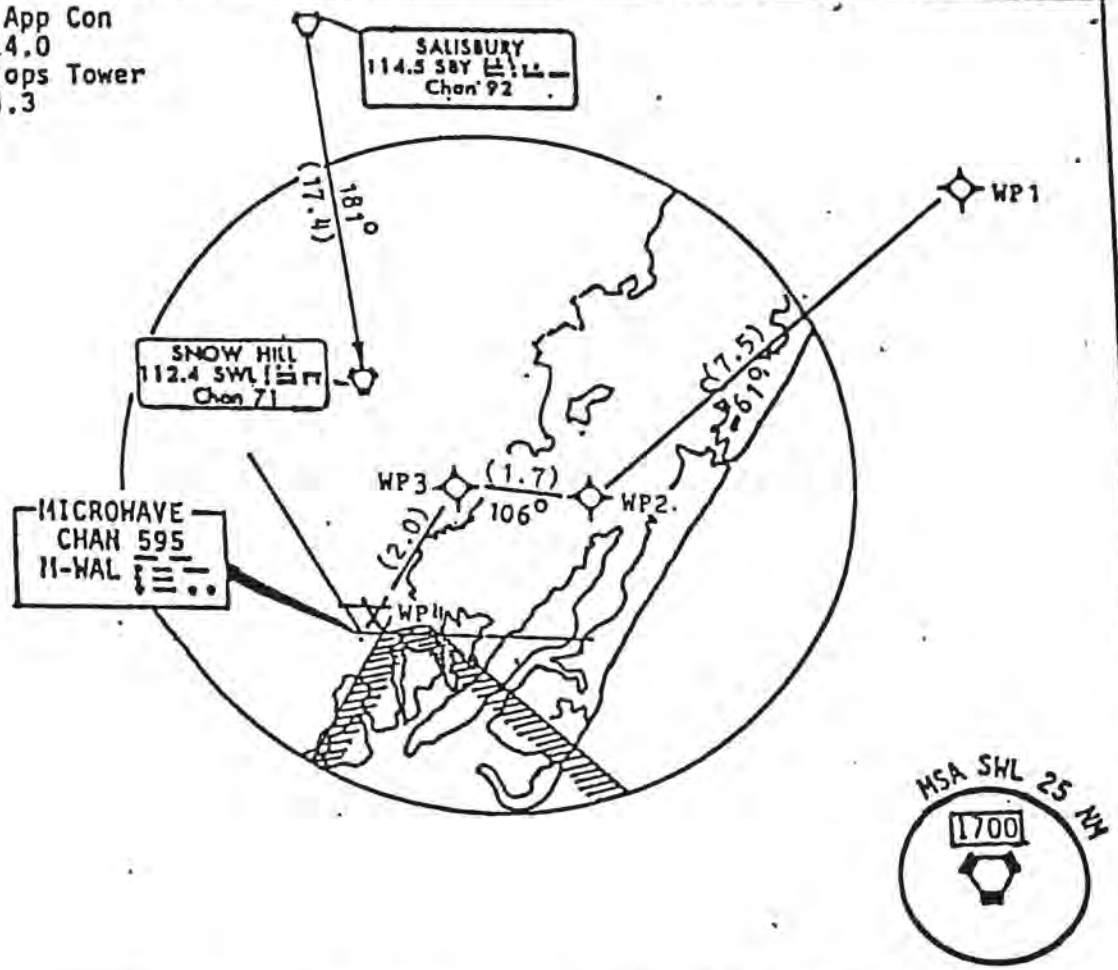

MLS PARALLEL OFFSET RWY 22
NASA WALLOPS FLIGHT CENTER
CHINCOTEAGUE ISLAND, VIRGINIA
PATUXENT APP CON
NASA WALLOPS TOWER
SALISBURY
Chan 97
SNOW HILL
Chan 71
MICROWAVE
CHAN 595
M-WAL
GLIDEPATH 3.0°
AZIMUTH 00°
MLS 00°
FAP
221°
MSA SWL 25 NM
1700
MLS TEST
VFR ONLY
Missed Approach: Climb
Heading 221° to 2000 feet
for radar vectors.
M-WAL
7.2DME
M-WAL
2.2 DME
MLS 00° 1800
GS 3.0°
.6
5.0NM
CATEGORY
A
B
C
D
S-MLS-22
235-½
200
(200-½)
* Final Approach Course Offset to the left of
Runway centerline 3000 feet.
CPP130
ELEV. 41
221°
MIRL Rwys 4-22
and 10-28
REIL Rwys 4 and 22
MLS RWY 22
CHINCOTEAGUE ISLAND, VIRGINIA

Figure 9

CHINCOTEAGUE ISLAND/NASA WALLOPS FLIGHT CENTER,(WAL)

MLS 20° OFFSET COMPUTED DEPARTURE — CHINCOTEAGUE ISLAND,VIRGINIA

Patuxent App Con
127.95 314.0
NASA Wallops Tower
126.5 394.3

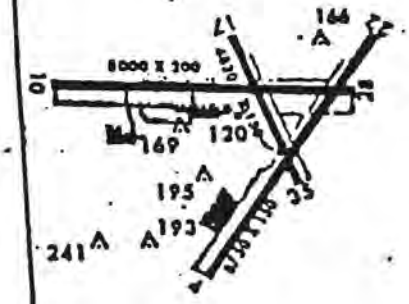


TAKE-OFF RUNWAY 04: Depart runway heading of 041° and fly outbound on the computed course from WP4 to WP1 to intercept the L20° offset, climb to 5000 feet or as assigned.

MLS TEST VFR ONLY

CPDR01

ELEV. 41



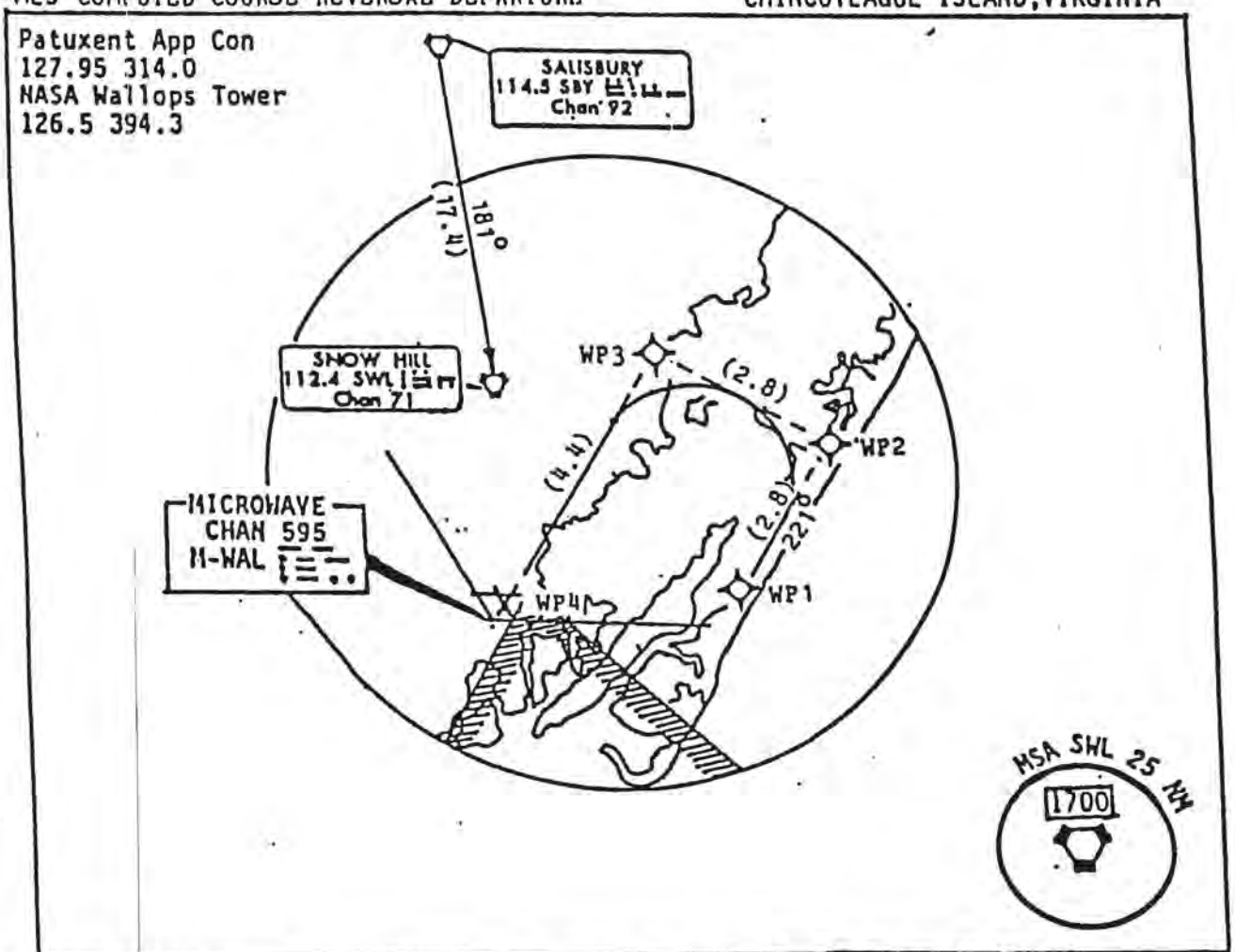
HIRL Rwys 4-22 and 10-28.
REIL Rwys 4 and 22

MLS — CHINCOTEAGUE ISLAND,VIRGINIA

Figure 10

CHINCOTEAGUE ISLAND/NASA WALLOPS FLIGHT CENTER,(WAL)

MLS COMPUTED COURSE REVERSAL DEPARTURE — CHINCOTEAGUE ISLAND,VIRGINIA

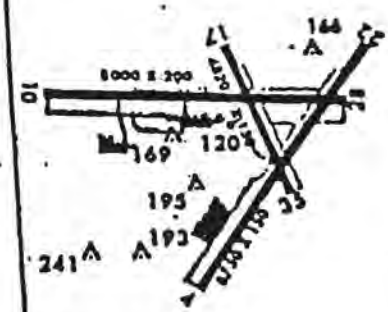


TAKE-OFF RUNWAY 04: Depart runway heading of 041° and fly outbound on the computed course from WP4 to WP1, climb to 5000 feet or as assigned.

MLS TEST VFR ONLY

CPDR02

ELEV. 41



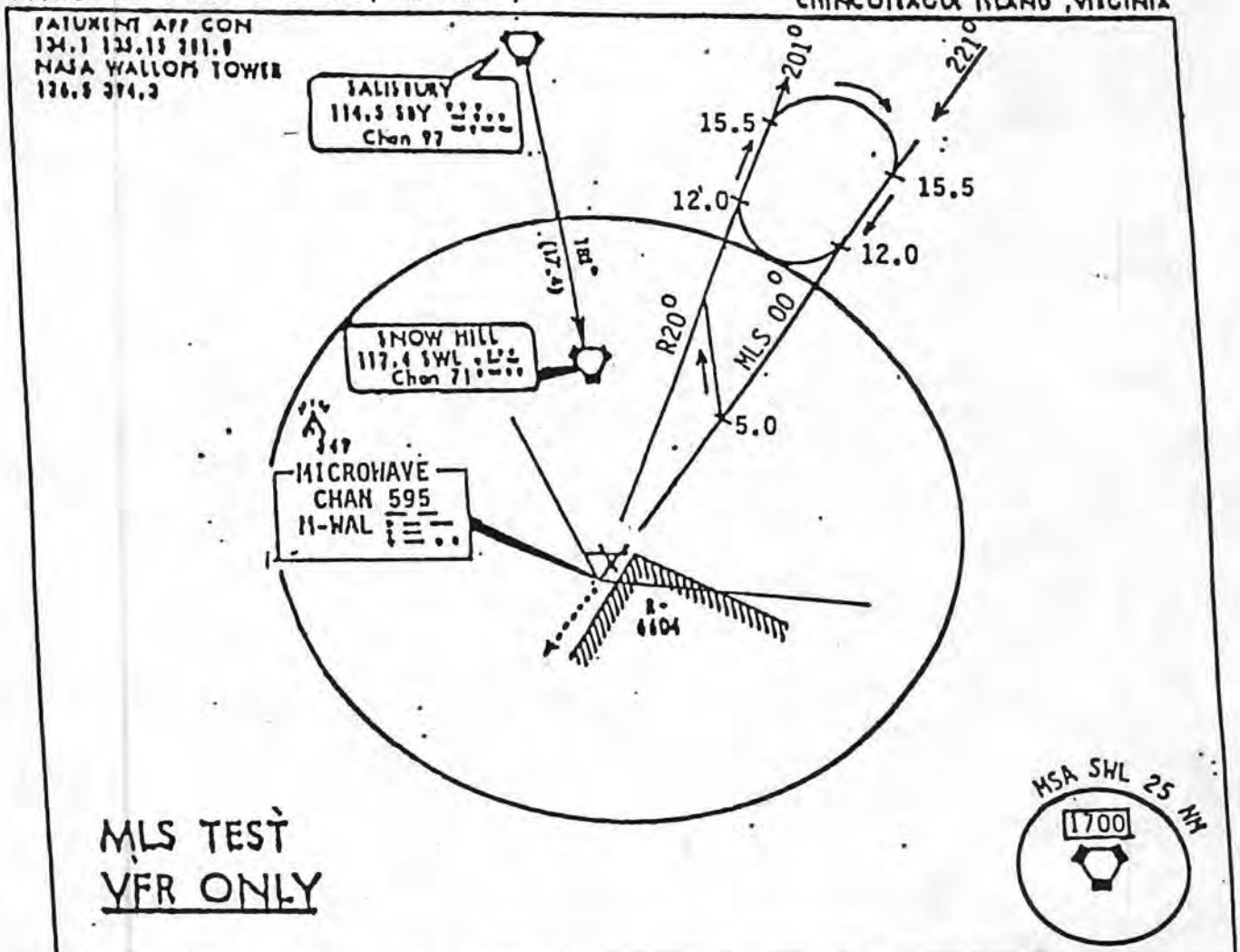
HIRL Rwys 4-22 and 10-28.
REIL Rwys 4 and 22

MLS — CHINCOTEAGUE ISLAND,VIRGINIA

Figure 11

MLS SHUTTLE DEPARTURE(PILOT NAV)

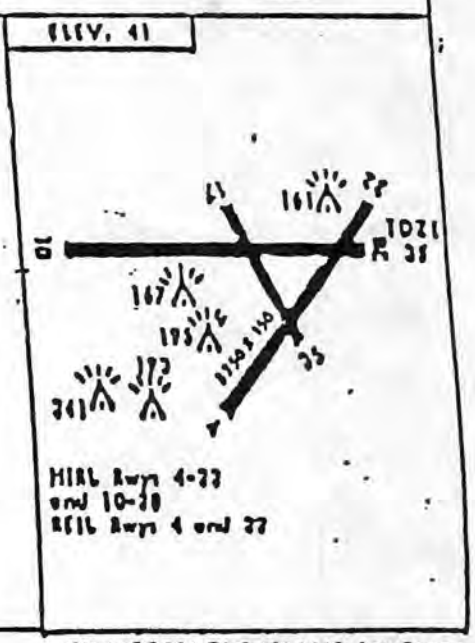
NASA WALLOPS FLIGHT CENTER
CHINCOTEAGUE ISLAND, VIRGINIA



TAKE-OFF RUNWAY 04: Depart runway heading 041° and track outbound on the M-WAL 00° Azimuth, climb to 2000 feet before reaching the 6.0 PDME, maintain altitude or continue climb to assigned altitude. At the 5.0 PDME turn left to a heading of 171° and intercept the R20° Azimuth outbound, at the 15.5 PDME hold as depicted or proceed inbound on the 00° Azimuth as directed by ATC.

Note: Holding Airspeed 230 Knots;
Inside Turn Bank Angle 20°
Outside Turn Bank Angle 16°
in a no wind condition.

SGK100



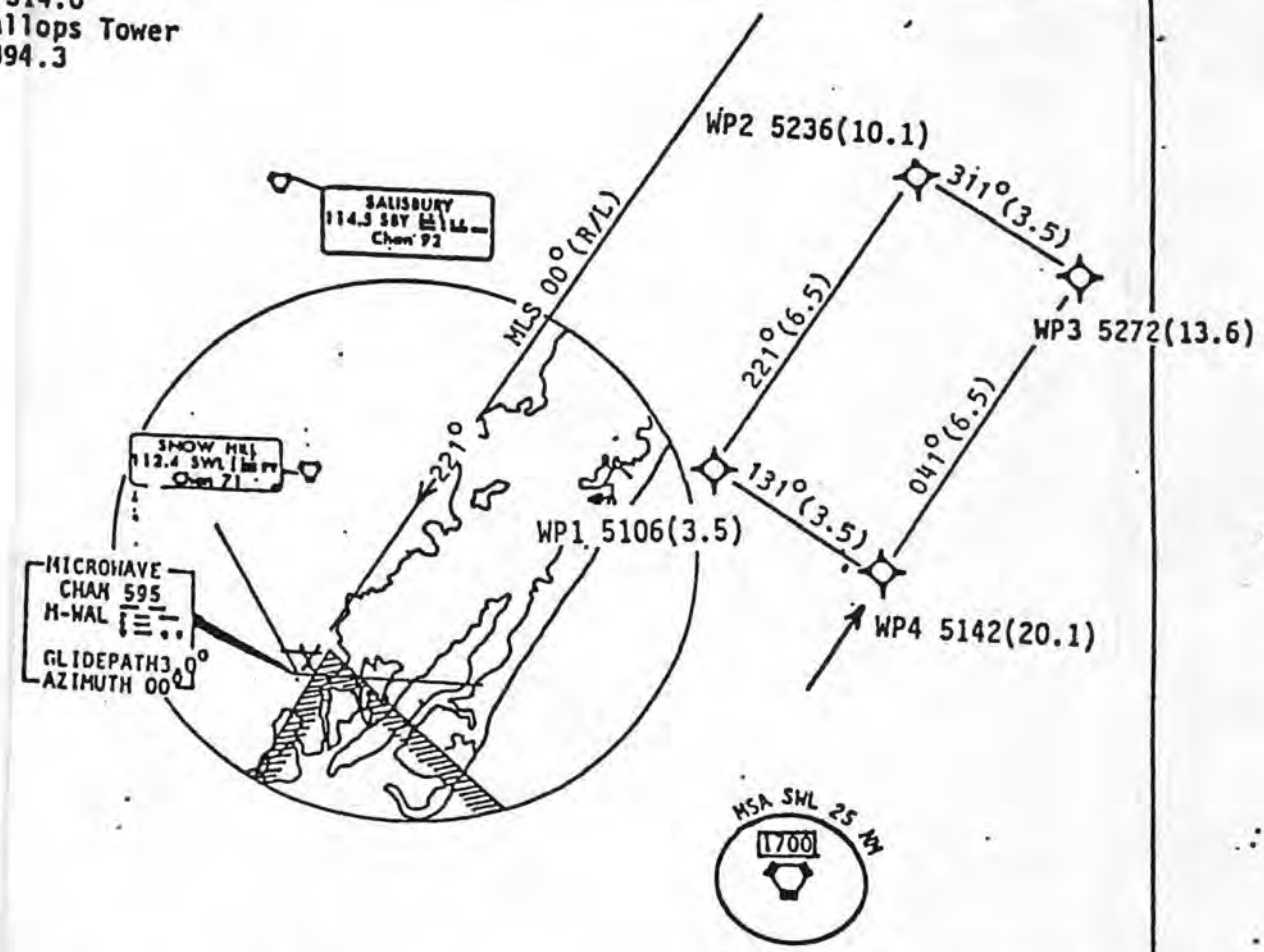
CHINCOTEAGUE ISLAND, VIRGINIA

Figure 12

MLS COMPUTED HOLDING

CHINCOTEAGUE ISLAND/NASA WALLOPS FLIGHT CENTER,(WAL)
CHINCOTEAGUE ISLAND,VIRGINIA

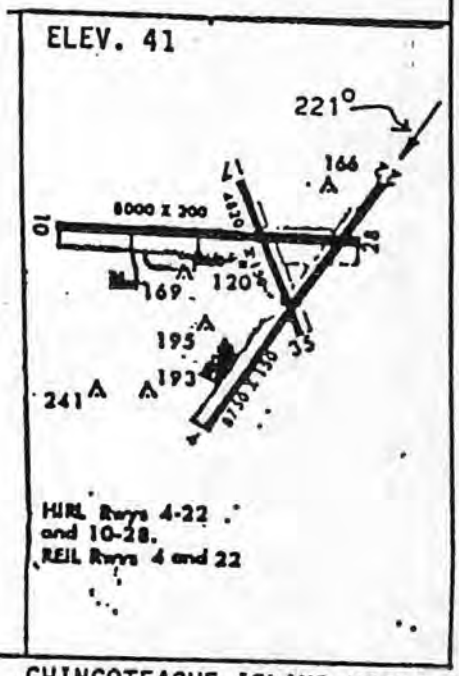
Patuxent App Con
127.95 314.0
NASA Wallops Tower
126.5 394.3



NOTE: WARNING AREA W-108A
Holding Pattern may extend
into W-108A Contact Patuxent
Approach Control

MLS TEST VFR ONLY

EXPERIMENTAL ONLY



MLS

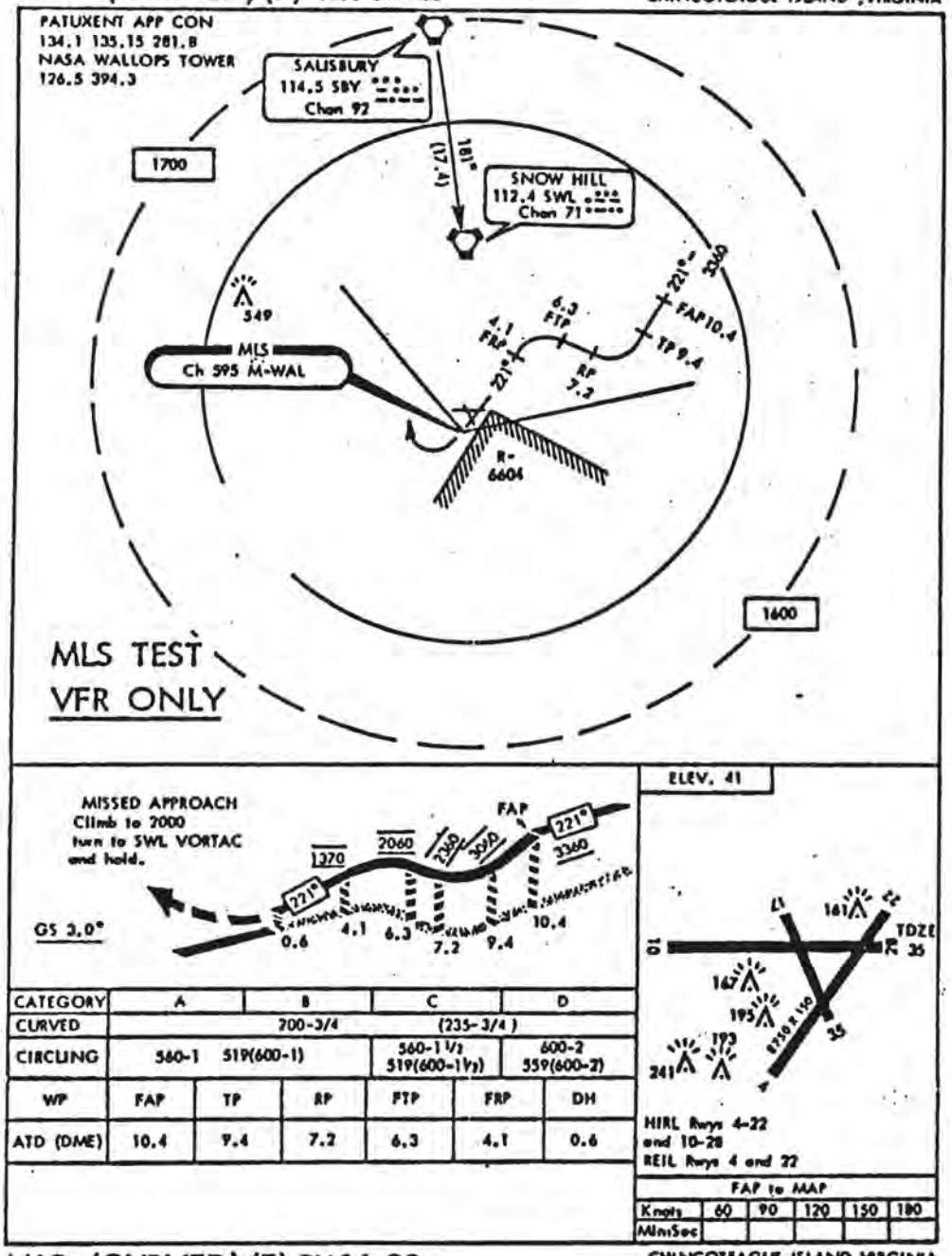
CHINCOTEAGUE ISLAND,VIRGINIA

Figure 13

PROFILE 4 (S01)

MLS (CURVED) (F) RWY 22

NASA WALLOPS FLIGHT CENTER
CHINCOTEAGUE ISLAND, VIRGINIA



CATEGORY	A	B	C	D
CURVED	700-3/4		(235-3/4)	
CIRCLING	560-1 519(600-1)		560-1 1/2 519(600-1 1/2)	600-2 559(600-2)

WP	FAP	TP	RP	FTP	FRP	DH
ATD (DME)	10.4	9.4	7.2	6.3	4.1	0.6

FAP to MAP					
Knots	60	90	120	150	180
Min:Sec					

MLS (CURVED) (F) RWY 22

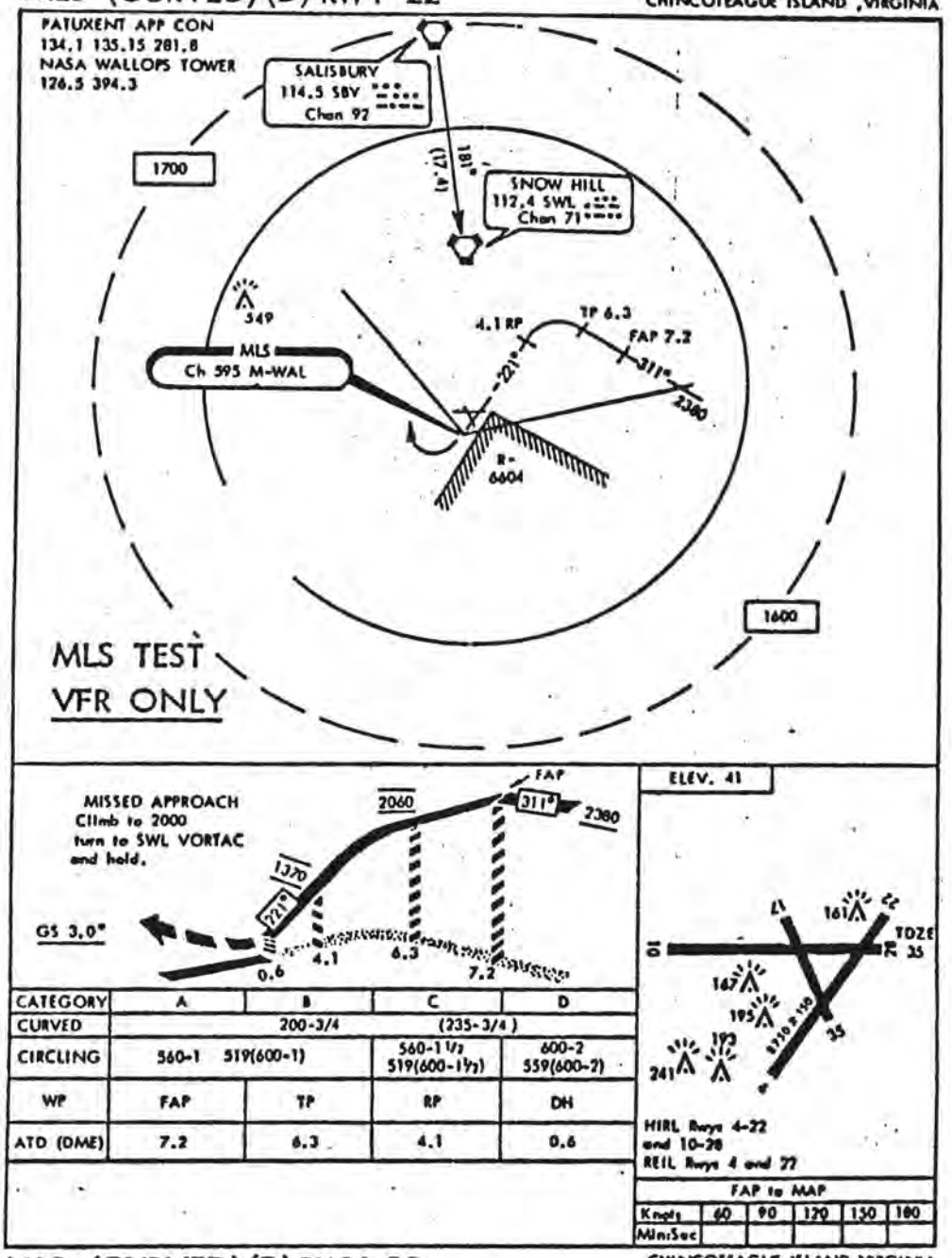
CHINCOTEAGUE ISLAND, VIRGINIA

Figure 14

PROFILE 2D2 (902)

MLS (CURVED) (D) RWY 22

NASA WALLOPS FLIGHT CENTER
CHINCOTEAGUE ISLAND, VIRGINIA



CATEGORY	A	B	C	D
CURVED	200-3/4		(235-3/4)	
CIRCLING	560-1 519(600-1)		560-1 1/2 519(600-1 1/2)	600-2 559(600-2)
WP	FAP	TP	RP	DH
ATD (DME)	7.2	6.3	4.1	0.6

FAP to MAP					
Knots	60	90	120	150	180
Min:Sec					

MLS (CURVED) (D) RWY 22

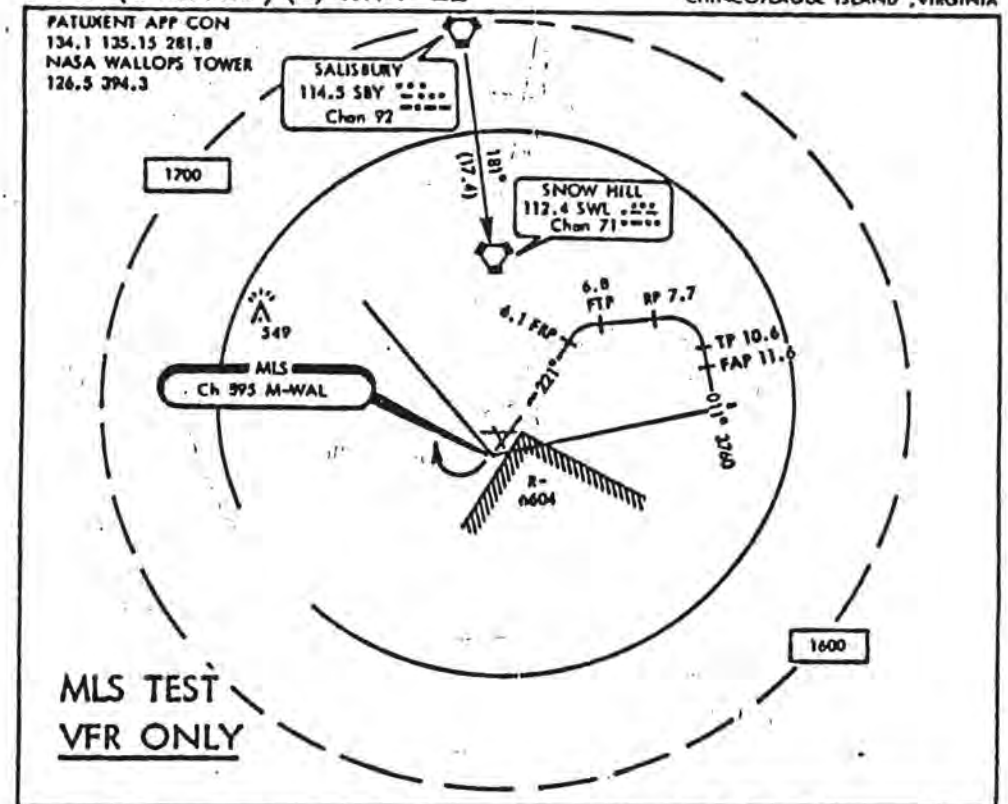
CHINCOTEAGUE ISLAND, VIRGINIA

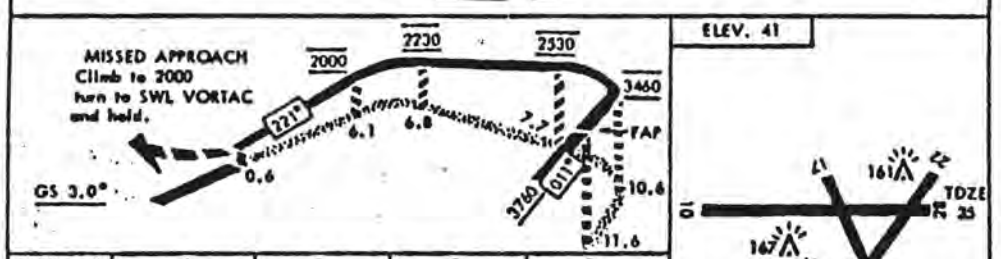
Figure 15

PROFILE 3 (131)

MLS (CURVED) (E) RWY 22

NASA WALLOPS FLIGHT CENTER
CHINCOTEAGUE ISLAND, VIRGINIA





CATEGORY	A	B	C	D
CURVED	200-3/4		(235-3/4)	
CIRCLING	560-1 519(600-1)		560-1 1/2 519(600-1 1/2)	600-2 539(600-2)

WP	FAP	TP	RP	FTP	FRP	DH
ATD (DME)	11.6	10.6	7.7	6.8	6.1	0.6

FAP to MAP					
Knots	60	90	120	150	180
Min:Sec					

MLS (CURVED) (E) RWY 22

CHINCOTEAGUE ISLAND, VIRGINIA

Figure 16

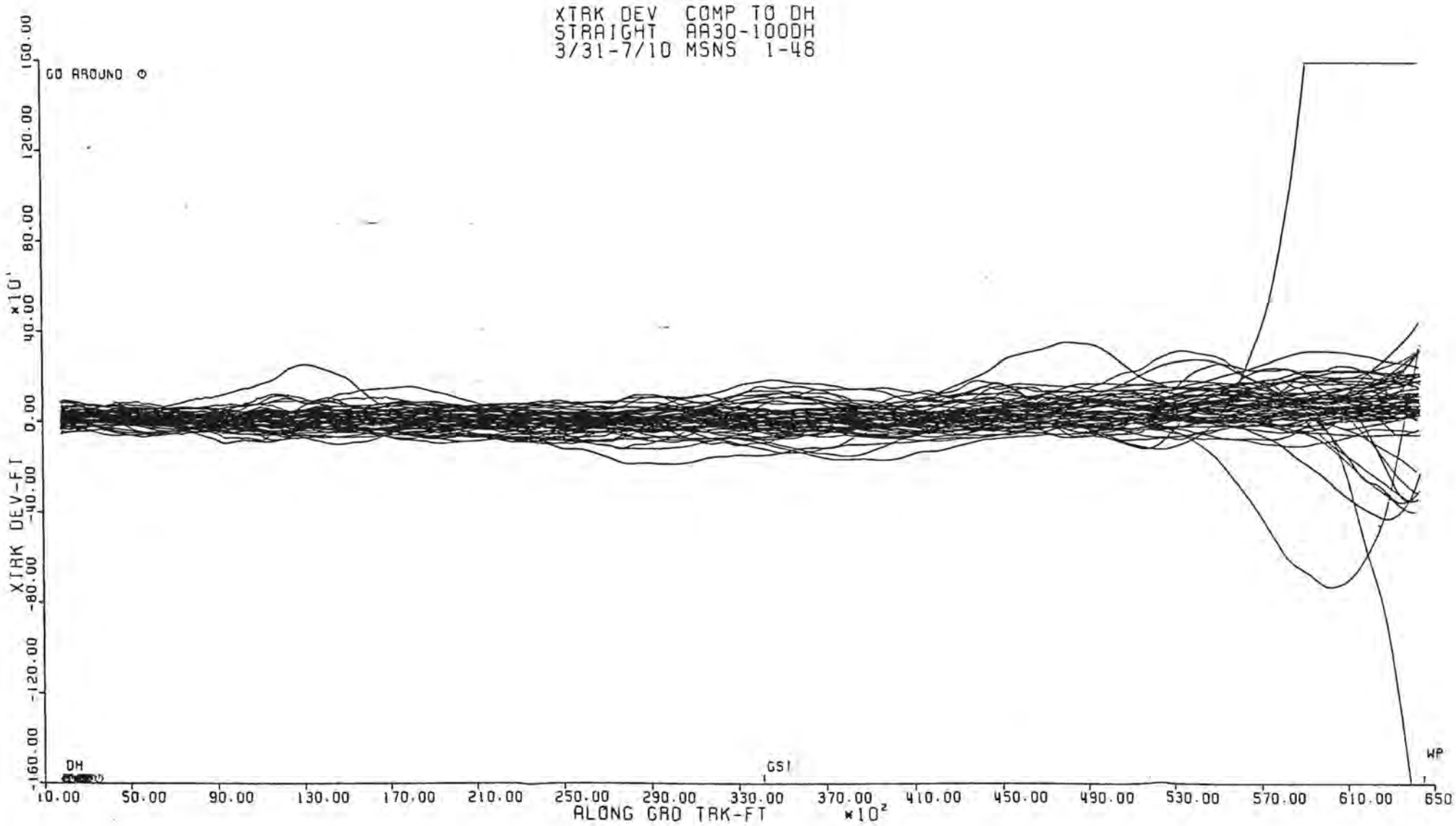

XTRK DEV COMP TO DH
STRAIGHT AA30-100DH
3/31-7/10 MSNS 1-48
GO AROUND
XTRK DEV-FT ×10¹
160.00
120.00
80.00
40.00
0.00
-40.00
-80.00
-120.00
-160.00
DH
GSI
WP
10.00
50.00
90.00
130.00
170.00
210.00
250.00
290.00
330.00
370.00
410.00
450.00
490.00
530.00
570.00
610.00
650
ALONG GRD TRK-FT ×10²

Figure 17

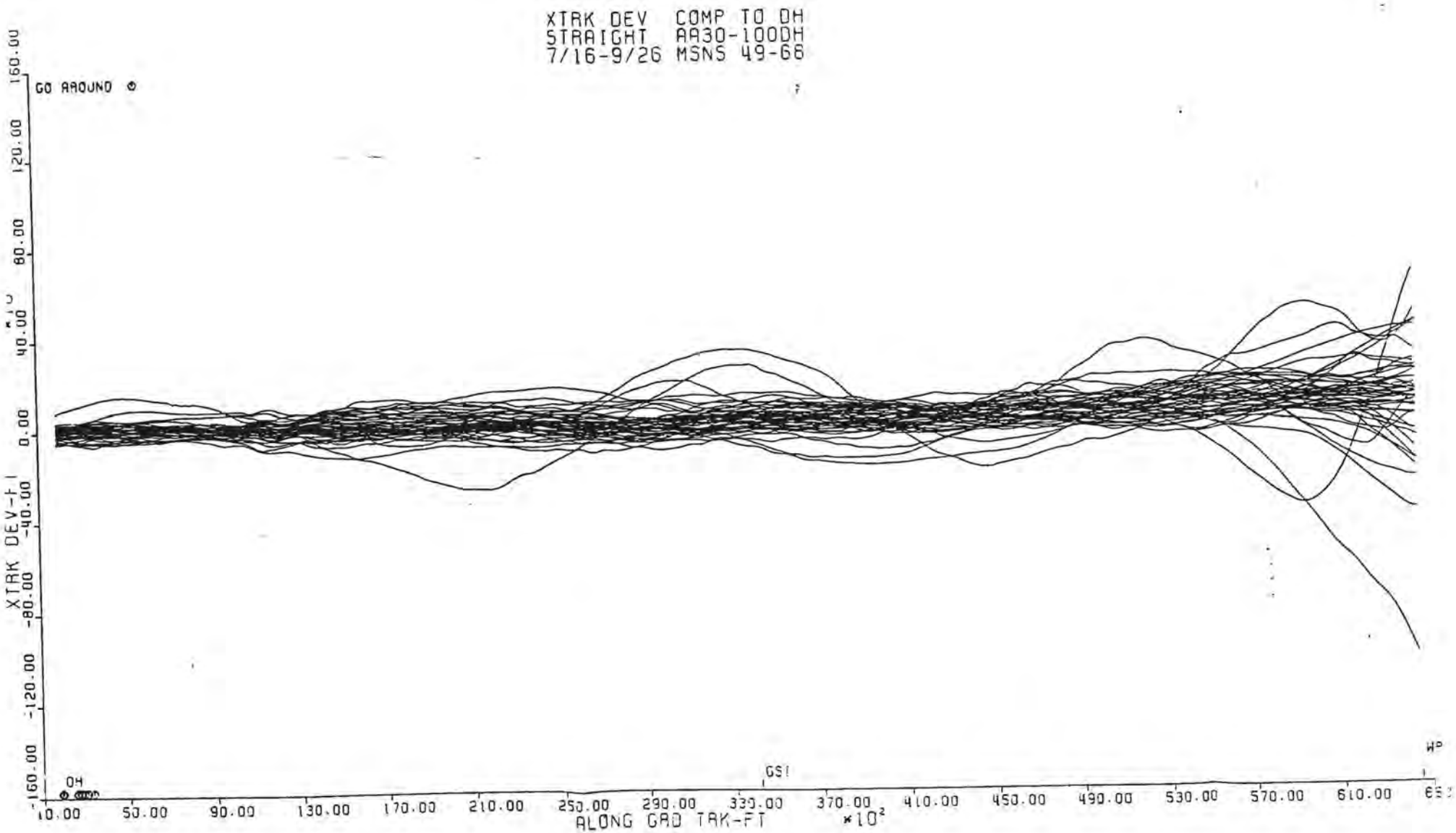

XTRK DEV COMP TO DH
STRAIGHT AA30-100DH
7/16-9/26 MSNS 49-68
GO AROUND
XTRK DEV-FT
160.00
120.00
80.00
40.00
0.00
-40.00
-80.00
-120.00
-160.00
DH
GSI
WP
10.00
50.00
90.00
130.00
170.00
210.00
250.00
290.00
330.00
370.00
410.00
450.00
490.00
530.00
570.00
610.00
ALONG GRD TRK-FT
×10²

Figure 18

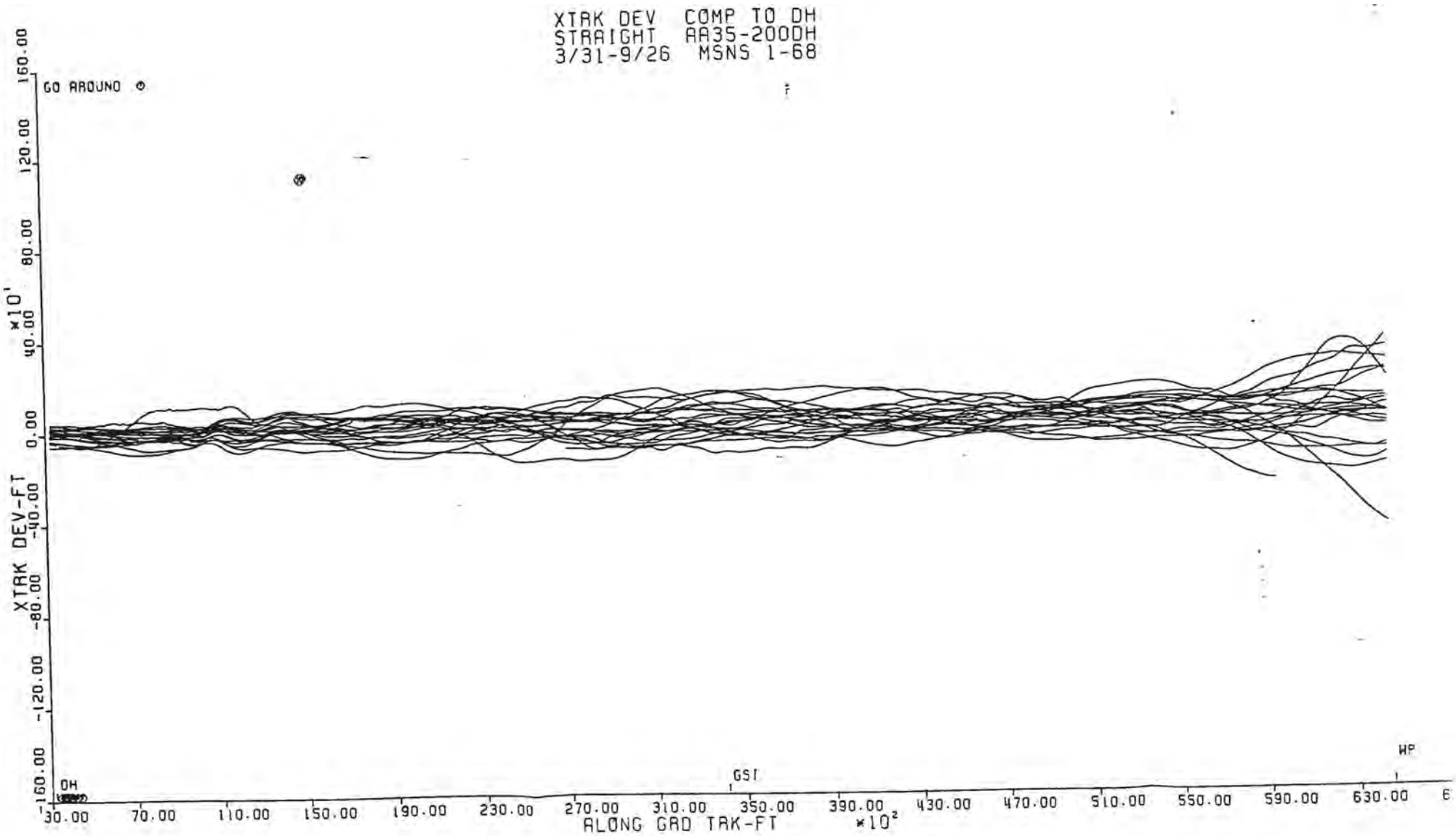

XTRK DEV COMP TO DH
STRAIGHT RA35-200DH
3/31-9/26 MSNS 1-68
GO AROUND
XTRK DEV-FT ×10¹
160.00
120.00
80.00
40.00
0.00
-40.00
-80.00
-120.00
-160.00
DH
GSI
WP
30.00
70.00
110.00
150.00
190.00
230.00
270.00
310.00
350.00
390.00
430.00
470.00
510.00
550.00
590.00
630.00
ALONG GRD TRK-FT ×10²

Figure 19

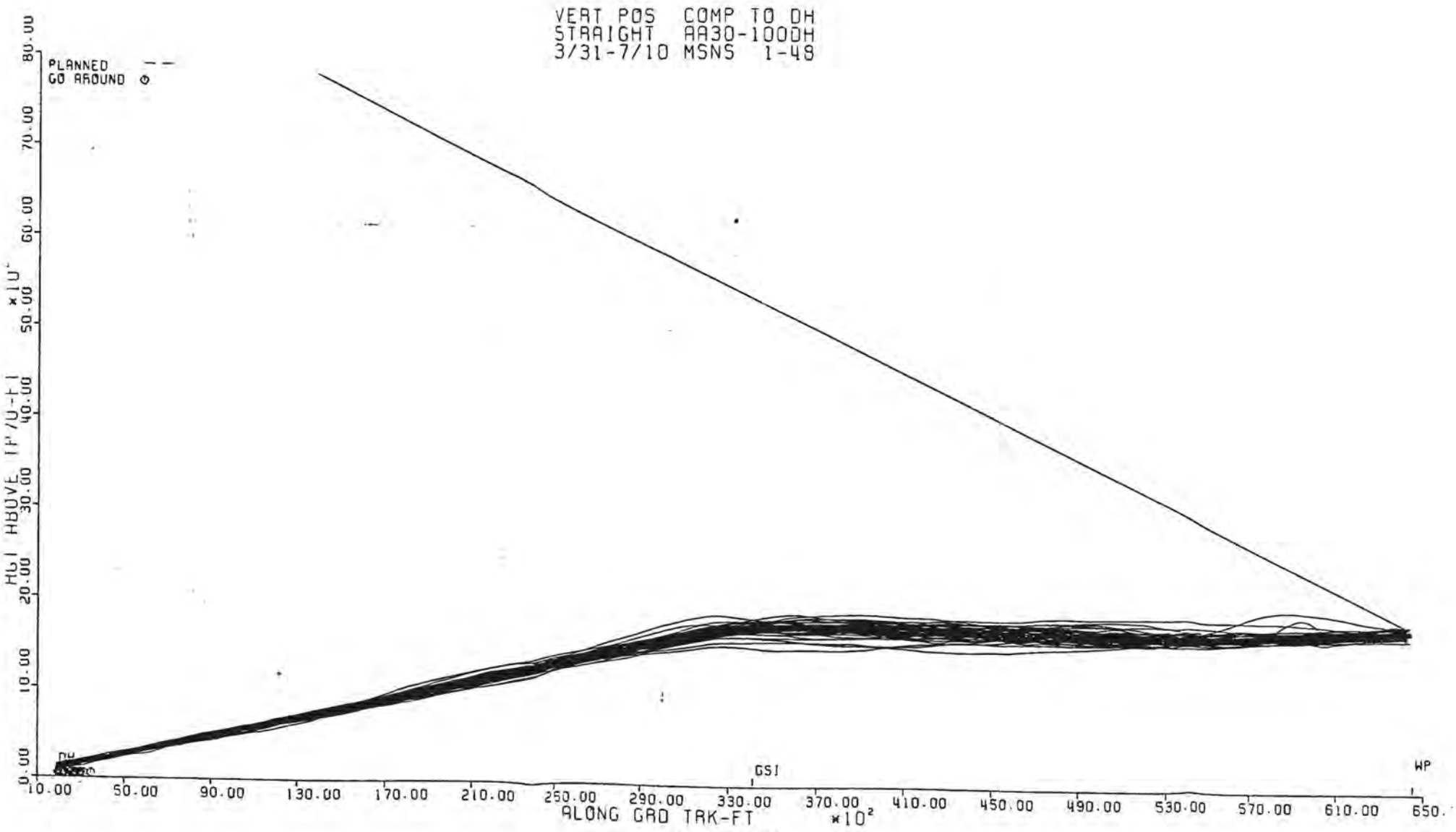

VERT POS COMP TO DH
STRAIGHT AA30-100DH
3/31-7/10 MSNS 1-48
PLANNED
GO AROUND
HGT ABOVE TP/O-FT ×10²
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
DH
GSI
WP
10.00
50.00
90.00
130.00
170.00
210.00
250.00
290.00
330.00
370.00
410.00
450.00
490.00
530.00
570.00
610.00
650.
ALONG GRD TRK-FT ×10²

Figure 20

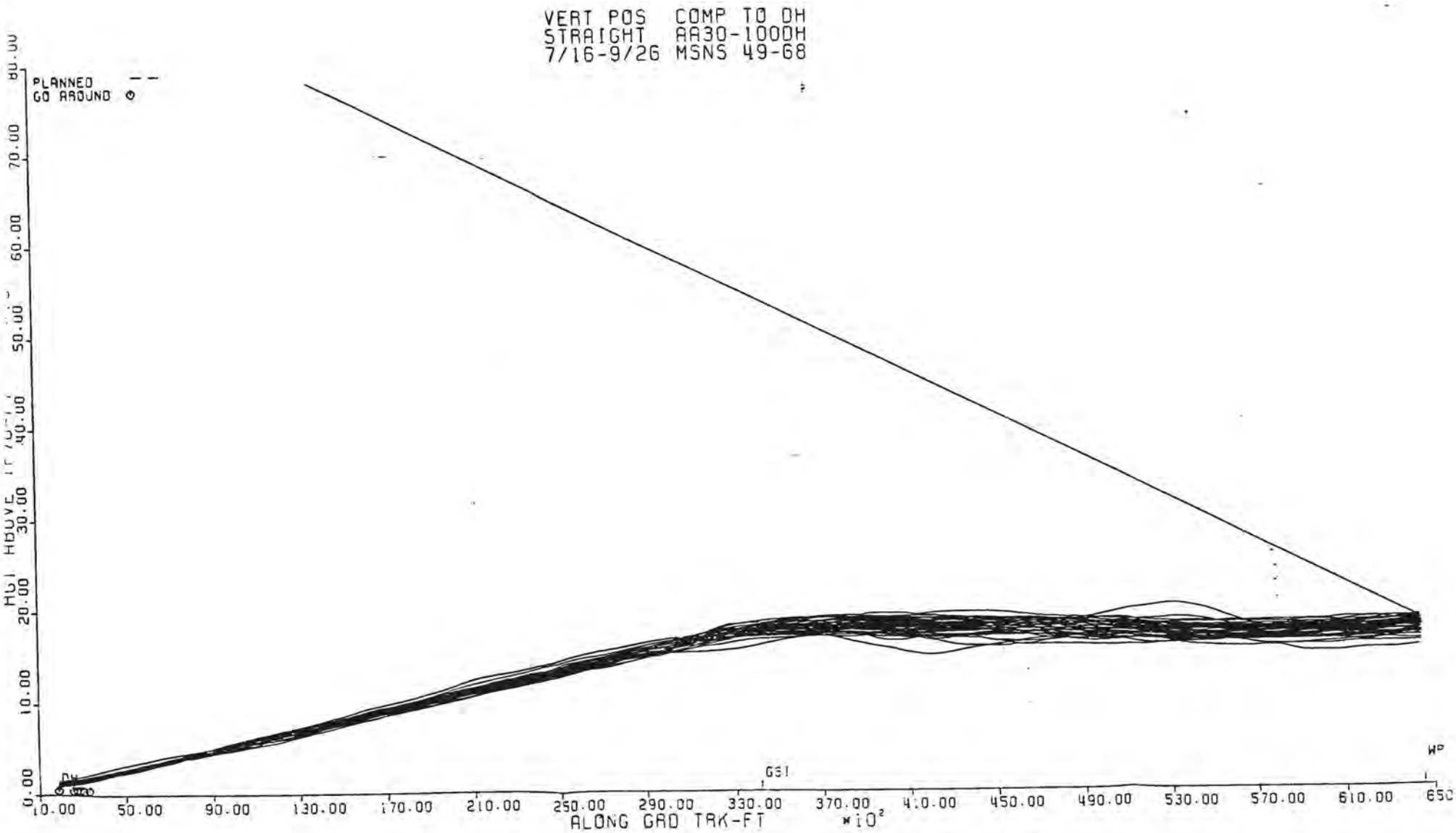

VERT POS COMP TO DH
STRAIGHT AA30-1000H
7/16-9/26 MSNS 49-68
PLANNED
GO AROUND
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
10.00
50.00
90.00
130.00
170.00
210.00
250.00
290.00
330.00
370.00
410.00
450.00
490.00
530.00
570.00
610.00
650
ALONG GRD TRK-FT
*10²
GSI
WP

Figure 21

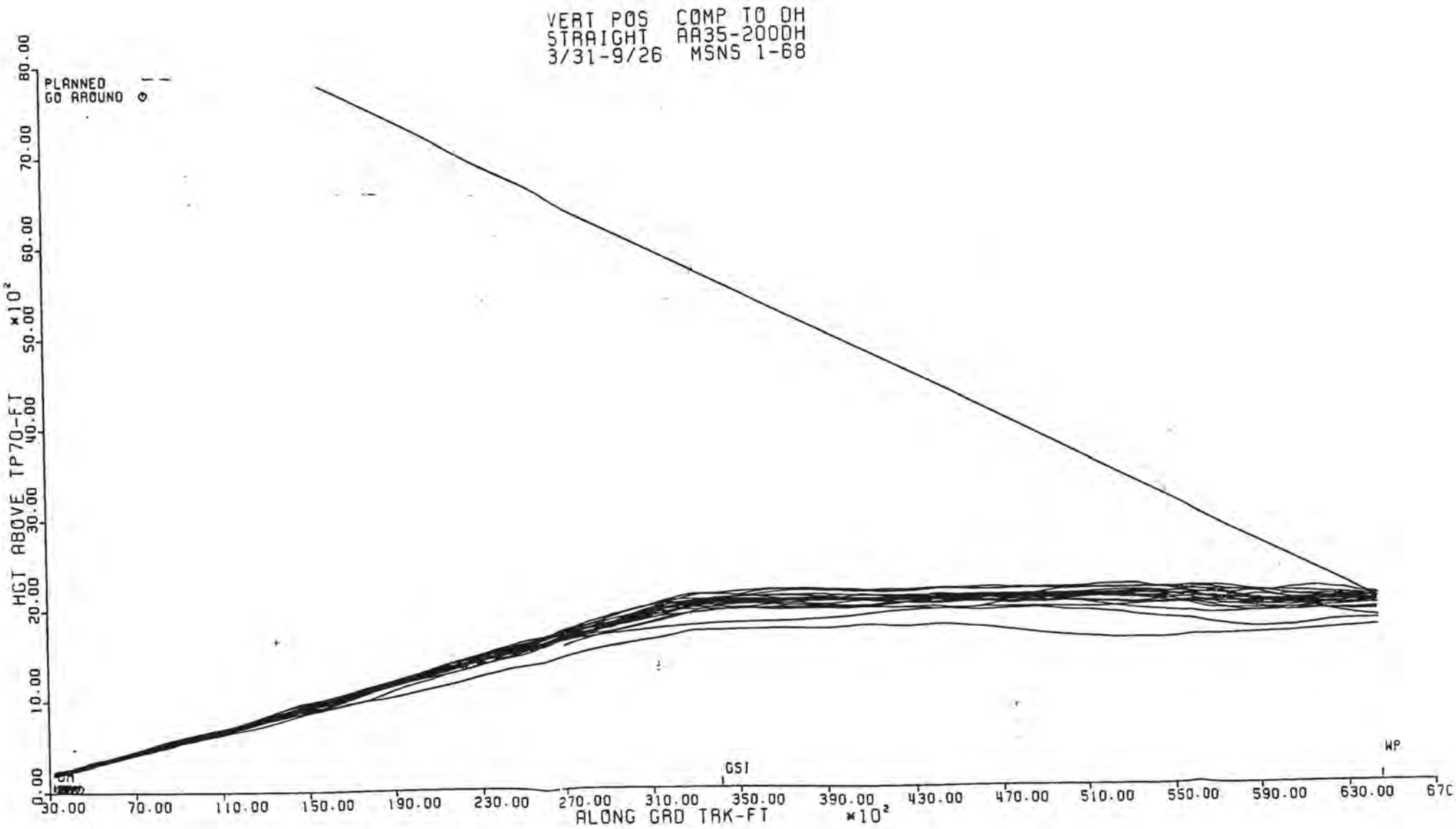

VERT POS COMP TO DH
STRAIGHT AA35-200DH
3/31-9/26 MSNS 1-68
PLANNED
GO AROUND
HGT ABOVE TP70-FT
×10²
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
DH
GSI
WP
30.00
70.00
110.00
150.00
190.00
230.00
270.00
310.00
350.00
390.00
430.00
470.00
510.00
550.00
590.00
630.00
ALONG GRD TRK-FT
×10²

Figure 22

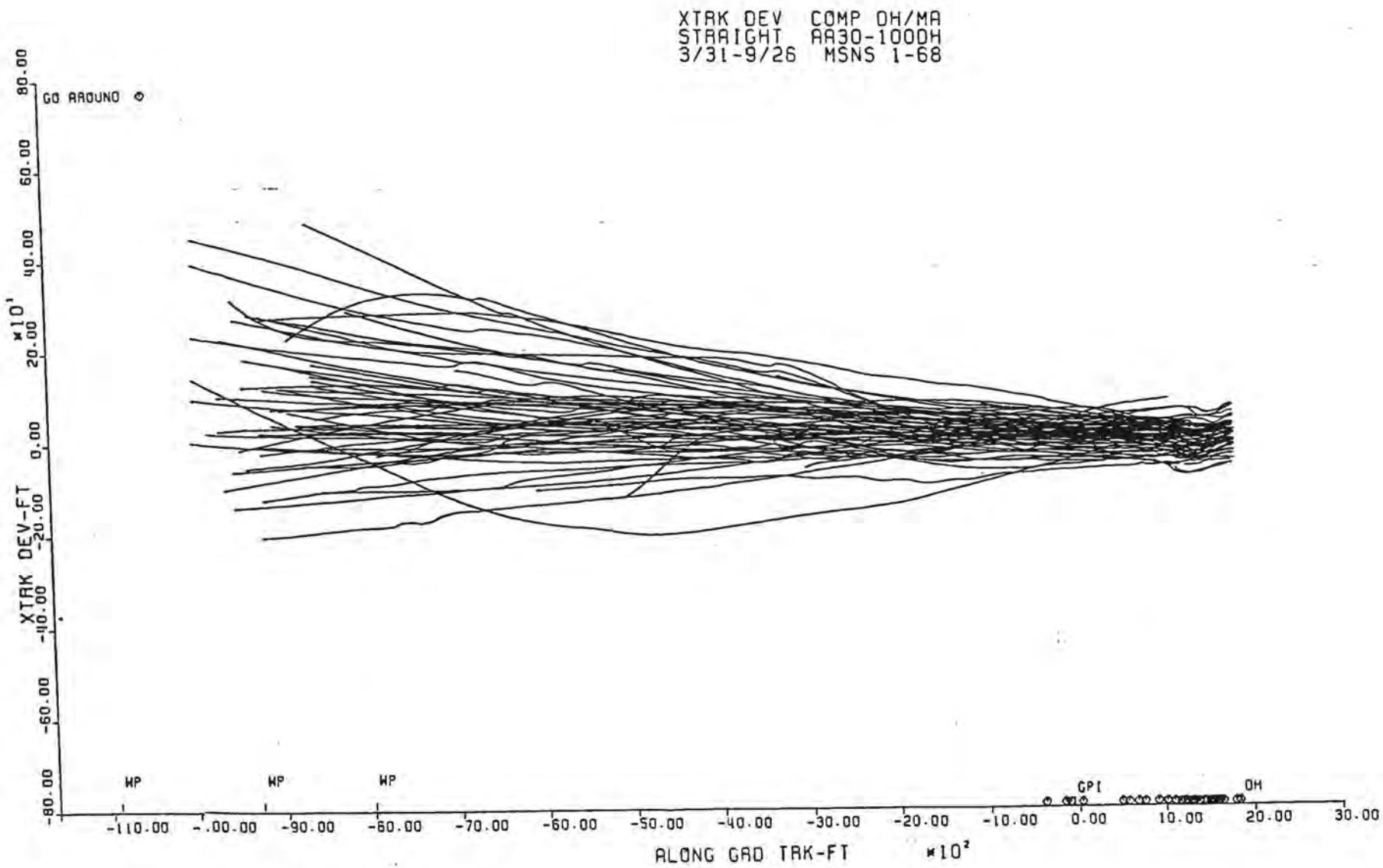

XTRK DEV COMP OH/MA
STRAIGHT AA30-1000H
3/31-9/26 MSNS 1-68
GO AROUND
XTRK DEV-FT ×10¹
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
-60.00
-80.00
WP
WP
WP
GPI
OH
-110.00
-100.00
-90.00
-80.00
-70.00
-60.00
-50.00
-40.00
-30.00
-20.00
-10.00
0.00
10.00
20.00
30.00
ALONG GRD TRK-FT ×10²

Figure 23

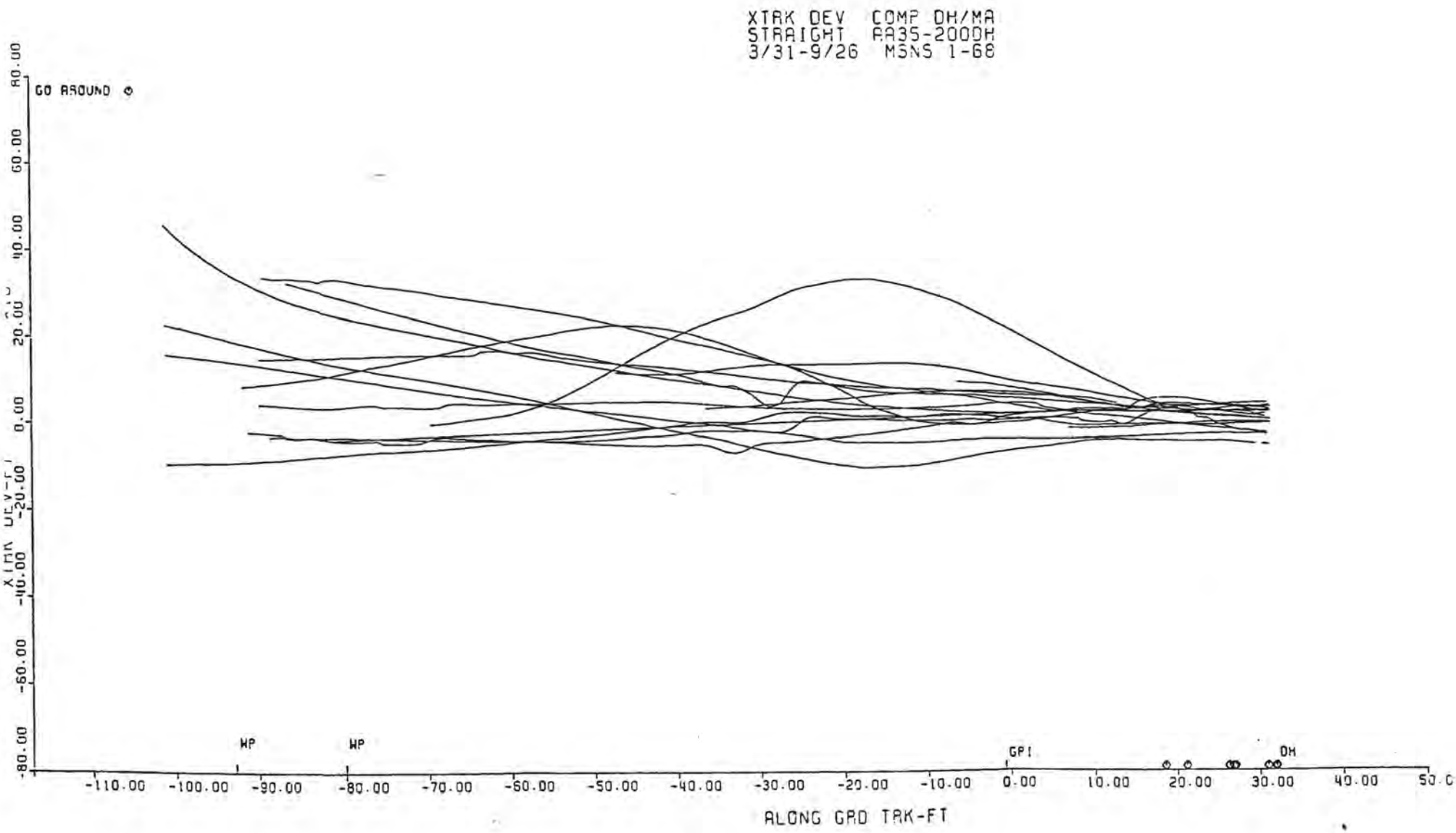

XTRK DEV COMP DH/MA
STRAIGHT RA35-2000H
3/31-9/26 MSNS 1-68
GO AROUND
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
-60.00
-80.00
WP
WP
GPI
DH
-110.00
-100.00
-90.00
-80.00
-70.00
-60.00
-50.00
-40.00
-30.00
-20.00
-10.00
0.00
10.00
20.00
30.00
40.00
50.0
ALONG GRD TRK-FT

Figure 24

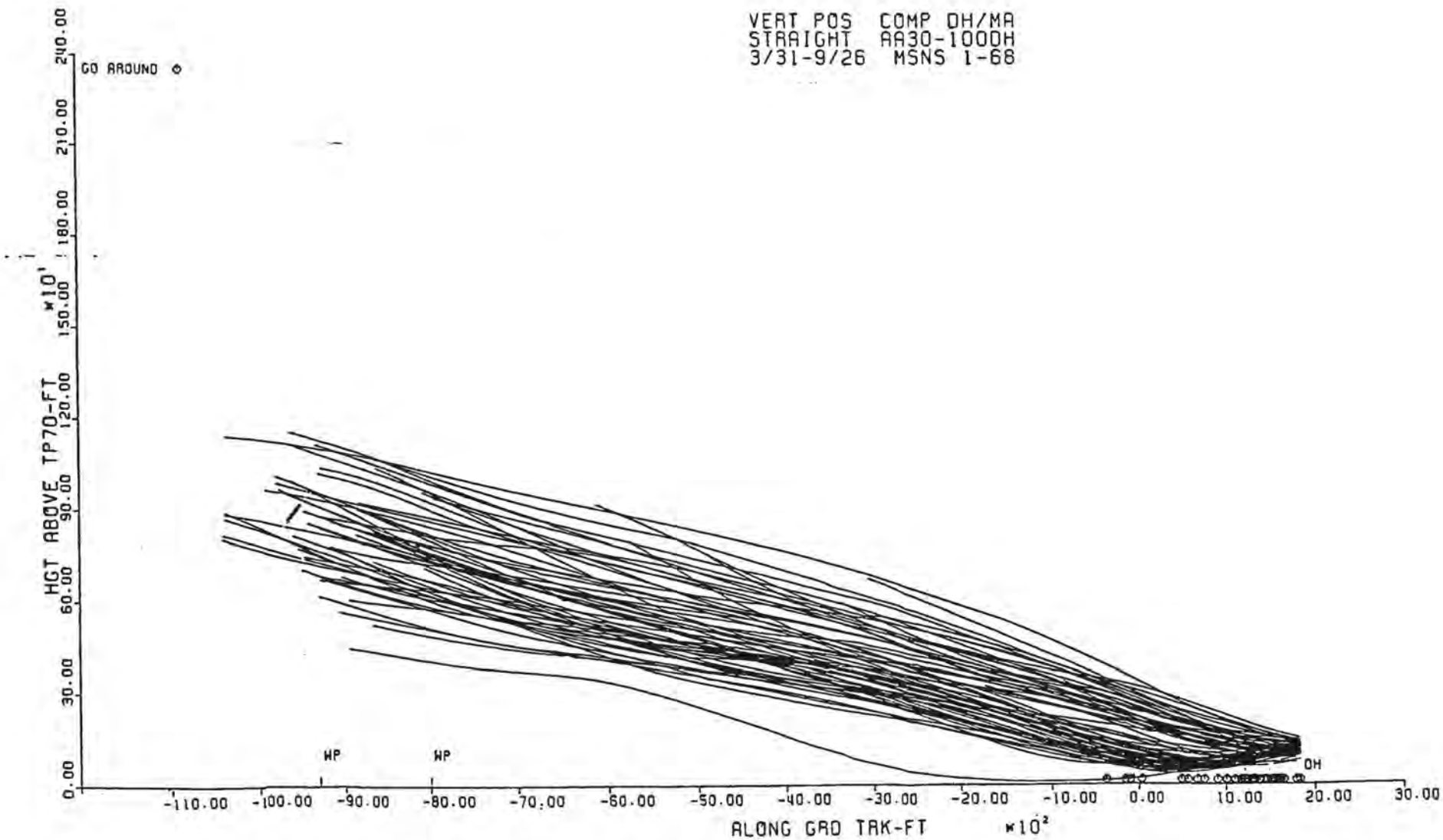

VERT POS COMP DH/MA
STRAIGHT AA30-1000H
3/31-9/26 MSNS 1-68
GO AROUND
HGT ABOVE TP70-FT ×10¹
0.00
30.00
60.00
90.00
120.00
150.00
180.00
210.00
240.00
WP
WP
DH
-110.00
-100.00
-90.00
-80.00
-70.00
-60.00
-50.00
-40.00
-30.00
-20.00
-10.00
0.00
10.00
20.00
30.00
ALONG GRD TRK-FT ×10²

Figure 25

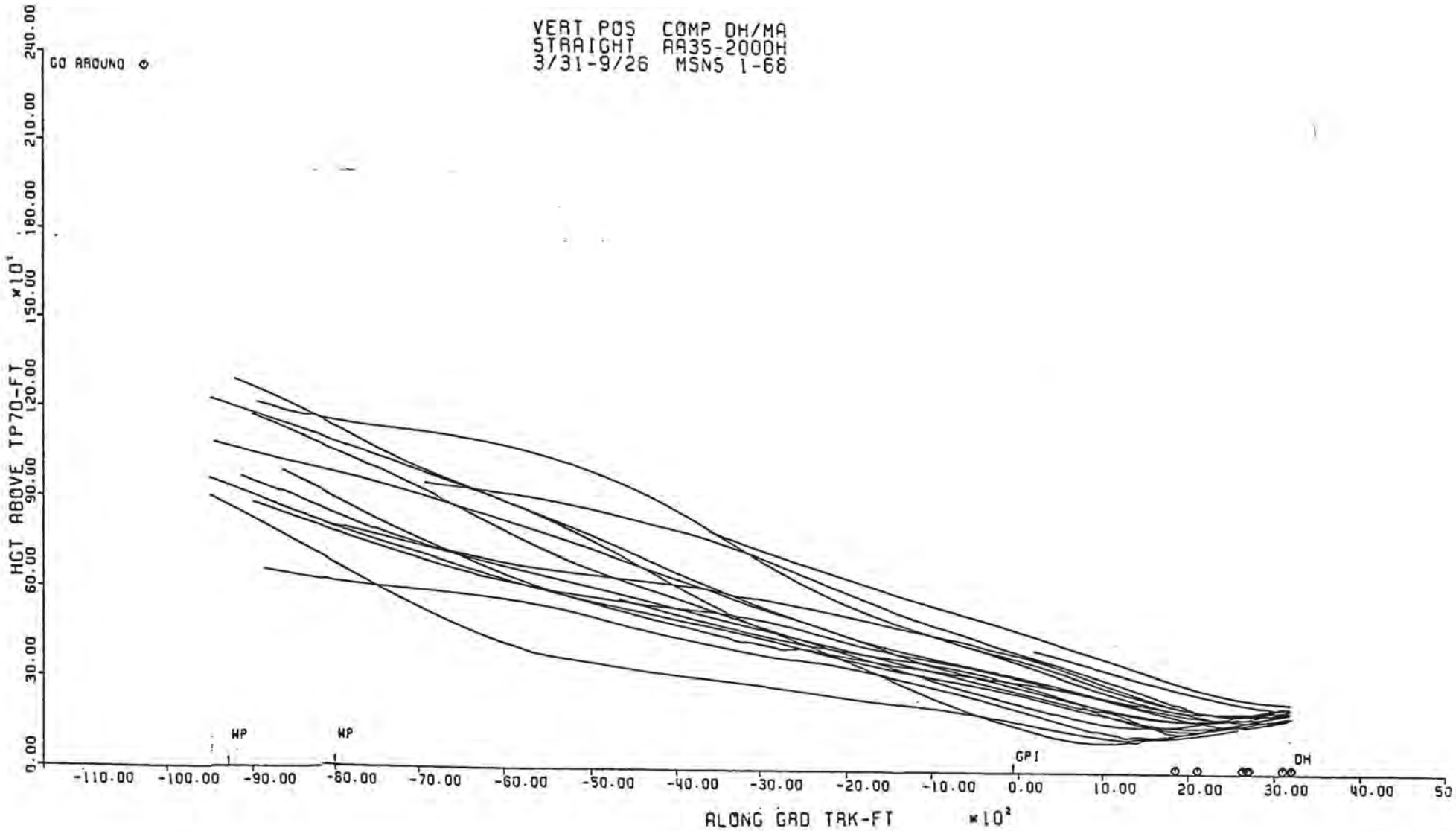

VERT POS COMP DH/MA
STRAIGHT AA35-2000H
3/31-9/26 MSNS 1-68
GO AROUND
HGT ABOVE TP70-FT ×10¹
ALONG GRD TRK-FT ×10²
WP
WP
GPI
DH
0.00
30.00
60.00
90.00
120.00
150.00
180.00
210.00
240.00
-110.00
-100.00
-90.00
-80.00
-70.00
-60.00
-50.00
-40.00
-30.00
-20.00
-10.00
0.00
10.00
20.00
30.00
40.00
50

Figure 26

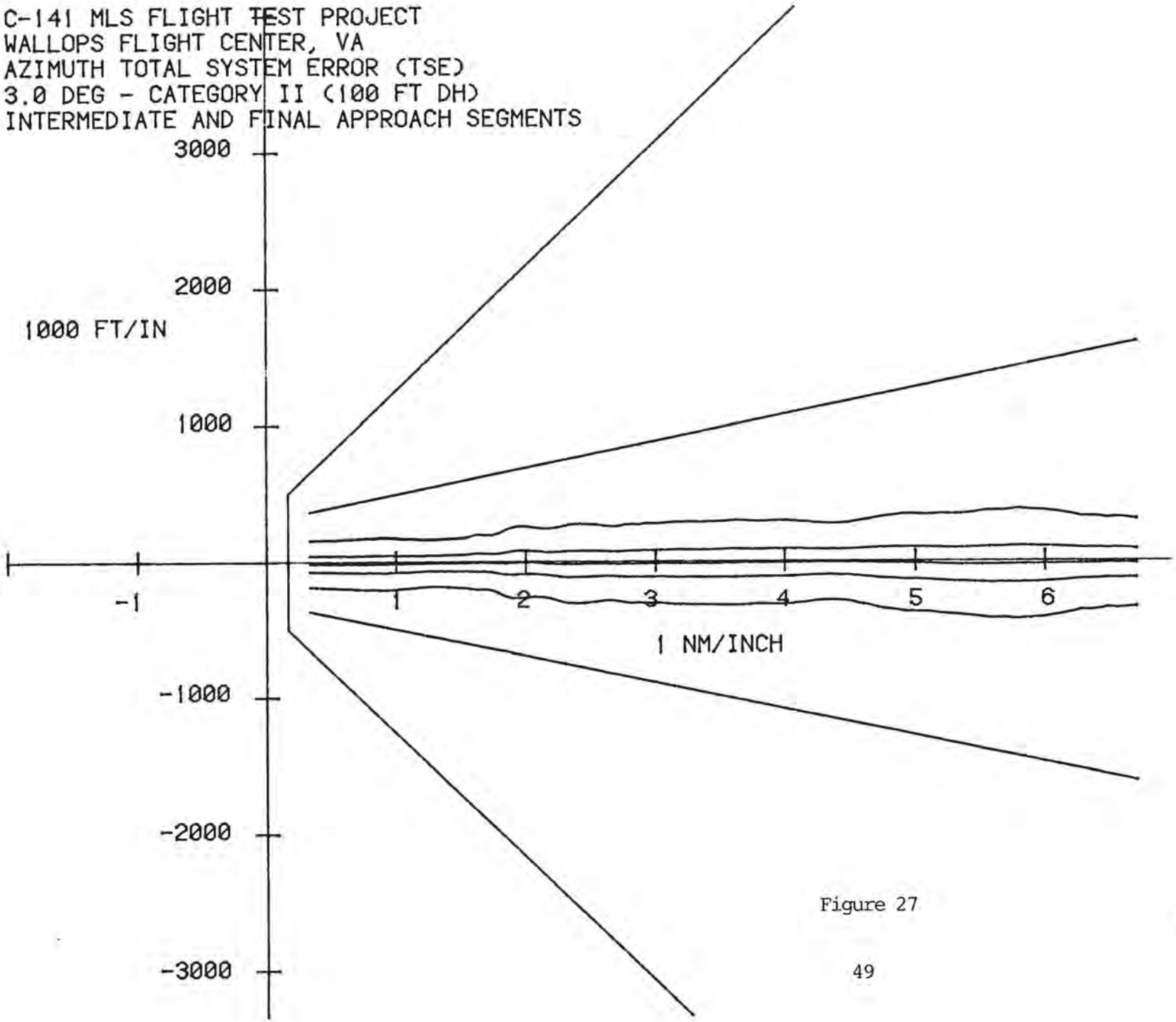

C-141 MLS FLIGHT TEST PROJECT
WALLOPS FLIGHT CENTER, VA
AZIMUTH TOTAL SYSTEM ERROR (TSE)
3.0 DEG - CATEGORY II (100 FT DH)
INTERMEDIATE AND FINAL APPROACH SEGMENTS
3000
2000
1000 FT/IN
1000
-1000
-2000
-3000
-1
1
2
3
4
5
6
1 NM/INCH

Figure 27

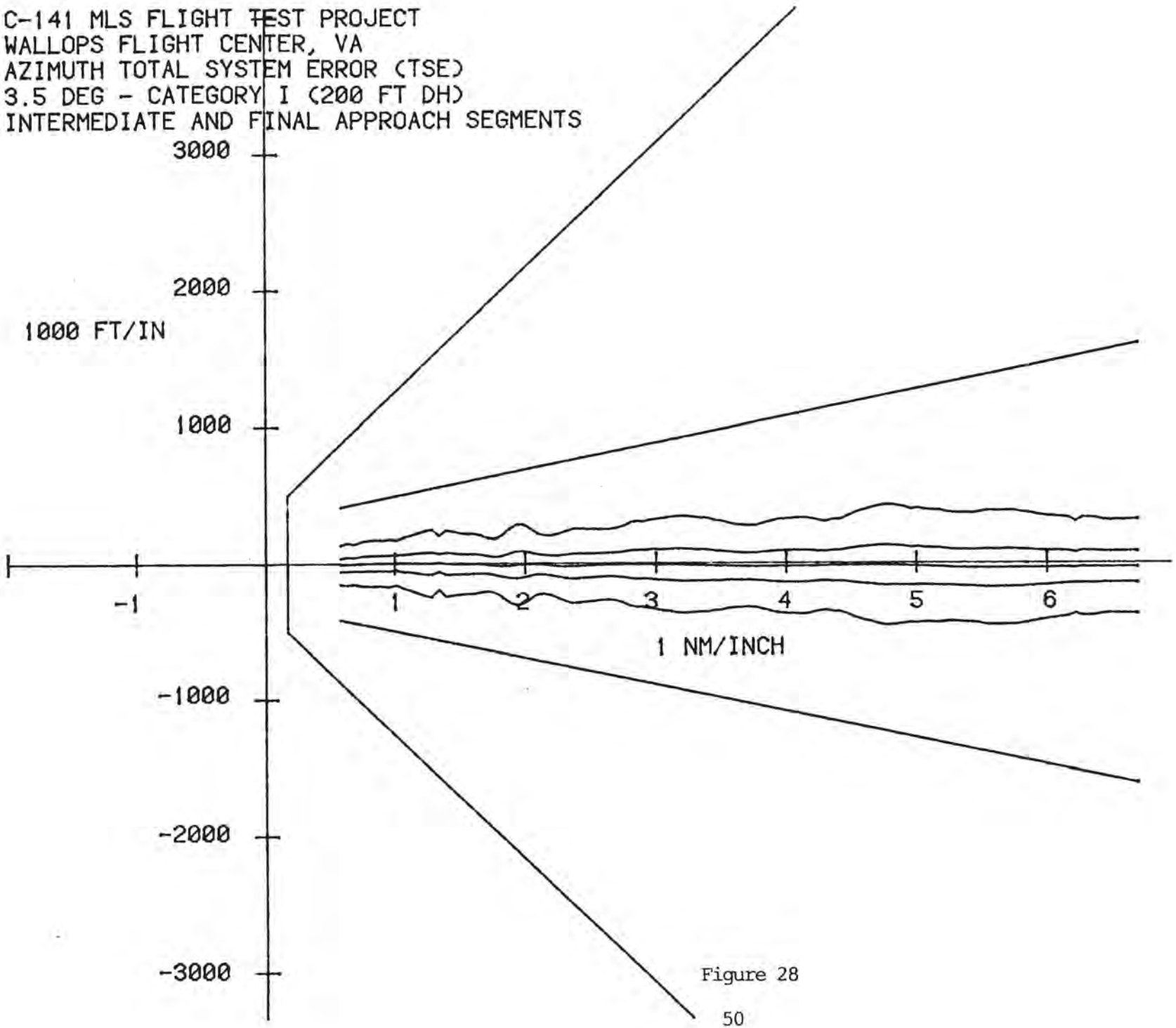

C-141 MLS FLIGHT TEST PROJECT
WALLOPS FLIGHT CENTER, VA
AZIMUTH TOTAL SYSTEM ERROR (TSE)
3.5 DEG - CATEGORY I (200 FT DH)
INTERMEDIATE AND FINAL APPROACH SEGMENTS
3000
2000
1000 FT/IN
1000
-1
1
2
3
4
5
6
1 NM/INCH
-1000
-2000
-3000

Figure 28

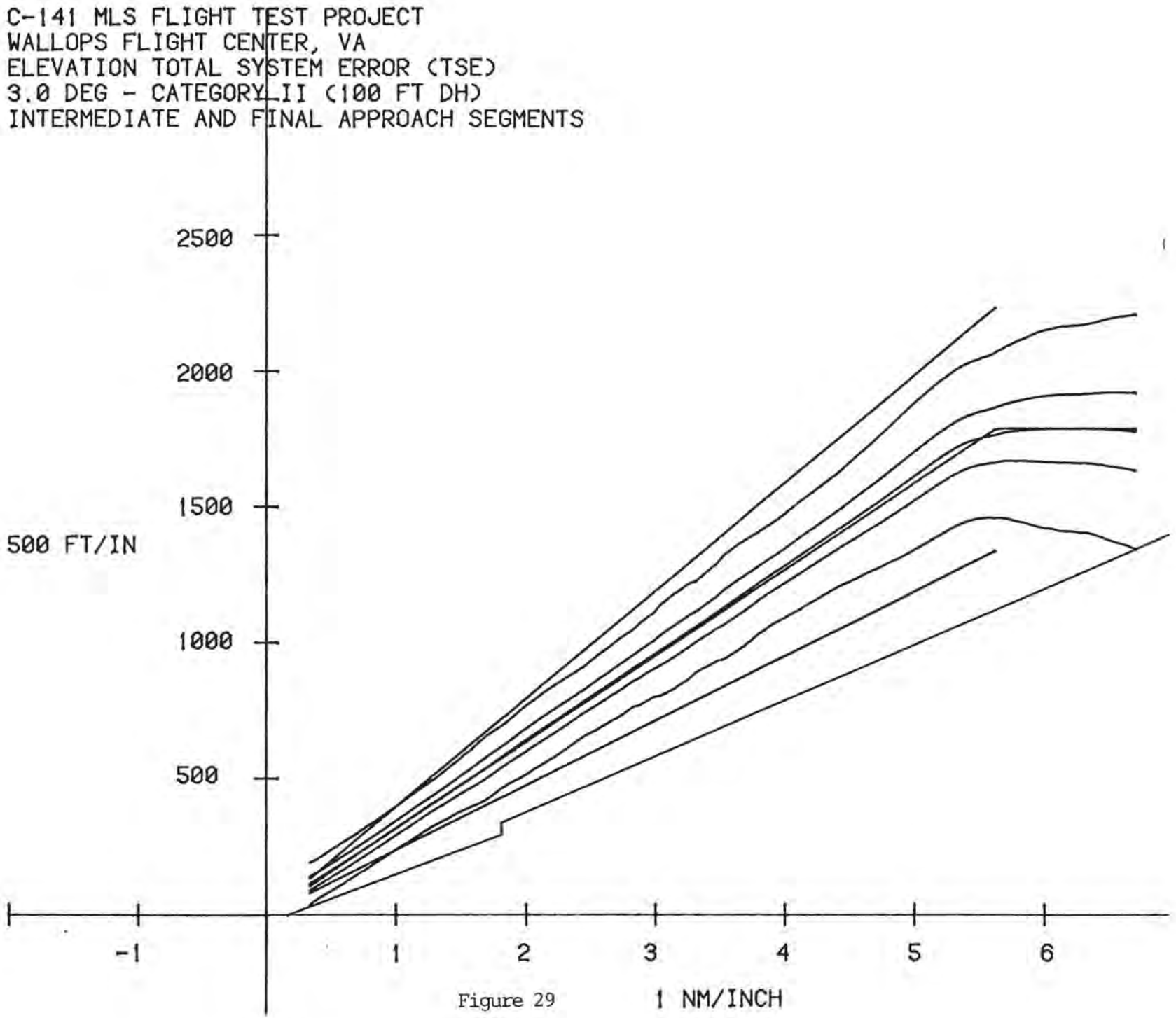

C-141 MLS FLIGHT TEST PROJECT
WALLOPS FLIGHT CENTER, VA
ELEVATION TOTAL SYSTEM ERROR (TSE)
3.0 DEG - CATEGORY II (100 FT DH)
INTERMEDIATE AND FINAL APPROACH SEGMENTS
2500
2000
1500
500 FT/IN
1000
500
-1
1
2
3
4
5
6
1 NM/INCH

Figure 29

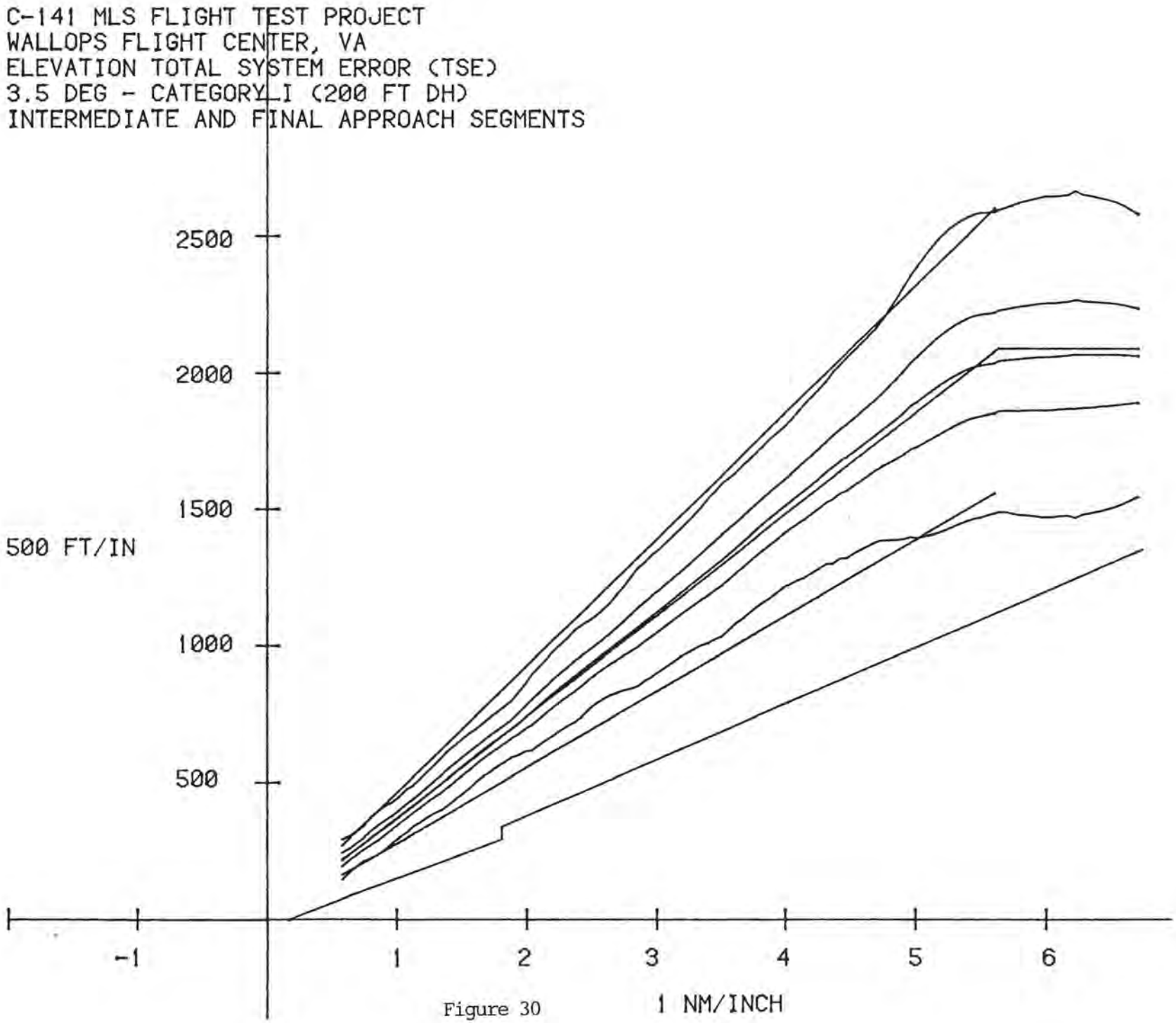

C-141 MLS FLIGHT TEST PROJECT
WALLOPS FLIGHT CENTER, VA
ELEVATION TOTAL SYSTEM ERROR (TSE)
3.5 DEG - CATEGORY I (200 FT DH)
INTERMEDIATE AND FINAL APPROACH SEGMENTS
2500
2000
1500
500 FT/IN
1000
500
-1
1
2
3
4
5
6
1 NM/INCH

Figure 30

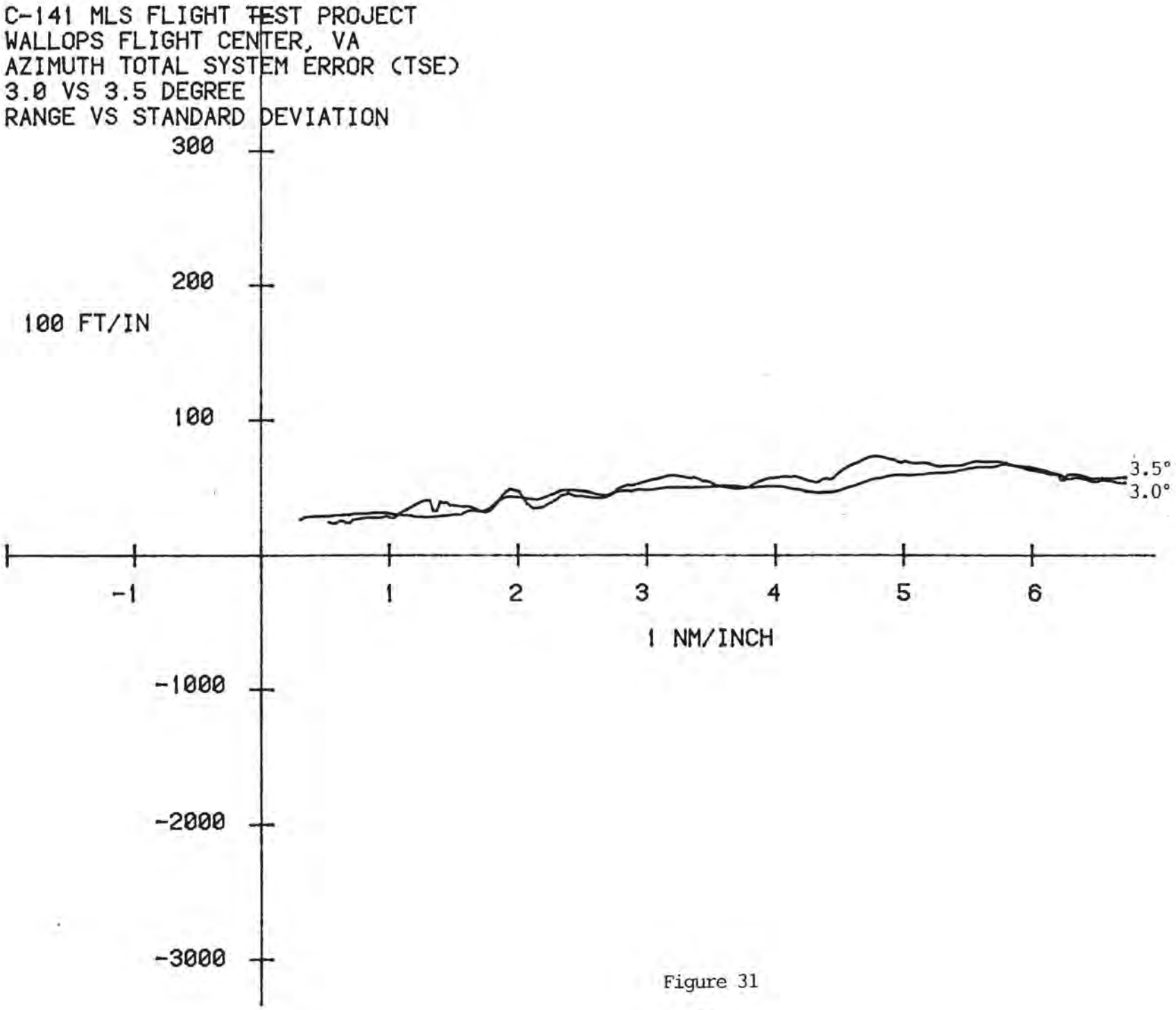

C-141 MLS FLIGHT TEST PROJECT
WALLOPS FLIGHT CENTER, VA
AZIMUTH TOTAL SYSTEM ERROR (TSE)
3.0 VS 3.5 DEGREE
RANGE VS STANDARD DEVIATION
300
200
100 FT/IN
100
-1000
-2000
-3000
-1
1
2
3
4
5
6
1 NM/INCH
3.5°
3.0°

Figure 31

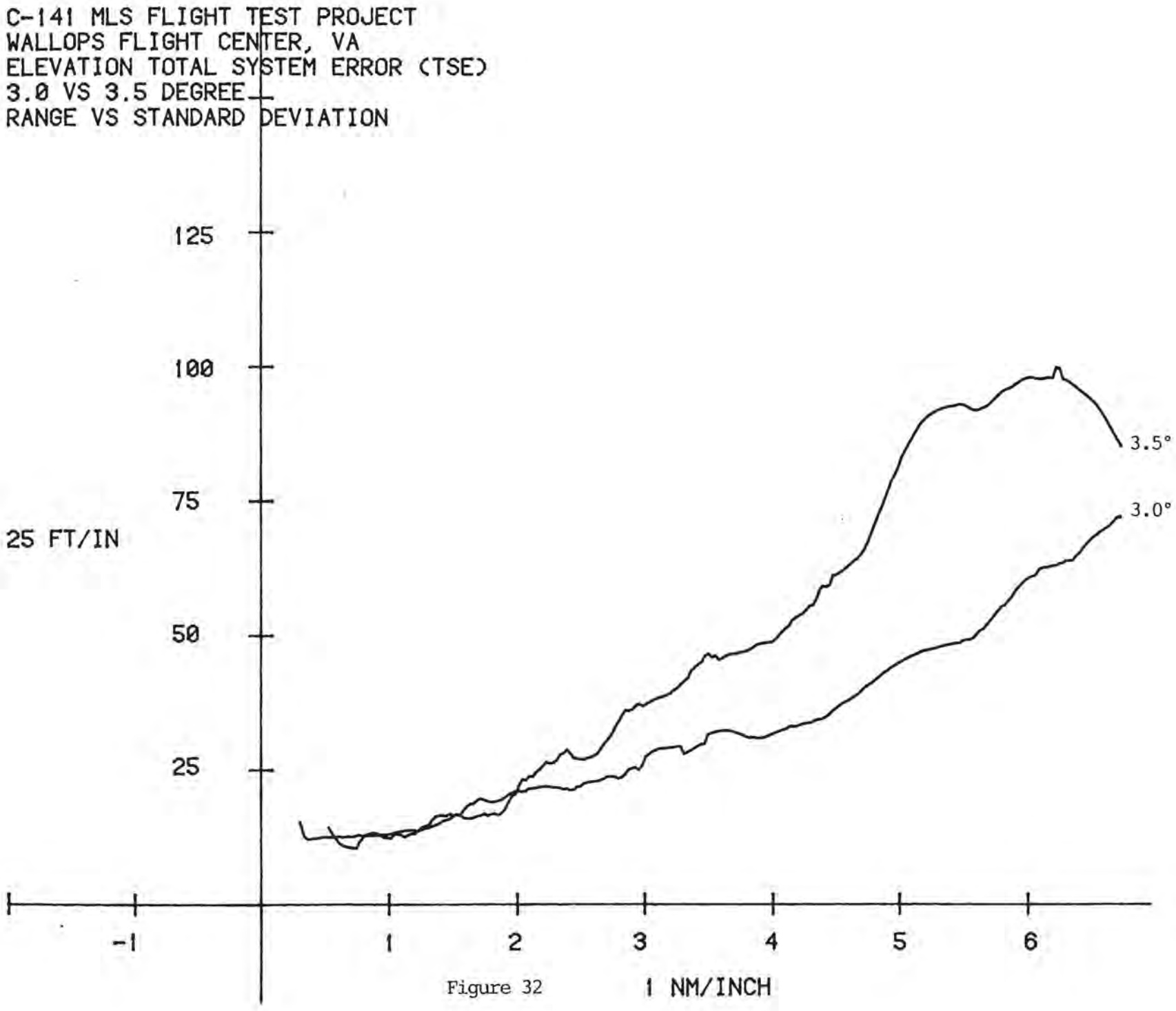

C-141 MLS FLIGHT TEST PROJECT
WALLOPS FLIGHT CENTER, VA
ELEVATION TOTAL SYSTEM ERROR (TSE)
3.0 VS 3.5 DEGREE
RANGE VS STANDARD DEVIATION
125
100
75
50
25
25 FT/IN
3.5°
3.0°
-1
1
2
3
4
5
6
1 NM/INCH

Figure 32

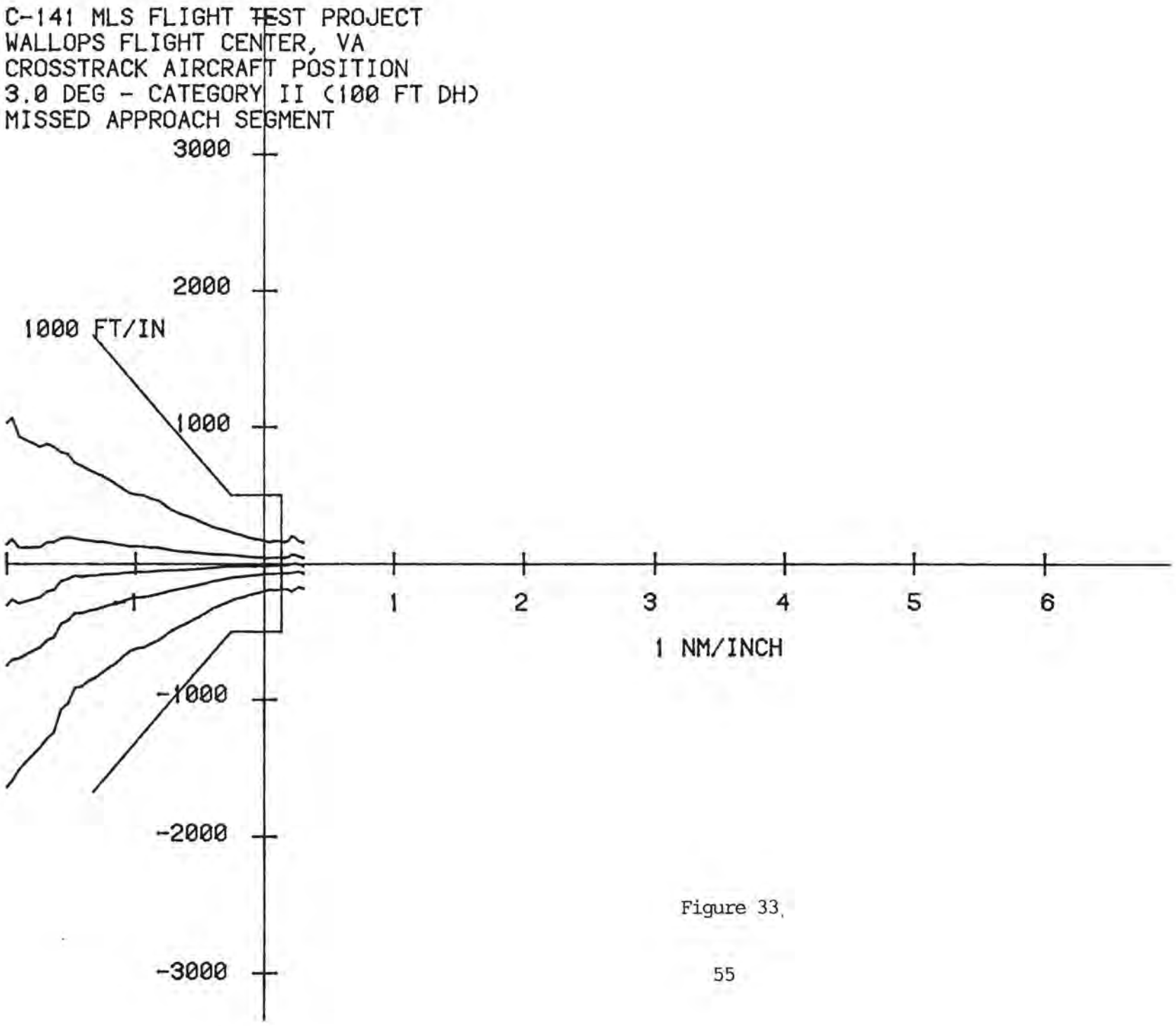

C-141 MLS FLIGHT TEST PROJECT
WALLOPS FLIGHT CENTER, VA
CROSSTRACK AIRCRAFT POSITION
3.0 DEG - CATEGORY II (100 FT DH)
MISSED APPROACH SEGMENT
3000
2000
1000 FT/IN
1000
-1000
-2000
-3000
1
2
3
4
5
6
1 NM/INCH

Figure 33.

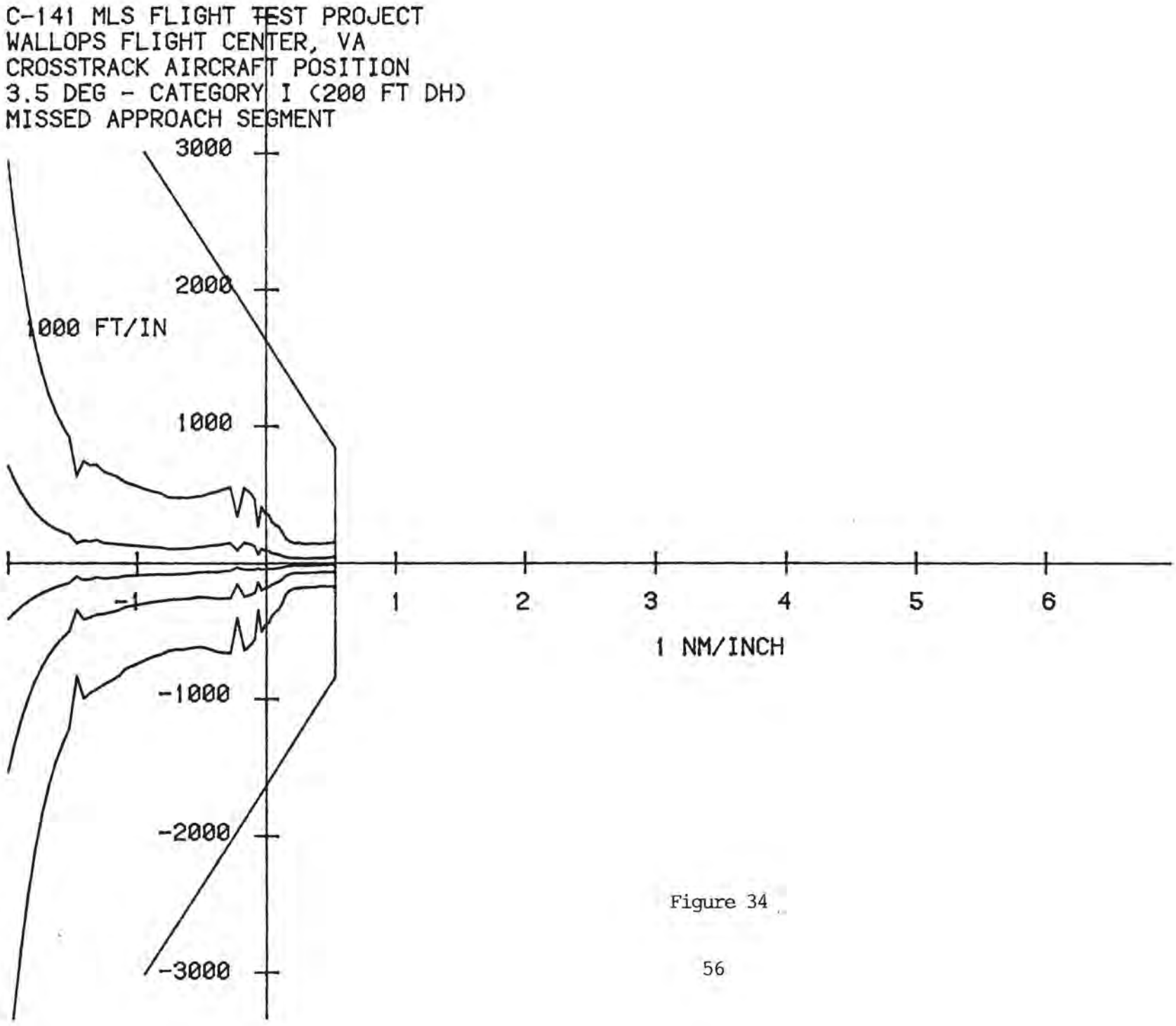

C-141 MLS FLIGHT TEST PROJECT
WALLOPS FLIGHT CENTER, VA
CROSSTRACK AIRCRAFT POSITION
3.5 DEG - CATEGORY I (200 FT DH)
MISSED APPROACH SEGMENT
3000
2000
1000
1000 FT/IN
-1000
-2000
-3000
-1
1
2
3
4
5
6
1 NM/INCH

Figure 34

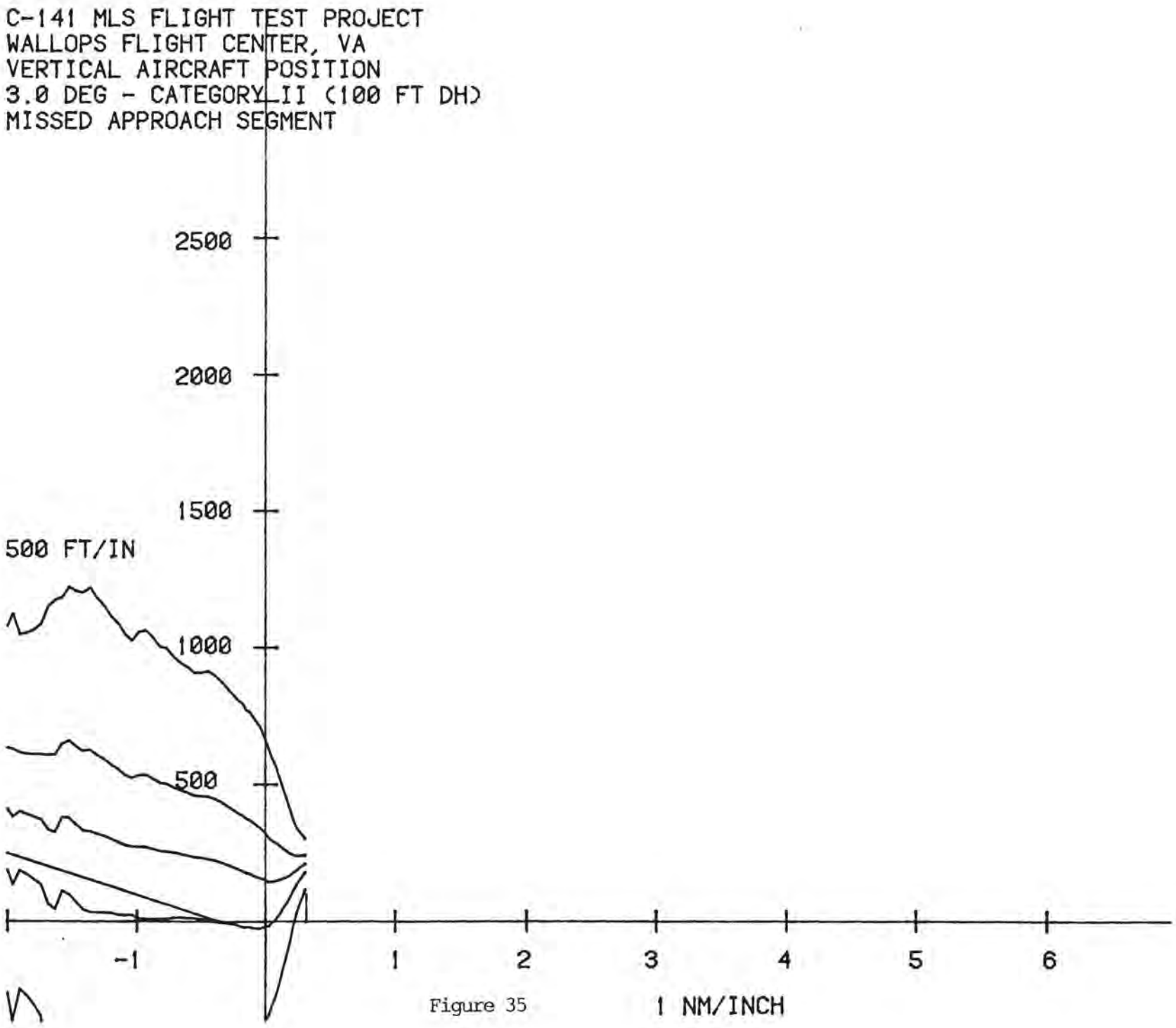

C-141 MLS FLIGHT TEST PROJECT
WALLOPS FLIGHT CENTER, VA
VERTICAL AIRCRAFT POSITION
3.0 DEG - CATEGORY II (100 FT DH)
MISSED APPROACH SEGMENT
2500
2000
1500
500 FT/IN
1000
500
-1
1
2
3
4
5
6
1 NM/INCH

Figure 35

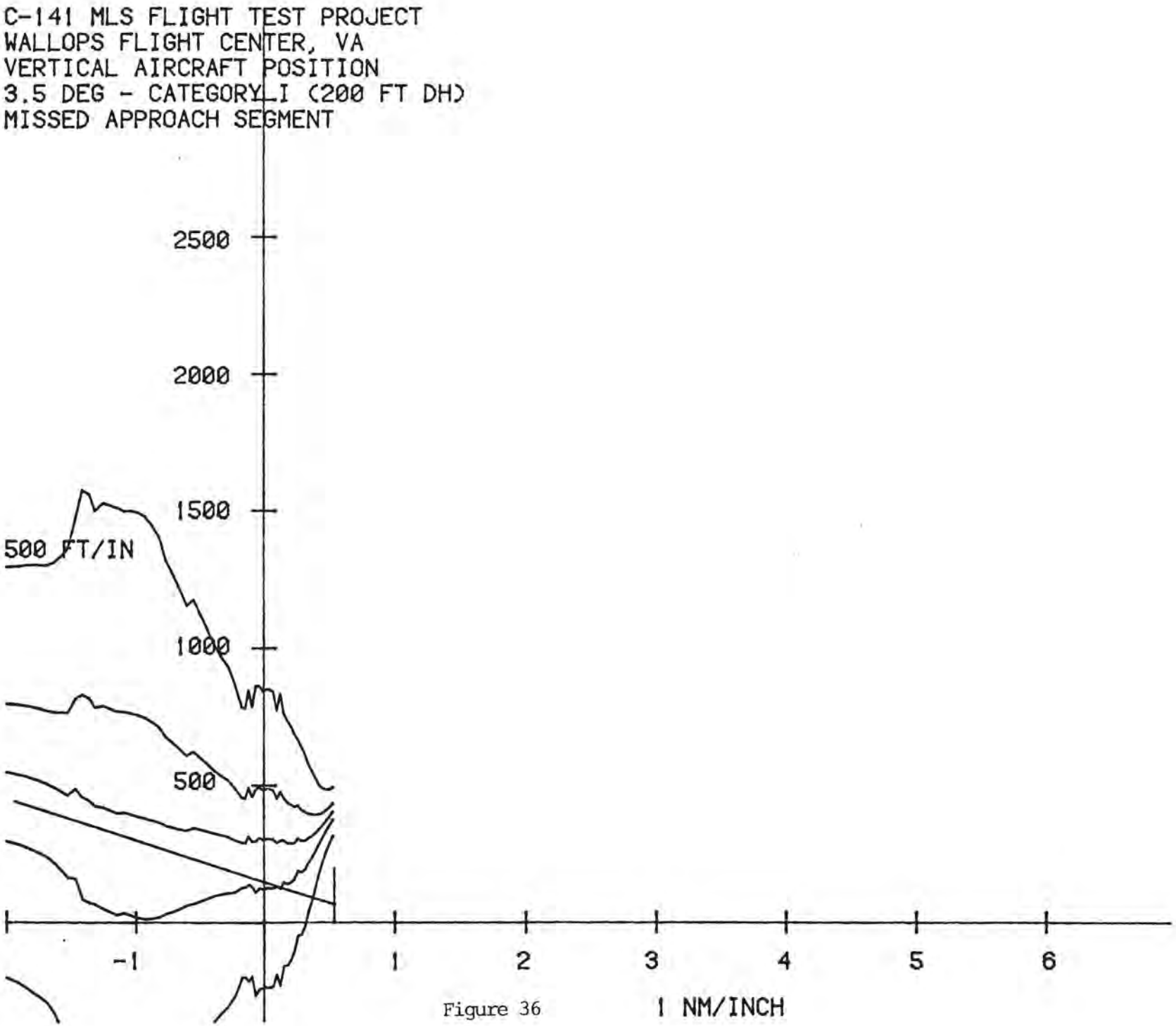

C-141 MLS FLIGHT TEST PROJECT
WALLOPS FLIGHT CENTER, VA
VERTICAL AIRCRAFT POSITION
3.5 DEG - CATEGORY I (200 FT DH)
MISSED APPROACH SEGMENT
2500
2000
1500
1000
500
500 FT/IN
-1
1
2
3
4
5
6
1 NM/INCH

Figure 36