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UNITED AIR LINES

Report of

THE OUT OF SERVICE GUEST PILOT EVALUATION

of the

TWO-SEGMENT NOISE ABATEMENT APPROACH

in the

BOEING B727-200

12 January thru 8 February 1973
and
14-15 May 1973

Prepared for:

THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Moffett Field, California

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OUT OF SERVICE GUEST PILOT EVALUATION

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INTRODUCTION

The B-727 Two-Segment Noise Abatement Approach Program, of which the Guest Pilot Evaluation is an integral and important part, is an operationally-oriented program. Previous studies and evaluations have shown the feasibility of approach profile modification as an effective means of reducing ground level noise under the approach paths to jet aircraft runways.

The principal program objective of the current evaluation is:

> "To fully develop the two-segment landing approach procedures and the equipment which is necessary in order to obtain pilot, airline and FAA acceptance of two-segment flight paths as a routine way of operating airplanes on approach and landing."

Program phases which preceded the Guest Pilot Evaluation addressed themselves to equipment development and to procedures development and profile optimization which were, in the view of the Project Team, safe, repeatable, pilot-acceptable and which significantly reduced ground level noise under the approach path.

Such tangibles as profile geometry, equipment performance, configuration and airspeed scheduling and crew procedures can be quite accurately observed and assessed. Pilot acceptance, on the other hand, is complex and abstract.

The Guest Pilot Evaluation was the first major step taken in the program to test whether the equipment and procedures which had been developed were acceptable to a representative group of industry pilots for further evaluation in the routine air carrier environment.

This report will describe the procedures used for introducing the fifty-seven Guest Pilots to the equipment operation and flight techniques involved in the approach procedure. It draws together the written comments of the group along with certain related statistical data. From this, an attempt has been made to arrive at a consensus (or lack thereof) on safety, workload and pilot acceptance of the procedure which they evaluated.

From this analysis, the conclusions which follow were drawn. Before they were included in this report as conclusions, they were submitted to all of the participating Guest Pilots for their review and comment. They were asked to respond to any specific points or to any conclusion which they felt mis-stated their position. No responses were received.

SUMMARY

The Guest Pilot Evaluation was conducted during the period 12 January to 8 February 1973, and on 14-15 May 1973. One additional foreign carrier (Lufthansa)was represented in mid-October. Ansett Airlines of Australia was represented in the February pilot group. The airline pilots were approximately balanced between pilots serving in management capacities within their companies and regular line pilots, a number of whom were nominated by professional pilot organizations. The FAA pilots were from National Headquarters and the Rocky Mountain and Western Regions. Two major airframe manufactures were represented. The varied backgrounds and industry affiliations of the Guest Pilot Group gave balanced industry representation. It was felt that this balance would insure that any unique concerns by the individual sectors of the industry would be objectively evaluated and represented in the program results.

Based on the very favorable results of the Guest Pilot Evaluation, the prototype installation was made in a regular UAL B727-222 (N7640U) and placed into line service for a six-month evaluation by UAL line pilots in regular air carrier service.

SUMMARY OF GUEST-PILOT EVALUATION CONCLUSIONS

I. Is the procedure safe?

A. A significant majority of the evaluation pilot group found the procedure to be as safe as the standard ILS procedure after they had completed the evaluation process (briefing, simulator and aircraft or briefing and aircraft).

B. The system as evaluated provides adequate vertical guidance for use in IFR.

C. The crew procedures and techniques required to fly the two-segment approach are not significantly different from the standard ILS in any way which degrades safety.

D. The profile transitions are safe and easy to fly. The speed change during glideslope transition does not appear to create an unacceptable trim or power control problem.

E. The typical engine power setting required for tracking upper segment under representative goundspeed conditions is acceptable. Under conditions requiring the use of full anti-ice capabilities, the procedure would not be recommended.

F. Upper segment rates of descent are acceptable except under some tailwind conditions.

G. The nominal glideslope transition and stabilization altitudes are acceptable.

II. Is the procedure pilot-acceptable?

A. The two-segment approach is generally as easy to fly as the standard ILS approach.

B. Instrument scanning and airspeed control are slightly more difficult in the two-segment approach. There is no significant difference in other major cockpit activity between the two types of approach.

C. The pilot would be familiar and competent to fly the procedure in IFR weather after a few approaches in the aircraft.

D. Crew workload is generally not increased. It appears to increase slightly under the following conditions:
(1) Tailwinds
(2) In the upper segment capture regime, configuration cues are slightly later than these same cues on the standard ILS.

(3) Instrument scanning and interpretation require additional pilot attention and concentration.
(4) Airspeed must be closely monitored during glideslope transition.

E. Autothrottles are not required for the two-segment approach.

F. Overall energy management and configuration scheduling are acceptable.

III. <u>Are cockpit instrument displays and annunciations adequate?</u>

A. The annunciator display and sequencing are acceptable.

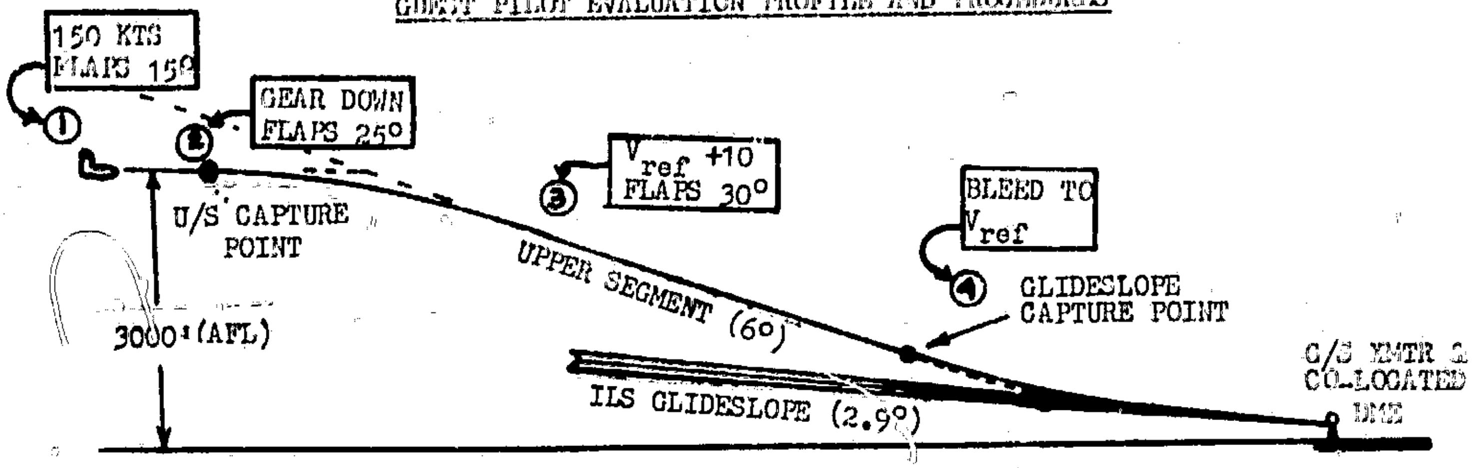
B. The vertical guidance display is acceptable.

C. Differences exist regarding the combination of raw and computed vertical deviation displays on the ADI and HSI. These differences can be accommodated by interface and minor equipment modifications.

D. The cockpit location of system controls, annunciators and switches is acceptable for a single-system installation.

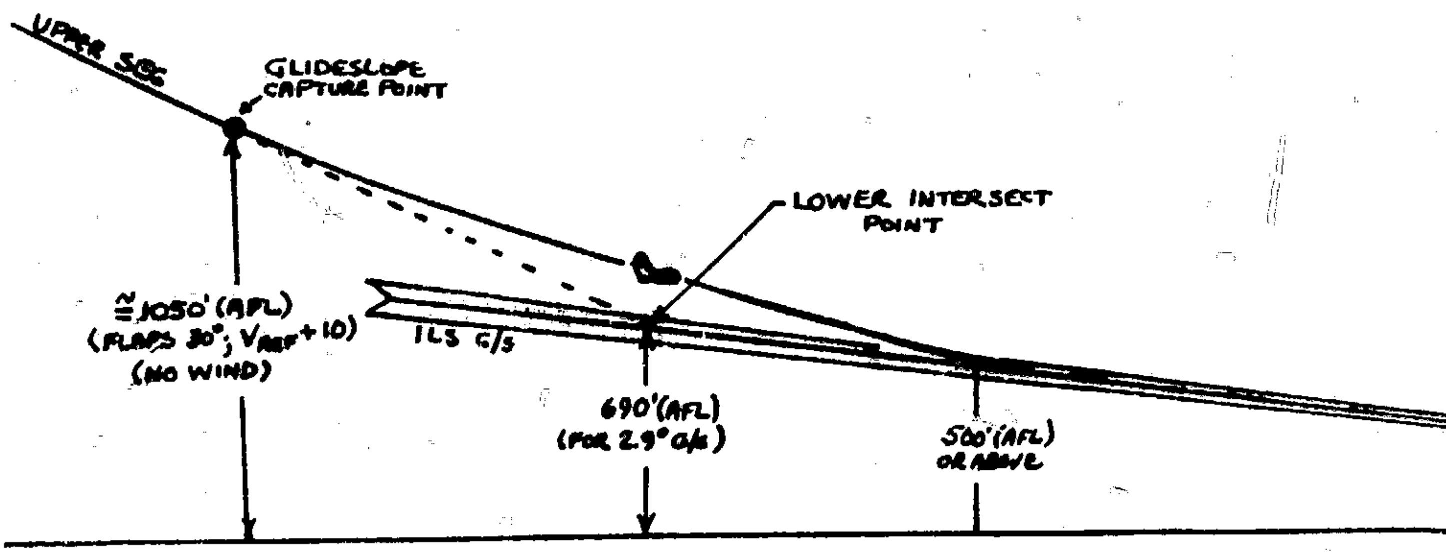
[redacted]

GUEST PILOT EVALUATION PROFILE AND PROCEDURES



The diagram above shows the basic profile and procedures which were used in the Guest Pilot Evaluation.

The diagram below expands the detail in the glideslope transition portion of the profile.



Except in one instance in which conditions required the flight to operate at Reno, all of the evaluation flights were conducted at Stockton. None of the flights involved icing or significant upper segment tailwind components.

GUEST PILOT EVALUATION

B727-200

PART I - ~~Eval~~

EVALUATION PROCEDURES, RECORDED DATA AND PARTICIPATING PILOTS

~~Evaluation Procedure~~

~~Recorded Date Analysis - General~~

Participating Pilots

GUEST-PILOT EVALUATION Criteria ~~PROCEDURE AND PILOT OPINION ANALYSIS~~

General

The Guest Pilot phase was conducted in order to obtain evaluations of the two-segment procedure from a representative sample of industry pilots. To maximize comparability among the individual evaluations, most of the participating pilots were given the same briefing, simulator familiarization session and evaluation flight in the airplane.

Each pilot was asked to complete the two-part questionnaire shown in Figures 1 and 2 after his simulator and/or airplane flights.

The simulator flight had three principal objectives:

(1) To permit the Guest Pilot to practice the two-segment procedure and flight techniques and to familiarize him with the use of the special cockpit hardware needed for setting up and managing the two-segment system.

(2) To provide the pilot a basis for direct comparison between the two-segment and standard ILS procedures by flying a prescribed mix of the two types of approaches in a concentrated time period.

(3) To permit any participating pilot who was not flying the B727 regularly to become familiar with its flight and handling characteristics and cockpit controls and instrumentation.

The airplane flight was designed to be the best test of three important items:

(1) Did the Guest Pilot consider the two-segment approach compatible with his experience in flying instrument approaches?

(2) Is the procedure generally adaptable to his own company or organization established operating procedures?

(3) Was the procedure acceptable for further evaluation in the day-to-day revenue service environment?

A total of 57 pilots participated in the Guest Pilot Evaluation. Not all of these submitted questionnaires. The pilot opinion analyses are based on 45 airplane questionnaires and 37 simulator questionnaires.

In the questionnaire summaries and analyses which follow in this report, it must be recognized that however objective a question might be, or however objectively the respondent may answer it, there is always the possibility that a response may be at least partially mis-interpreted in the process of grouping individually worded narrative answers under a few broadly-worded general categories. For this reason, the verbatim responses upon which the analyses and conclusions have been based are contained in Appendices I and II.

RANKED ITEM	Standard ILS Approach			Two-Segment Approach	
	Significantly Easier	Slightly Easier	No Difference	Slightly Easier	Significantly Easier
A. Autopilot Usage					
B. Flight Dir. Following					
C. Instrument Interpretation					
D. Flt. Progress Annunciation					
E. Inst. Scanning Requirements					
F. Airspeed Control					
G. Flap Management					
H. Trim Control					
I. Pre-App. Cockpit Set-up					
J. Radio Communications					
K. Check List Management					

FIGURE 1 - GUEST PILOT QUESTIONNAIRE - PART I

1. WOULD YOU LIKE TO SEE ANY CHANGES MADE TO THE EXISTING ANNUNCIATION DISPLAY? IF YES, WHAT CHANGES?

2. WOULD YOU LIKE TO SEE ANY CHANGE IN THE INSTRUMENT DISPLAY? IF YES, WHAT CHANGES?

3. IS THERE ANY DIFFERENCE IN OVERALL FLIGHT SAFETY BETWEEN THE STANDARD ILS AND THE TWO-SEGMENT ILS? IF SO, WHAT?

4. A. DO YOU FEEL THE TWO-SEGMENT APPROACH YOU HAVE FLOWN CAN BE FLOWN IN NORMAL LINE OPERATION?

   B. WHAT FACTORS ARE INVOLVED IN YOUR ANSWER TO 4-A?

5. WHAT IS YOUR OPINION OF THE TRANSITION TO THE UPPER SEGMENT?

6. WHAT IS YOUR OPINION OF THE TRANSITION TO THE GLIDESLOPE?

7. HAVING FLOWN SOME TWO-SEGMENT APPROACHES AS A PASSENGER, DO YOU FEEL THERE WOULD BE ANY ADVERSE PASSENGER REACTION TO THIS APPROACH? IF SO, WHY?

FIGURE 2 -GUEST PILOT QUESTIONNAIRE - PART 2

Pre-Simulator Briefing and Simulator Familiarization Period

Forty-five of the participating pilots flew both the simulator and the aircraft. These pilots received a one and a half hour briefing and a familiarization period in the flight simulator at the UAL Flight Training Center in Denver, Colorado. Generally, two pilots were scheduled for this briefing and simulator period, and they usually remained together to fly in the aircraft. Each Guest Pilot was teamed with a Project Pilot. Where possible, the same Project Pilot also flew with him in the aircraft at San Francisco the next day or the day following. This was considered particularly desirable because, having observed the Guest Pilot in the simulator, he was in the best position to judge any substantial differences between the pilot's simulator and aircraft performances.

The pre-simulator briefing was devoted principally to discussing the two-segment profile and procedures, flight techniques and a discussion of equipment management and operation. Included in this briefing was an audio-visual package which described the function and operation of the two-segment hardware, procedures for configuring the cockpit for the approach and information concerning interpretation of the progress annunciations and instrumentation. Appendix IV was furnished to each pilot and discussed in the briefing.

The simulator period consisted of eleven approaches which were flown generally in the order shown below. The ILS approaches were the lead-off so that the pilot could become familiar with the flight and handling characteristics of the simulator before attempting to fly the two-segment approach.

The simulator permitted instantaneous slewing to selected initial positions, altitudes and headings. For the eleven approaches described below, the following starting conditions were used:

STANDARD ILS - On localizer centerline, on runway heading, 1800'(AFL), 10 N.M. from touchdown (Except #1).

TWO-SEGMENT - On localizer centerline, on runway heading, 3000'(AFL), 10 N.M. from touchdown.

APPROACH #	DESCRIPTION
1	STANDARD ILS - FLIGHT DIRECTOR Take off, manually flies downwind. Turns in for localizer intercept at approximately 10 N.M.
2	STANDARD ILS - AUTO COUPLED Glideslope capture 135 KIAS.
3	TWO-SEGMENT APPROACH - AUTO COUPLED Upper segment capture at 135 KIAS.
4	TWO-SEGMENT APPROACH - FLIGHT DIRECTOR Upper segment capture at 135 KIAS.
5	TWO-SEGMENT APPROACH - AUTO COUPLED - AUTOTHROTTLE Upper segment capture at 135 KIAS.
6	STANDARD ILS - FLIGHT DIRECTOR Upper segment capture at 160 KIAS.
7	TWO-SEGMENT - FLIGHT DIRECTOR Upper segment capture at 160 KIAS.
8	STANDARD ILS - FLIGHT DIRECTOR Upper segment capture at 160 KIAS, Crosswind 90°/20 KTS gusting to 30 KTS.
9	TWO-SEGMENT - FLIGHT DIRECTOR Upper segment capture 160 KIAS. Crosswind 90°/20 KTS dying off to calm at touchdown.
10	APPROACH OF GUEST PILOT'S CHOICE
11	TWO-SEGMENT - AUTO COUPLED Upper segment capture at 135 KIAS.

The above 11 simulator approaches required 1.5 hours per pilot. While one Guest Pilot was flying, the other Guest Pilot observed. The Project Pilot Observer occupied the First Observer seat while his Guest counterpart was flying. He took notes and recorded pilot comments as they happened.

A de-briefing to discuss any questions was held after the simulator period.

Approach Syllabus

Evaluation Aircraft Flight

There was a one and a half hour pre-flight briefing prior to going to the airplane. This briefing was devoted to the general plan for the flight and a brief review of procedures and techniques. The differences in the simulator flight director (Collins FD-109A) and the Ansett Aircraft (Collins FD-108) were also discussed.

Stockton was the primary evaluation airport and was used whenever weather conditions permitted. In a few cases, Reno was used because Stockton conditions were not acceptable.

The pilots flew the approaches described below. In most cases, these were flown in the order shown, so that the comparison of performance on the first, second, third, and sixth approaches could be made.

Approach #	Description
1.	Standard ILS, Flight Director, Manual Throttles to Missed Approach.
2.	Two-Segment, Flight Director, Manual Throttles to Missed Approach.
3.	Same as #2 above.
4.	Two-Segment, Auto-Coupled, Auto Throttles to Missed Approach.
5.	Same as 4 above.
6.	Two-Segment, Flight Director, Manual Throttles to Missed Approach.
7.	Standard ILS, Auto-Coupled, Auto Throttles to Touch-and-go.
8.	Two-Segment, Auto-Coupled, Auto Throttles to Full Stop.

Data - GENERAL
~~STATISTICAL~~ ANALYSIS ~~- RECORDED DATA~~

General - Data records were taken on each of the Guest Pilots in the simulator and/or in the aircraft.

The simulator records were in the form of a 14-channel oscillograph trace and a real-time (once each second) line printer record and X-Y profile and noise plots. Figure 3 shows the format of the oscillograph record and the parameters recorded. Figure 4 is a typical simulator line printer record. Figure 5 is a typical X-Y profile and noise plot. These records were used in the simulator de-briefing session. They were not normalized for group performance analysis.

Figure 6 shows a portion of a typical approach record processed from the aircraft digital recorder data. All approaches were similarly recorded and processed. The analyses appearing in this report are based on aircraft data only. The recorded data analysis will not directly influence the conclusions which are drawn regarding pilot opinion. Just as the opinion analysis derived from the questionnaires is intended to reflect group opinion on certain matters, it is considered equally germane to show how well the group actually performed the tasks involved in flying the two-segment approach.

In selecting the approaches which were used in the statistical sample, the individuals who made the selections did not know who the particular pilots were. They did not have any idea (or way of knowing) what the specific questionnaire responses were, nor did they know, even in general terms, what the questionnaire analysis would show. They employed completely impartial and valid statistical criteria for the sample selection.

A statistical sample of 252 approaches of all kinds was selected. They were sorted first on an approximate ratio of a given type of approach to the total evaluation approaches flown. From this first cut, the approaches that were finally selected were those made under approximately the same meteorological and other conditions which would maximize statistical comparability. The distribution of the sample is as follows:

	Approaches
Flight Director, ILS	32
Flight Director, 2-segment	97
Auto coupled, Manual Throttle ILS	27
Auto coupled, Manual Throttle 2-segment	54
Auto coupled, Autothrottle 2-segment	42
Total	252

Certain statistical analyses were made using the entire statistical sample above. The results of these analyses in tabular form are included in Appendix III.

An additional detailed analysis was made in order to determine the following:

(1) How well did the group fly the two-segment approach?

(2) How well did they perform their first Flight Director two-segment approach as compared with the ILS flown immediately prior?

(3) What was the rate and degree of improvement between the first, second and third Flight Director two-segment approaches? (These were the second, third and sixth approaches flown in the aircraft)

(4) How does the pilot workload in flying the two-segment approach compare with the ILS workload?

For this analysis, comparisons have been made of the following approaches:

First Approach	- Flight	Director,	Standard ILS		
Second	"	"	"	Two-Segment	
Third	"	"	"	"	"
Sixth	"	"	"	"	"

In order to make this analysis, a statistical sample from the Flight Director ILS and the Flight Director two-segment approaches had to be selected. As in the previous sample selection, certain statistical criteria were employed. A critical review of the Flight Director ILS and two-segment approaches in the 252-approach sample was made. Because direct comparisons between approaches were to be made, a major selection criterion was that a given pilot (known to the selectors only by a number) must have completed all of the prescribed approaches in the aircraft in the order such that the first approach was a Flight Director standard ILS and that his second, third and sixth approaches were Flight Director two-segment approaches. Since the sample was necessarily going to be relatively small (because the total 97 two-segment approaches would be divided among the second, third, sixth and other approaches), it was necessary also to insure that any set of approaches selected did not contain any unacceptably wide or unusual variations which would unduly influence the smaller statistical sample.

The statistical sample for this analysis consists of the Flight Director ILS and two-segment records of 19 Evaluation Pilots. While this might seem a small sample, the plotted data from this sample compares very closely with the plotted data from the larger statistical sample.

The plots which appear later in this report graphically portray certain normalized data. The interpretation, analysis and conclusions will accompany each plot.

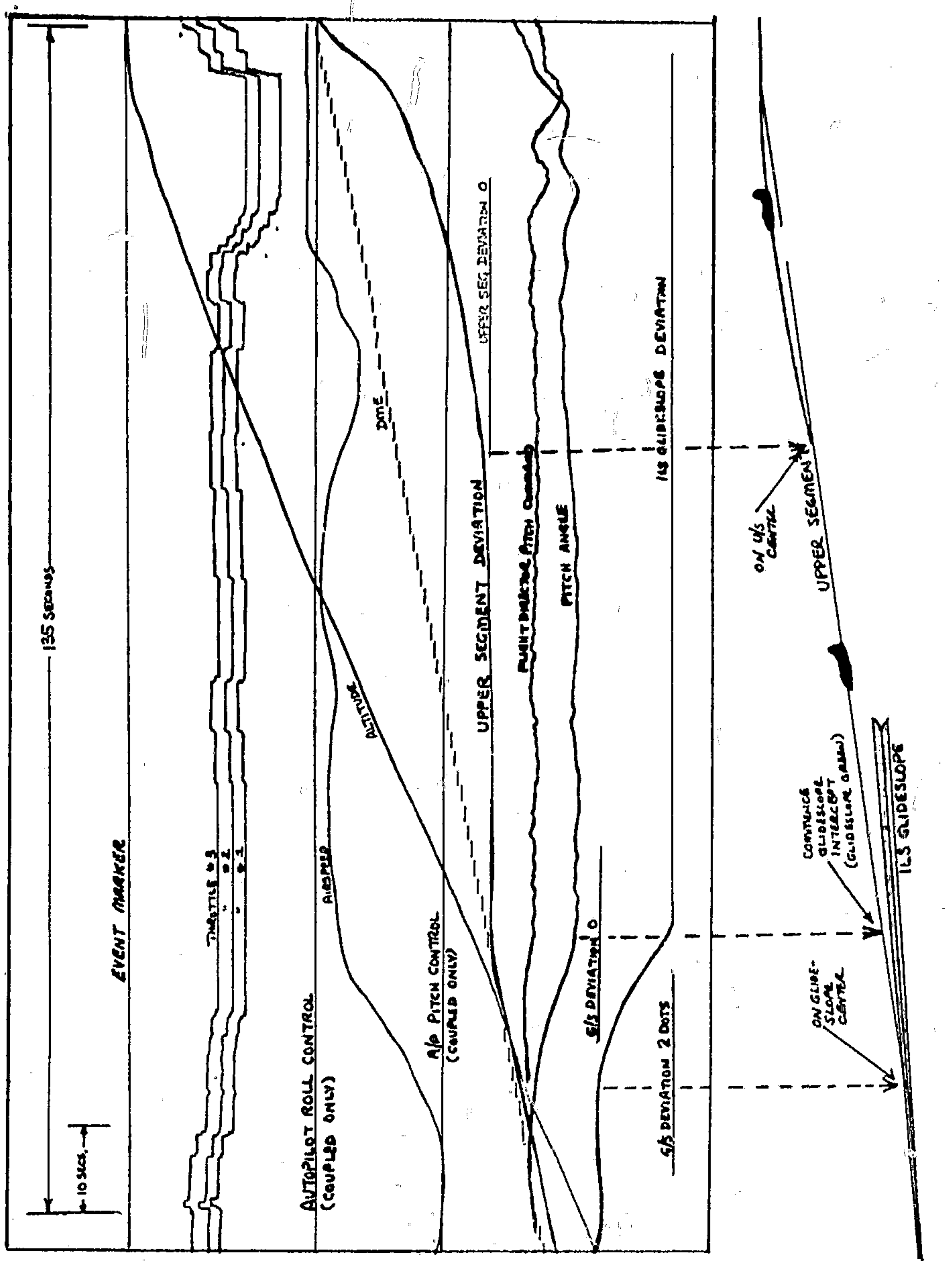
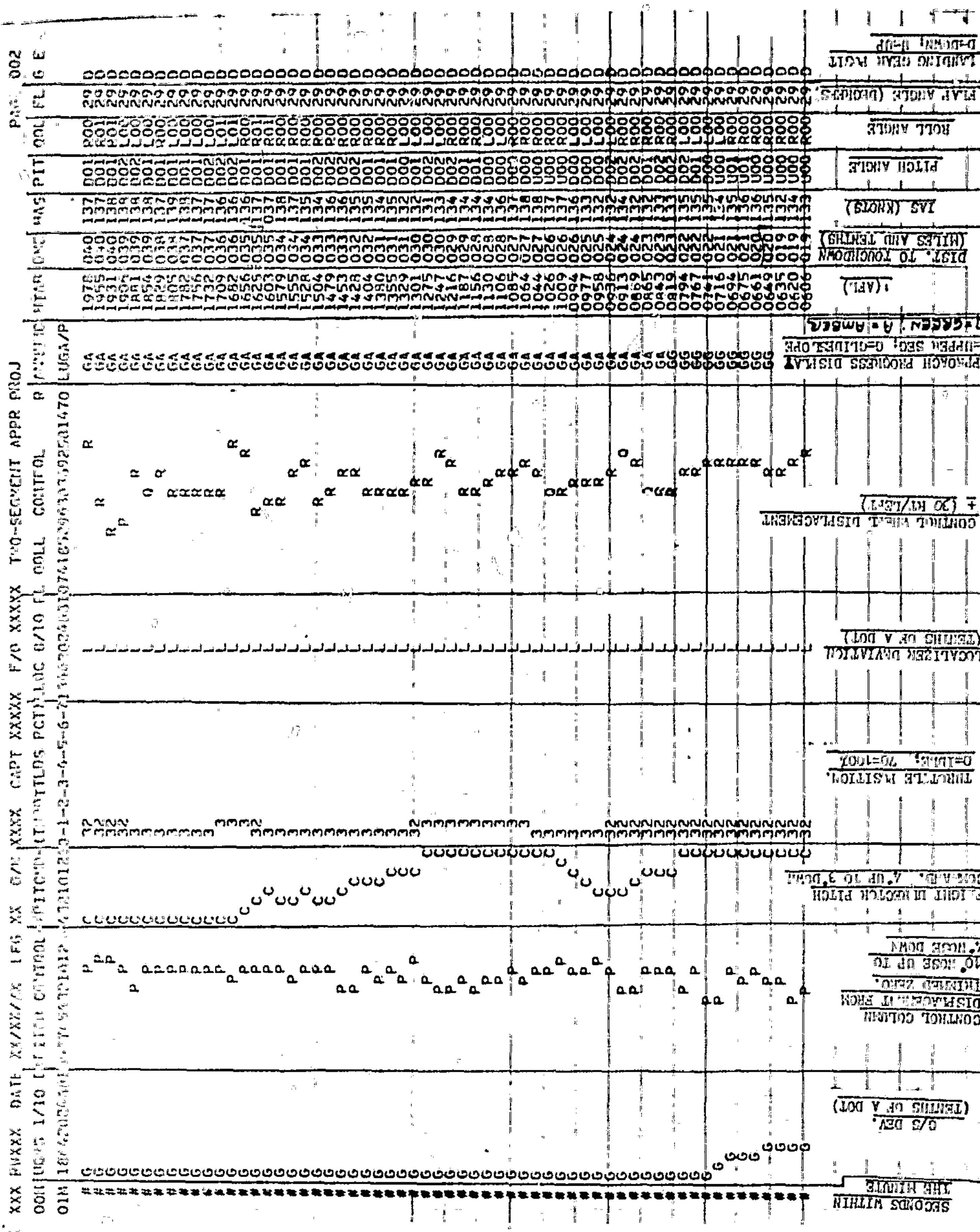


FIGURE [illegible] - TYPICAL FLIGHT SIMULATOR 14-CHANNEL OSCILLOGRAPH RECORD



Note: Additional detail on this program contained in UAL 727 2-Segment Engineering Sim. Eval Report

FIGURE 4 - TYPICAL FLIGHT SIMULATOR LINE PRINTER RECORD (F/D 2-SEGMENT)
(DATA PRINT-OUT ONCE EACH SECOND)

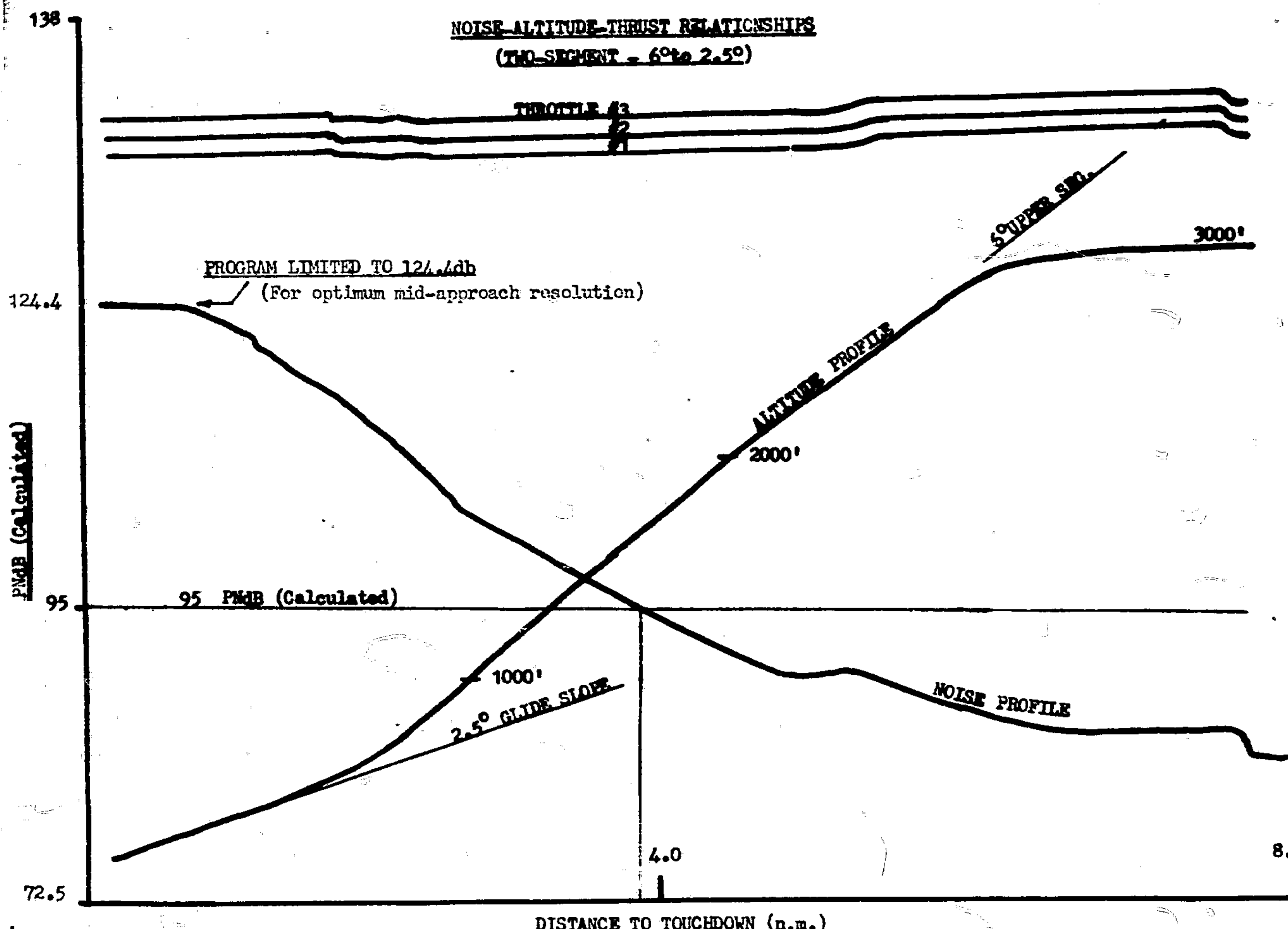


FIGURE 5 - TYPICAL X-Y ALTITUDE AND NOISE PROFILE PLOTS - FLIGHT SIMULATOR

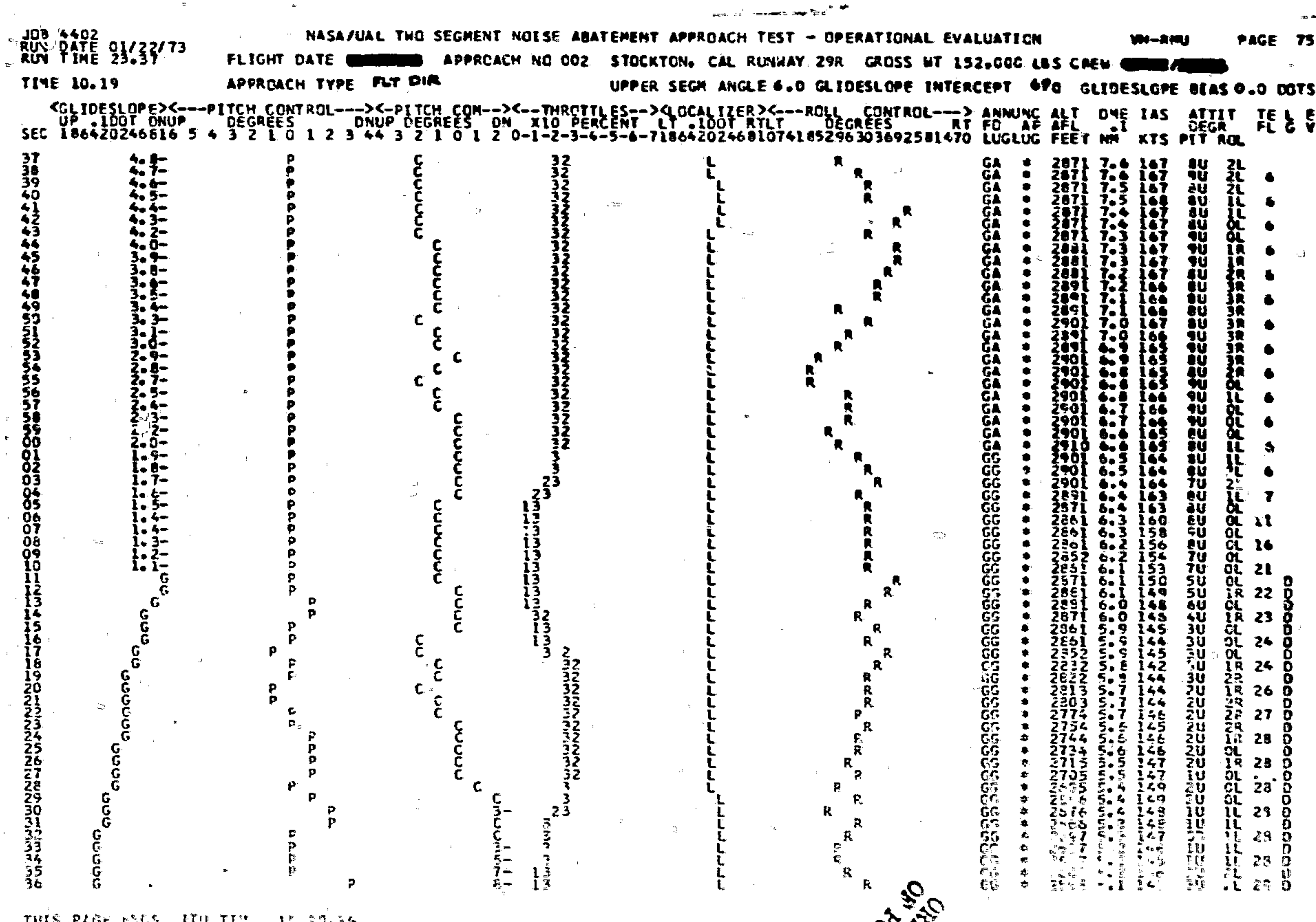


FIGURE 6 - TYPICAL RECORDED DATA FROM EVALUATION AIRCRAFT (2-SEG FLT DIRECTOR)

PARTICIPATING PILOTS

PROJECT PILOT TEAM

The pilot and flight engineer group within the program team was charged with the development of operationally sound procedures using the Collins special-purpose 2-segment approach system. The principal members of this group were:

Captain Howard G. Mayes - Vice President, Flight Technical Services. The senior corporate officer involved directly with the program. Provided overall program policy guidance through George Schwind, Program Director.

Captain Bob Stimely - UAL 727 Fleet Manager and Manager of 727 Flight Procedures and Development. Involved in establishing operational criteria for equipment design and in establishing the operational constraints in procedures development.

Fred Drinkwater - NASA Pilot. Participated actively in the planning and development phases and in the Engineering Flight Evaluation. Articulated principal NASA concerns related to overall operational program goals.

John "Mo" Morrison - Lead Project Pilot. Headed up the Project Pilot and Project Flight Engineer team at Denver. Directed project pilot team effort in test plan development and Simulation and Engineering Flight Evaluations.

Project Pilots and Flight Engineers -

Tom Branch - Project Pilot
"Monty" Monteith - " "
Floyd Snyder - " "

Vince Hagan - Project Flight Engineer
George Martin - " " "
Dave Walkinshaw - " " "

Jim Bugbee - FAA Western Region Engineering Pilot. Conducted the Non-Interference STC flights on both the Ansett B727-277 and UAL B727-222 prototype installations.

Pilots Participating in the Guest Pilot Evaluation During the Period 1/12/73 - 2/8/73

	SIMULATOR	AIRCRAFT
AMERICAN		
Capt. Frank McCormick	1/15	1/16
Capt. Al Reeser	1/24	1/25
ANSETT AIRLINES OF AUSTRALIA		
Capt. A. F. "Dusty" Lane	2/6	2/7
ATA		
Bill Russell	1/30	2/1
BOEING SEATTLE		
Brian Wygle	1/18	1/20
BRANIFF		
Capt. Bruce Douglass	1/12	1/14
Capt. John Pieburn	2/5	2/6
CONTINENTAL		
Capt. Wayne Fisher	1/26	1/27
Capt. Carl Rogers	1/30	1/31
Capt. Bill Lively	2/7	2/8
EASTERN		
Capt. Jim Cousins	1/31	2/1
Capt. Bruce Putney	2/3	2/4
FAA		
Ivan Behel	1/19	1/21
Gayle Mace	1/21	1/22
Joe Ferrarese	1/24	1/25
Dick Sliff	-	1/24 (At LAX)
Charlie House	-	1/24 "
Sal Nucci	-	1/24 "
Phil Nisgore	-	1/24 "
Jim Baker	1/28	1/29
Ralph Noltemeier	1/31	2/1
Dick Skully	2/4	2/5

MC DONNELL-DOUGLAS (Long Beach)

Roger Sanders	1/13	1/14
Bill Casey	2/3	2/4

NATIONAL

Capt. Charlie Caudle	2/4	2/5

NORTHWEST

Capt. Don DeBolt	1/16	1/17
Capt. Ed Johnson	1/16	1/18
Capt. John Carlson	2/2	2/3

PAA

Capt. Jack Teters	1/29	1/30
Capt. Jack Wilson	1/29	1/30

PSA

Capt. Don Coney	1/30	1/31

TWA

Capt. Gordon Granger	1/25	1/26
Capt. Joe Harris	1/27	1/28

WESTERN

Capt. Ed Richardson	-	2/7

USAF

Major Ken Dyson	1/19	1/20

UNITED

Capt. Walt Matsui	1/12	1/13
Capt. G. H. "Dag" Dorward	1/15	1/16
Capt. Howard Mayes	-	1/17
Capt. H. E. "Tat" Tatman	-	1/17
Capt. Mel Volz	1/18	1/19
Capt. Bob Collins	1/22	1/23
Capt. Ray Lahr	1/22	1/23
Capt. Frank Cowles	-	1/24 (At LAX)
Capt. Warren Mugler	1/25	1/26
Capt. Jim Gates	1/26	1/27
Capt. Bob Patterson	1/27	1/28
Capt. Ernie Burmeister	1/28	1/29
Capt. Gerry Zimmerman	2/2	2/3

Capt. Lloyd Troece	2/5	2/6
Capt. Ernie Maulsby	2/6	2/8
Capt. Gene Tritt	2/7	2/8

The WAL On-Line aircraft was taken out of service on 14-15 May for noise measurements at Stockton. During this period, the following additional pilots evaluated the procedures:

DELTA		
Capt. Ray Daniel	-	5/15
EASTERN		
Capt. Al Cleaver	5/14	5/15
UNITED		
Capt. George Henderson	-	5/15
AMERICAN		
Capt. Bernie Wohl	-	5/15
LUFTHANSA		
Capt. Robert Salzl (Dr. Johann-Peter Hach)	10/16	10/17

In addition to the above, the following pilots evaluated the procedures in the simulator on the dates shown:

11/11/72	Capt. Bob Stimely (UAL) Capt. Bob Patterson (UAL ALPA Central Safety Committee Chairman)
11/27/72	Mr. Lynn Mayfield (FAA) Mr. Ivan Behel (FAA)
12/ 6/72	Mr. Bob Westhoff (FAA) Mr. Bob Ramage (FAA)
12/11/72	Capt. T.G. Foxworth (PAA)
12/29/72	Capt. John Kirk (Alaskan)

PART II

~~GUEST PILOT~~ EVALUATION RESULTS

~~Is the Procedure Acceptably Safe~~

Is the Procedure Pilot Acceptable

Cockpit Instrumentation and Displays

~~GUEST PILOT~~ EVALUATION RESULTS

Analysis Criteria - General

To arrive at the conclusions relating to the Guest Pilot acceptance of the two-segment system and procedures, two esentially independent source inputs were analyzed:

(1) Pilot responses to Part 1 and certain Part 2 responses and combinations of responses were analyzed to determine pilot opinion as objectively as possible. Where there was follow-up correspondence, this was considered in the pilot opinion analysis.

(2) The recorded data from the aircraft was statistically analyzed. The actual statistical data appears in Appendix III.

Some conclusions are the net result of considering some portion of the statistical data and certain pilot comments. Others are derived either from pilot comments or statistical data alone. The nature of the conclusion will usually suggest the source from which it is derived.

With the varied backgrounds and industry affiliations of the Guest Pilot Group, it was recognized that the individual pilots would probably base their opinions of the operational acceptability of the equipment and procedures on those specific factors which are most characteristic of their industry involvement. The Pilot Questionnaire attempted to gather specific information relating to factors which it was felt would enter into all, or nearly all, of the individual pilots' assessments. In broad terms these are:

(1) Is the developed procedure acceptably safe for use in the routine air carrier operational environment?

(2) Given a reasonable introduction to the system management and to the procedures, is it acceptably easy to manage and to fly?

(3) Do the cockpit instrument displays and annunciations provide the pilot with all of the information he needs to fly the approach with confidence under IFR conditions?

The analyses which follow will be grouped under the three broad categories above. This does not imply that they are totally independent considerations. They are, in fact, interrelated. They have been broken down to make it easier to understand the analysis rationale. Each analysis has been given appropriate weight in any conclusion to which it pertains.

SAFETY OF THE PROCEDURE

~~IS THE PROCEDURE ACCEPTABLY SAFE?~~

EVALUATION CRITERIA

~~IS THE PROCEDURE ACCEPTABLY SAFE?~~

The equipment failure safeguards and effects were discussed in the briefings. The Guest Pilots were not purposely exposed to system malfunctions in the simulator or aircraft except when the pilot requested specific demonstration of some failure effect. One principal objective of the evaluation was to determine whether the system and procedures were acceptably safe when used under normal operating conditions.

To draw the conclusions about the safety of the procedure, the responses to Question 3 were considered the principal source of pilot opinion relating to this aspect. The wording of this question invites the pilot to compare the relative safety merits of the two-segment and standard ILS procedures.

Part 1 of the Pilot Questionnaire was summarized and analyzed principally to determine the pilot activity areas impacted most by the procedure. The recorded data analysis which relates to safety of the procedure is that data which shows how well the group tracked the two-segment profile while using the flight director, and the comparison between their flight director two-segment and ILS profile tracking performance. The other principal ingredient, which must be considered, is how much, if any, the workload was increased in order for the group to attain acceptable two-segment tracking performance. Finally, an analysis of airspeed control, particularly in the glideslope transition regime, has been considered.

The conclusions which resulted from the analysis which follows are predicated on the following basic rules:

(1) If there was a significant expression of pilot opinion that the procedure, or some part of it, was not safe, the conclusions regarding safety of the overall procedure reflects this fact, the performance data notwithstanding.

(2) If the performance data analysis showed that the group did not track the two-segment profile within operationally safe limits at any point, the conclusions reflect this fact, pilot comment notwithstanding.

(3) If the data analysis showed that pilot workload increased inordinately over standard ILS workload in order to attain comparable tracking performance, this fact influenced the conclusions. The basic rationale involved here is that an experienced pilot has the motor skills to master any reasonable maneuver. His performance of that maneuver cannot be considered safe, however, if it demands undue concentration to the exclusion of other important activity.

(4) If the data analysis showed any significant speed control problems, particularly in the glideslope transition and stabilization portion of the profile, this is reflected in the conclusions.

QUESTION 3 SUMMARY AND ANALYSIS

QUESTION 3 - IS THERE ANY DIFFERENCE IN OVERALL FLIGHT SAFETY BETWEEN THE STANDARD ILS AND THE TWO-SEGMENT? IF SO, WHAT?

A total of fifty seven pilots participated in the Guest Pilot Evaluation. Of these, 45 evaluated in both the flight simulator and the airplane, 6 flew the evaluation approaches prescribed in the airplane only, 5 flew sample approaches at LAX when the plane was there for a demonstration to the FAA Western Region and one flew late in the program in one brief out of service test period.

The Question 3 summary and subsequent summaries appearing in this report are based on the 37 Simulator Questionnaires and 45 Airplane Questionnaires which were received from the Guest Pilot group. It will not be uncommon that the total number of break-down comments exceeds the 37/45 pilot totals. This is due to the fact that a pilot may have commented on more than one item in his response to the question.

The Question 3 responses have been categorized using the following general criteria:

(1) No difference or loss in safety - If the response consisted of a word or short phrase which was not subject to any other reasonable interpretation than that the pilot saw no compromises in safety or differences between the two-segment and the ILS safety, it was counted in this category.

(2) Two-segment safer - If a comment clearly stated that the pilot considered the two-segment procedure safer than the ILS, it was counted in this category.

(3) Potential difference or loss in safety - A comment which stated some condition(s) under which the pilot felt that the two-segment procedure is potentially less safe than the ILS procedure was counted in this category.

(4) ILS safer - Any comment interpreted as a statement that the ILS is the safer of the two procedures was counted in this category.

QUESTION 3 COMMENT SUMMARY
(57 PILOTS)

COMMENT CATEGORY	SIMULATOR	AIRPLANE
No questionnaire received	20	12
No Difference or loss in safety	11	18
Two-Segment Safer	2	4
Potential Difference or Loss in Safety	11	14
ILS Safer	13	9
	57	57

OPINION SHIFT SUMMARY BETWEEN SIMULATOR AND AIRPLANE
(37 Simulator Questionnaires)

COMMENT CATEGORY	SIMULATOR		AIRPLANE
No Difference	11	→	10 No Change 1 to Potential
Two-Segment Safer	2	→	1 No Change 1 to No Diff.
Potential Difference	11	→	4 No Change 6 to No Diff. 1 to 2-Seg safer
ILS Safer	13	→	7 No Change 5 to Potential 1 to 2-Seg safer

Comments from the six pilots who flew the prescribed evaluation approaches in the airplane only distribute as follows:

No questionnaire received	1
No Difference	3
Two-segment Safer	1
Potential Difference	-
ILS Safer	1

SUMMARY OF THE NATURE OF PILOT COMMENTS FROM QUESTION 3

The summary above distributes the individual pilots' comments into the four broad categories shown. The summary below divides each of these categories in order to show the nature of the items mentioned in the comments and to show how many pilots within the group expressed substantially the same view on that item.

TWO-SEGMENT SAFER	SIMULATOR	AIRPLANE
Provides higher terrain clearance	-	1
Higher profile on Upper increases safety in emergency situations	1	2
Increases pilot awareness of altitude in the 700'-500' area	1	-
Provides pilot with distance to touchdown	-	1
Provides better view of terminal area traffic	-	1

POTENTIAL DIFFERENCE OR LOSS IN SAFETY	SIMULATOR	AIRPLANE
Glideslope speed stabilization	2	-
Glideslope transition/stabilization altitude	3	3
Icing limitation	3	4
Tailwind limitation	3	4
Engine spool-up time	-	1
Upper Segment rate of descent	1	1
Instrument scanning	-	1
Pilot familiarity with procedure/training	1	1

ILS SAFER	SIMULATOR	AIRPLANE
Icing conditions	1	1
Tailwinds	1	2
Vertical speed/transition altitude	2	3
Transition/stabilization altitude	-	2
Engine spool-down	1	-
Pilot workload	8	3

The nature of the comments which have been counted in the pilot workload category above are as follows:

	SIMULATOR	AIRPLANE
General increase in pilot attention/workload	2	-
Instrument scanning/power on lower transition	5	1
Increases when flying approach manually	1	-
High sink rate close to ground	-	1
Lookout poor	-	1

The following findings relating to Guest Pilot opinion of the safety of the two-segment procedure have been considered in the conclusions:

1. None of the Guest Pilots considers the two-segment approach which was evaluated to be unsafe.

   In the question 3 analysis above, responses from nine pilots (13 simulator/11 airplane comments) were categorized as statements that these pilots considered the ILS the safer of the two procedures. None, however, stated that the two-segment procedure is unsafe. In the briefings, emphasis was placed on the pilots' evaluating every aspect of the safety of the procedure. In view of this emphasis, and in view of the background and experience of the pilot group, it has been assumed that a pilot would have made an unequivocal statement regarding safety if he had seen anything in the procedure that he considered unsafe. It has been further assumed that he would also have reflected this fact in his response to question 4 by indicating that he did not consider the procedure safe for line operations. No such responses were received.

2. *The procedure has tailwind limitations.

   None of the guest pilots experienced significant tailwind components in the evaluation. The Project Pilot group investigated this factor in the simulation evaluation. They determined that an upper segment tailwind component of 20 knots maximum is manageable.

3. *The procedure has icing limitations.

   Engine power required for upper segment tracking under average conditions does not provide the 70% N_1 required for full anti-ice capability.

4. The two-segment approach procedure increases pilot workload in some areas. This increase does not significantly impact safety.

* The Project Pilots had tentatively concluded that they would limit the use of the procedure if conditions requiring full anti-icing capabilities were present or if the upper segment tailwind component exceeded 15 knots.

PART I QUESTIONNAIRE SUMMARY AND ANALYSIS

This part of the questionnaire concerns the generally most vital areas of pilot activity during an instrument approach. Though the questionnaire does not lend itself to fine shadings, it is felt that it adequately measures pilot opinion as to the relative difficulty between the two approaches and is an indirect indicator of how the two-segment procedure impacts pilot workload. Tables I through IV summarize the results.

Part I of the Pilot Questionnaire has been analyzed as follows:

(a) Tables I and II show the distribution of the total marks by number and percentage for each of the eleven ranked items for the simulator and aircraft questionnaires respectively.

(b) Any additional written comments are taken into account in the conclusions. Generally these comments reflect some specific, reservation or condition which influenced the pilot's marking certain item(s) as he did.

(c) Table III shows the direction and specific number of pilot opinion changes between simulator and aircraft rankings.

(d) Table IV shows the numerical and approximate overall percentage differences between the 37 simulator and 45 aircraft questionnaires.

TABLE I SIMULATOR QUESTIONNAIRE SUMMARY (PART I)

A total of 37 evaluation pilots completed the questionnaire in the simulator phase. Not all pilots commented on all categories. The percentages shown in each category are based on the total responses received for that particular item.

RANKED ITEM	Standard ILS Approach			Two-Segment Approach	
	Significantly Easier	Slightly Easier	No Difference	Slightly Easier	Significantly Easier
A. Autopilot Usage		10 (27%)	27 (73%)		
B. Flight Dir. Following	1 (2.8%)	18 (48.6%)	18 (48.6%)		
C. Instrument Interpretation	1 (2.7%)	22 (59.5%)	13 (35.1%)	1 (2.7%)	
D. Flt. Progress Annunciation		13 (35.2%)	23 (62.3%)	1 (2.5%)	
E. Inst. Scanning Requirements	3 (8.1%)	23 (62.2%)	11 (29.7%)		
F. Airspeed Control	3 (8.1%)	25 (67.6%)	9 (24.3%)		
G. Flap Management	1 (2.7%)	5 (13.5%)	31 (83.8%)		
H. Trim Control	3 (8.1%)	16 (43.3%)	17 (45.9%)	1 (2.7%)	
I. Pre-App. Cockpit Set-up		21 (58.4%)	14 (38.9%)	1 (2.7%)	
J. Radio Communications			30 (96.9%)	1 (3.1%)	
K. Check List Management		3 (9.0%)	29 (88.0%)	1 (3.0%)	

TABLE I - PILOT RESPONSE SUMMARY (SIMULATOR)

TABLE II - AIRCRAFT QUESTIONNAIRE SUMMARY

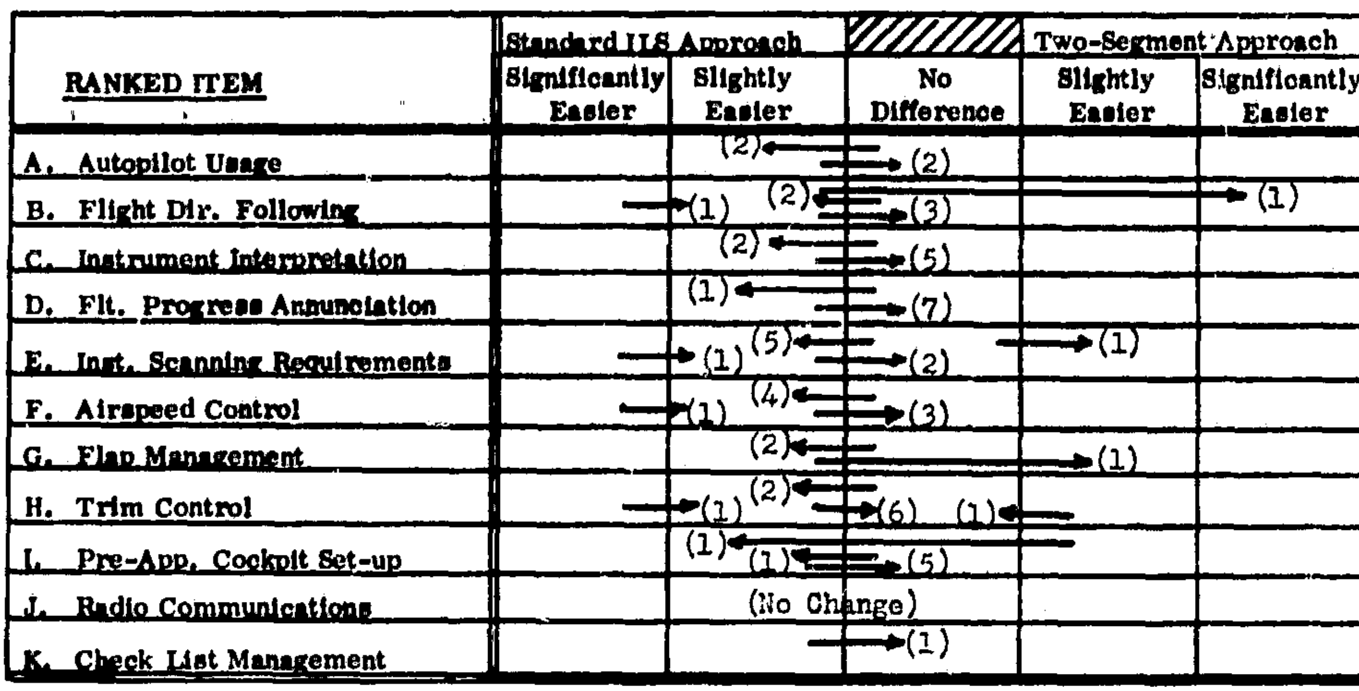
A total of 45 pilots completed the aircraft questionnaire. In some categories, not all of the pilots ranked a given item. The percentages shown are based on the total responses to that item which were received.

RANKED ITEM	Standard ILS Approach			Two-Segment Approach	
	Significantly Easier	Slightly Easier	No Difference	Slightly Easier	Significantly Easier
A. Autopilot Usage		10 (22.4%)	35 (77.6%)		
B. Flight Dir. Following		19 (43.2%)	24 (54.6%)		
C. Instrument Interpretation	1 (2.2%)	22 (48.9%)	21 (46.7%)		1 2.2%)
D. Flt. Progress Annunciation		8 (17.8%)	36 (80.0%)	1 (2.2%)	
E. Inst. Scanning Requirements	2 (4.4%)	29 (65.9%)	12 (27.5%)	1 (2.2%)	
F. Airspeed Control	1 (2.1%)	32 (71.0%)	12 (26.9%)	1 (2.2%)	
G. Flap Management	1 (2.2%)	6 (13.3%)	38 (84.5%)		
H. Trim Control	2 (4.5%)	18 (40.0%)	25 (55.5%)		
I. Pre-App. Cockpit Set-up		22 (48.8%)	23 (51.2%)		
J. Radio Communications			39 (97.5%)	1 (2.5%)	
K. Check List Management		2 (4.6%)	40 (93.2%)	1 (2.3%)	

TABLE II - PILOT RESPONSE SUMMARY (AIRCRAFT)

TABLE III - SPECIFIC OPINION SHIFT SUMMARY

A total of 35 pilots completed questionnaires for both the simulator and aircraft. Table III shows the direction which specific pilots' opinions shifted between their simulator and aircraft rankings. e.g.: Item B - One pilot changed his opinion in the simulator (significantly easier) to slightly easier in the aircraft; three pilots changed from slightly easier to no difference, etc.



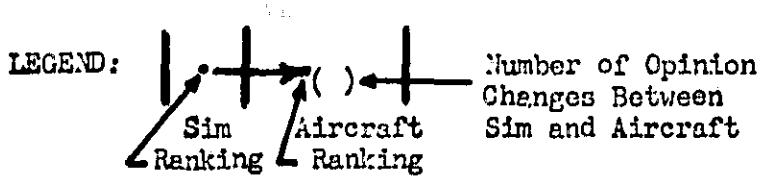


TABLE III - SPECIFIC OPINION SHIFT SUMMARY
(Simulator to Aircraft)

(Below Figures Based on 37 Sim Questionnaires; 45 Aircraft Questionnaires)

RANKED ITEM	Standard ILS Approach Significantly Easier	 Slightly Easier	 No Difference	Two-Segment Approach Slightly Easier	 Significantly Easier
A. Autopilot Usage		S 10(27%) A 10(22%)	S 27(73%) A 35(78%)		
Sim-to-Acft Net Change # (%)		0(-5%)	+8(+5%)		
B. Flight Dir. Following	S 1(3%)	S 18(48.5% A 19(43%)	S 18(48.5% A 24(55%)		A 1(2%)
"	-1(-3%)	+1(-5.5%)	+6(+6.5%)		+1(+2%)
C. Instrument Interpretation	S 1(3%) A 1(2%)	S 22(59%) A 22(49%)	S 13(35%) A 21(47%)	S 1(3%) A 1(2%)	
"	0(-1%)	0(-10%)	+8(+12%)	0(-1%)	
D. Flt. Progress Annunciation		S 13(35%) A 8(18%)	S 23(62%) A 36(80%)	S 1(3%) A 1(2%)	
"		-5(-17%)	+13(+18%)	0(-1%)	
E. Inst. Scanning Requirements	S 3(8%) A 2(4%)	S 23(62%) A 29(66%)	S 11(30%) A 12(28%)	A 1(2%)	
"	-1(-4%)	+6(+4%)	+1(+2%)	+1(+2%)	
F. Airspeed Control	S 3(8%) A 1(2%)	S 25(68%) A 32(71%)	S 9(24%) A 12(27%)		
"	-2(-6%)	+7(+3%)	+3(+3%)		
G. Flap Management	S 1(3%) A 1(2%)	S 5(13%) A 6(13%)	S 31(84%) A 38(85%)		
"	0(-1%)	-1(0%)	+7(+1%)		
H. Trim Control	S 3(8%) A 2(4%)	S 16(43%) A 18(40%)	S 17(46%) A 25(56%)	S 1(3%)	
"	-1(-4%)	+2(-3%)	+8(+10%)	-1(-3%)	
I. Pre-App. Cockpit Set-up		S 21(58%) A 22(49%)	S 14(39%) A 23(51%)	S 1(3%)	
"		+1(-9%)	+9(+12%)	-1(-3%)	
J. Radio Communications			S 30(97%) A 29(97%)	S 1(3%) A 1(3%)	
"			+9(0%)	0(0%)	
K. Check List Management		S 3(9%) A 2(5%)	S 29(88%) A 40(93%)	S 1(3%) A 1(2%)	
"		-1(-4%)	+11(+5%)	0(-1%)	

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TABLE IV- SIM-AIRCRAFT NET DIFFERENCES-SUMMARY.

(Pilot Questionnaire - Part I)

The Part I analysis shows the following:

(1) Of the 35 pilots who submitted questionnaires for both the simulator and aircraft, specific pilot opinion shifted toward the "no difference" ranking in almost twice as many cases as an opinion shifted from "no difference" toward some preferential ranking (see Table III). How much of this opinion change should be attributed to the additional learning and accomodation factors resulting from eight additional approaches in the airplane and how much is the result of real-world vs simulation environment cannot be objectively determined or stated.

(2) Of the eleven categories rated, instrument interpretation, scanning and airspeed control categories show a considerable majority of the pilots indicating that the ILS was slightly easier than the two-segment approach (Table IV). Specific pilot shifts in this direction were heaviest (5 to 2) in instrument scanning (Table III). How much of this shift should be attributed to a change from the FD 109-A in the simulator to the FD 108 in the aircraft cannot be determined. The fact that significant majorities exist in both the simulator and aircraft questionnaires, however, would indicate that these items appear the generally most difficult part of pilot activity in the two-segment approach.

(3) Table IV summarizes the net pilot count and percentage of total differences between the simulator and aircraft Part I questionnaires. These reflect the specific opinion shifts in Table III plus the larger sample from the aircraft (45) vs simulator (37). It can be seen that the only two items which registered pilot number and percentage gains between the sim and aircraft are instrument scanning and airspeed control. All eleven ranked items show both number and percentage gains in the "no difference" ranking. All of the items ranked "ILS significantly easier" in the simulator show numbers shifts toward a lesser preferential ranking except the one pilot who marked item C and the one who marked item G and did not moderate his opinion after the aircraft evaluation.

The Part I analysis is weighted in the conclusions related to the pilot opinion of the safety aspects of the procedure because it is an indirect measurement of those areas of cockpit activity which are impacted by the two-segment procedure. If a task in the two-segment approach is ranked as appreciably more difficult than the same task in the standard ILS, the presumption has been made that there is an impact on safety for the reasons relating to workload stated earlier.

The following findings from the Part I analysis have been considered in the conclusions regarding safety:

(1) Instrument scanning and airspeed control are ranked slightly easier in the ILS by about 70% of the evaluating pilots.

While the term "slightly easier" is an inexact statistical term, in the context used in this finding, it has been interpreted as indicating that most pilots in the group felt that these factors did not impact their cockpit activity to the point of being detrimental to safety.

(2) The group is split fairly evenly between "no difference" and "ILS slightly easier" for flight director following, instrument interpretation, trim control and pre-approach cockpit set-up categories. The significant fact which is shown in Table III is that the aircraft flight shifted opinion toward "no difference" more heavily than away from it. In addition most of the larger aircraft sample (45 vs 37) appears to have fallen in the "no difference" category, even without benefit of the simulator familiarization period (Table IV). The finding regarding these categories as they affect workload (and therefore indirectly affect safety) is that these factors have negligible impact upon the overall safety of the procedure.

(3) The remaining items are heavily ranked as "no difference" factors in cockpit activity.

STATISTICAL DATA ANALYSIS OF FACTORS RELATED TO SAFETY -

Three principal analyses of the aircraft recorded data have been made in connection with drawing conclusions regarding the overall safety of the procedure:

(1) Aircraft displayed vertical deviation from profile center. These plots are derived from data which measured the deviation displayed on the HSI vertical deviation indicator. This was averaged and normalized in 0.1 N.M. increments (see Appendix III).

(2) Pitch and roll activity has also been analyzed. These factors serve as an indicator of how the pilot's physical workload in flying the two-segment approach compares to his ILS workload under the same conditions.

(3) Airspeed control with emphasis on the glideslope transition.

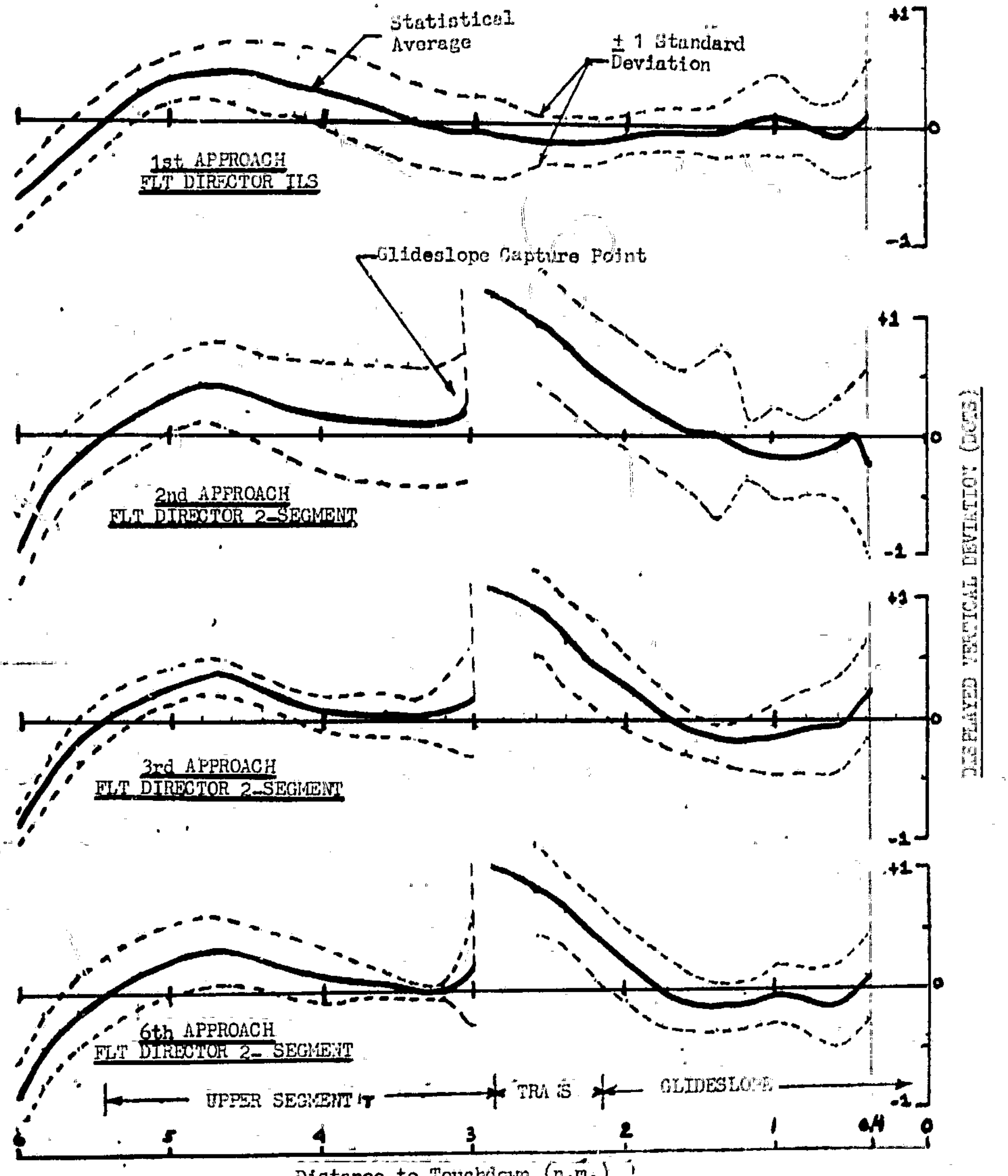
In the above cases, more detail is included in the analysis accompanying the plotted data.

PLOT 1 - ~~AIRCRAFT~~ DISPLAYED VERTICAL DEVIATION FROM PROFILE CENTER

These four approach plots show aircraft deviation (in dots) from the vertical profile center. In the first approach, the deviation reference is the ILS glideslope. In the three two-segment plots, vertical deviation reference is the upper segment from the 6 N.M. point to glideslope capture point (about 2.8 N.M.). For the remainder of the approach, reference is the ILS glideslope.

The deviation scale used on each of the four approach plots is ± 1 dot. This is blown up to facilitate plotting and visually comparing the data. Upper segment deviation display sensitivity is linear at 250'/dot. ILS glideslope deviation display sensitivity is 75 micro-amps/dot as with the standard ILS.

The discontinuity in the 2-segment plots is the result of the system's shifting its deviation reference from Upper Segment to ILS Glideslope at Glideslope Capture Point ("GLIDE SLOPE" GREEN)



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PLOT 1 - VERTICAL DEVIATION FROM PROFILE (DOTS OF DISPLAYED DEVIATION)

PLOT 1 ANALYSIS

This data analysis shows how closely the aircraft was flown to the profile vertical center (upper segment and glideslope centers) from the pre-capture point onward to about 0.4 N.M. from touchdown. These are all manually flown flight director approaches. In the following analyses, deviations will be expressed in dots. The statistical term sigma will be used to signify one standard deviation. The value of sigma is also expressed in dots. It can be seen from the Plot 1 labels that the solid line represents the statistical average in all cases and the dashed lines show the ± 1 standard deviation envelope.

First Approach (Flight Director ILS) - As expected, the standard ILS was well-flown. It can be seen that the maximum average deviation after glideslope capture (0.42 dots, sigma 0.269 dots) occurs at 4.6 N.M. At this distance from touchdown, this is a vertical deviation of about 85' high. Correction back to within 0.25 dot has been accomplished by 4.0 N.M. Average deviations thereafter remain substantially less than 0.25 dot. The closer the aircraft approaches touchdown, the deviation in feet from glideslope center becomes progressively smaller for the same displayed deviation (in dots).

Second Approach - (First Flight Director Two-Segment) - This is the first two-segment approach of any type that the pilots flew in the aircraft. The average upper segment overshoot maximizes at 0.46 dot, sigma 0.336 at 4.8 N.M. This overshoot is 115'. Correction back to 0.25 dot has been accomplished by 4.4 N.M. and remains less than this for the remainder of the approach. The vertical deviation reference shift which occurs at glideslope capture point (nominally about 1050'(AFL) 2.85 N.M. DME) causes a momentary statistical "blackout" on this kind of a plot during the initial portion of the glideslope transition. Since this data is normalized in only 0.1 N.M. increments, it must be realized that at glideslope capture point, the actual deviation swing is nominally to about 1.75 dots high instantaneously. The plot from that point onward is a good indicator of how well the remainder of the approach was flown.

On this approach (the pilot's first 2-segment approach in the airplane), the group was holding slightly above Upper Segment center (0.2 dot, sigma .568 at 3.0 n.m.) just prior to Glideslope Capture point. This forced the capture point slightly closer to touchdown than nominal.

Because the glideslope capture point was forced slightly closer to touchdown by riding the upper segment slightly high, it follows that the point at which deviation from ILS glideslope becomes 0.25 dot or less is closer to touchdown. It can be seen by comparing the plots that this is the case. On the second approach, deviation became 0.25 dot somewhere between 1.9 N.M. (0.27 dot) and 1.8 N.M. (0.18 dot). On the third and sixth approaches (both of which are very close to nominal), deviation became less than 0.25 dot between 2.1 and [illegible] N.M. After glideslope capture, it can be seen that the group goes slightly below glideslope (maximizes at 0.2 dot sigma 0.338 at 0.9 N.M., which is approximately 15' low at this point).

Third and Sixth Approaches - (Second and third Flight Director Two-Segment Approaches flown in the aircraft) - The initial upper segment overshoot on these two approaches is very nearly the same as the second approach above (first two-segment approach). Both of these approaches show tighter upper segment tracking from the 3.6 mile point onward. The glideslope capture points and glideslope stabilization points are very close to nominal. A particularly important point to consider is the significantly tighter 1 sigma envelope which is in both cases as tight or tighter than the standard ILS envelope.

FINDINGS FROM THE PLOT 1 ANALYSIS -

1. Average two-segment vertical profile tracking accuracy by the pilots in the sample was consistently comparable to ILS tracking accuracy throughout most of the profile.

2. Initial average overshoot of upper segment is only slightly greater (in feet) than the average ILS overshoot. The group required about 0.6 miles to correct back to within 0.25 dots after overshooting the ILS and only about 0.4 mile to correct back to within 0.25 dots after overshooting upper segment. Since upper segment capture requires a flight path angle change of about twice that required for ILS glideslope capture, it is felt that the upper segment transition was as well or better flown than the ILS transition.

3. On average, the group flew very slightly through ILS glideslope on transition from upper segment. The largest deviation below glideslope is 0.21/sigma .326 dot on the third approach (second two-segment) at 1.3 miles from touchdown. The maximum for the 97 flight director two-segment approaches (Plot 1-A) is 0.16/sigma .[illegible] dot at 1.2 miles. On the standard ILS the pilots were slightly below glideslope from 3.3 to 2.1 miles and were 0.14/sigma .222 below at 0.7 miles from touchdown. At 0.4 miles they were 0.16/sigma .4[illegible] low; although this is the area at which the data scatter starts to become fairly large on all of the approaches. The point in this comparison is that deviations below glideslope out of the transition

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from upper segment are of substantially the same magnitude as deviations after stabilization on glideslope in the standard ILS, and in all cases, these deviations are less than 0.25 dot.

4. The data scatter inside of 0.4 N.M. from touchdown precludes accurate analysis of group performance at Category II DH (100'AGL). This appears to be principally the result of breaking the approach off slightly earlier than this. (Of 60 two-segment flight director approaches considered, recorded data shows application of power for Go-Around in 48 of the sixty cases at 0.4 miles or greater from touchdown).

   In the last mile (from about 300'AGL at 1 mile to about 122'AGL at 0.4 mile), the group average deviation from glideslope was about 0.01 dot high for the ILS, 0.14 dot low for the first two-segment approach; 0.03 dot low for the second two-segment and 0.03 dot low for the third two-segment (6th approach).

   While it cannot be stated as fact that at Category II DH, 96% (±2 sigma) of the group would have been within Category II tolerances, the analysis of the approach down to 0.4 N.M. (122'AGL) strongly suggests that they would have been well within Category II tolerances at DH if they had continued down to 100' AGL before applying go-around power.

PLOT 1-A ANALYSIS

This plot shows the larger statistical sample average (97 flight director two-segment) plotted against the average auto-coupled manual throttle tracking performance (based on 54 two-segment approaches).

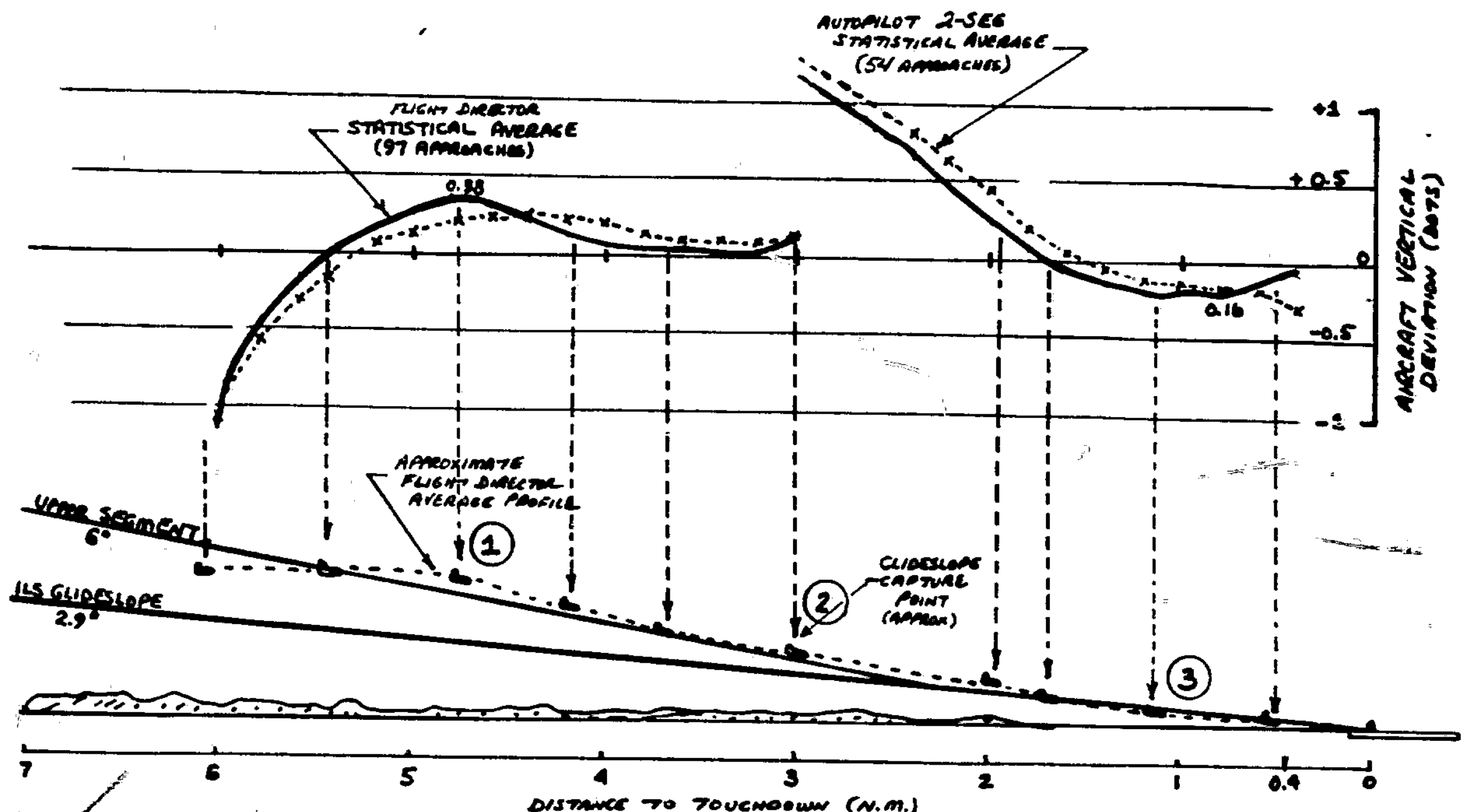
This plot shows the following:

(1) The upper segment pre-capture profiles are nearly identical. The autopilot maximum overshoot is slightly smaller and is a generally more deliberate transition maneuver. The deviation washout is more deliberate on autopilot than when the approach is manually flown.

(2) Approaching glideslope capture point, the flight director and autopilot deviations from upper segment are very close to equal. The pilots flew slightly tighter on flight director than the autopilot flew the same portion of the profile.

(3) The deviation excursion differences in the 3.0-2.6 N.M. range suggest that the pilots started to anticipate the transition and thus delayed glideslope capture point by a small amount. The autopilot plot suggests that it continued to correct toward upper segment and at the approximately nominal 2.8-mile point, upper segment capture point was reached and the deviation reference switched, which accounts for the discontinuity which is shown at that point. The transition shows that the pilots completed their transition a little faster than the autopilot (they started slightly later and were on glideslope center slightly earlier). This faster correction probably accounts for the slightly greater deviation below glideslope, though it should be recognized that the difference is very small between flight director and autopilot.

At the 0.4 N.M. point, the turn-up of the flight director plot and the turn-down of the autopilot plot are partially from small sample sizes and other factors which affect data scatter. It should be remembered that at this range, the beam is very tight, and deviations (in dots) this close in represent very small displacements (in feet) from beam center.



NOTE: NOT TO SCALE

NOTES:

① AVERAGE MAXIMUM OVERSHOOT 0.38 DOT = 95' (FLT DIR)
AVERAGE MAXIMUM AUTOPILOT O'SHOOT 0.28 DOT = 70' AT 4.5 N.M.

② VERTICAL DEVIATION REFERENCE SWITCHES FROM UPPER SEGMENT TO ILS GLIDESLOPE

③ AVERAGE MAXIMUM G/S OVERSHOOT 0.16 DOT AT 0.7 N.M. (FLT DIR)
" " " " 0.12 DOT AT 1.1 N.M. (AUTOPILOT)

PLOT 1A - AVERAGE VERTICAL TRACKING PERFORMANCE 2-SEG FLIGHT DIR VS AUTOPILOT
(97 FLT DIR APPROACHES; 54 AUTOCOUPLED APPROACHES)

FINDINGS FROM PLOT 1-A ANALYSIS -

1. On average, the pilots flew the approach on flight director as well as the autopilot flew it. The slightly more rapid corrections back to profile center on flight director as compared to autopilot are characteristic of human judgment and reaction factors as compared to the mechanized correction rate of the autopilot when it is this close to beam center.

2. As with Plot 1, the data scatter and statistical sample size inside of 0.4 miles precludes accurate analysis. In the 1-mile to 0.4-mile range, the pilot group were maintaining very small deviation tolerances. The data suggests that at Category II DH (100'AGL), it is reasonable to assume that 96% (2 sigma) would have been within Category II vertical deviation tolerances if they had continued to this point prior to applying go-around power.

FLIGHT DIRECTOR PITCH COMMAND FOLLOWING

Plots 1 and 1A show how closely the Pilot Group tracked the zero vertical deviation profile. Plots 2 and 2A show how closely the pilots followed the flight director pitch commands throughout the four different approaches analyzed. As with Plot 1, the solid curve is the statistical average. The dashed curves represent the ± 1 sigma envelope.

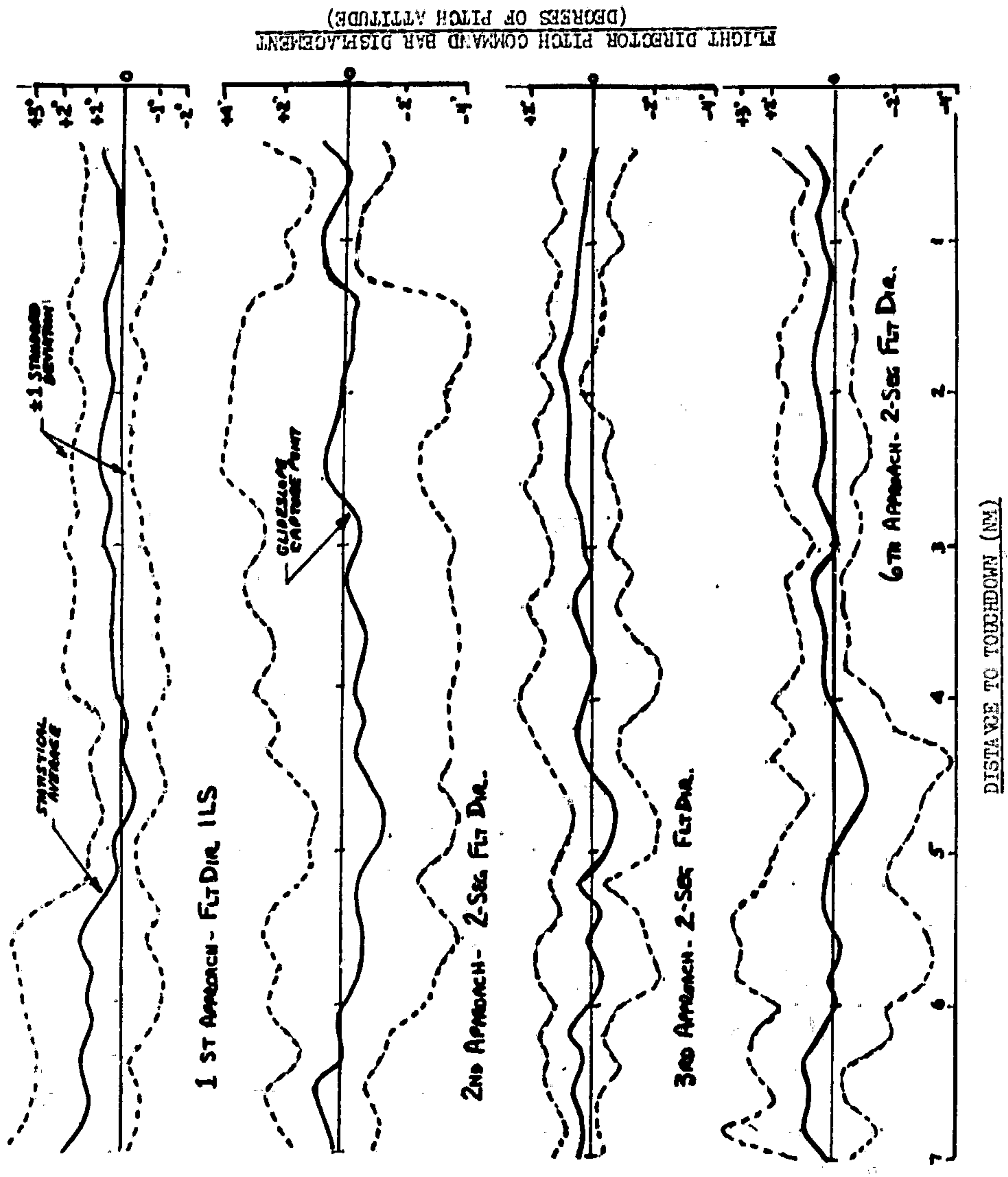
In interpreting Plots 2 and 2A, it is important to recognize that when the pilot is maintaining the commanded pitch attitude at any given point on the profile, the pitch command bar displacement should be zero. While these curves are plotted as pitch command bar displacement, the real meaning which should be attached to them is that the Pilot Group were maintaining a pitch attitude which was at variance with the attitude needed to track the zero vertical deviation profile.

PLOT 2 ANALYSIS

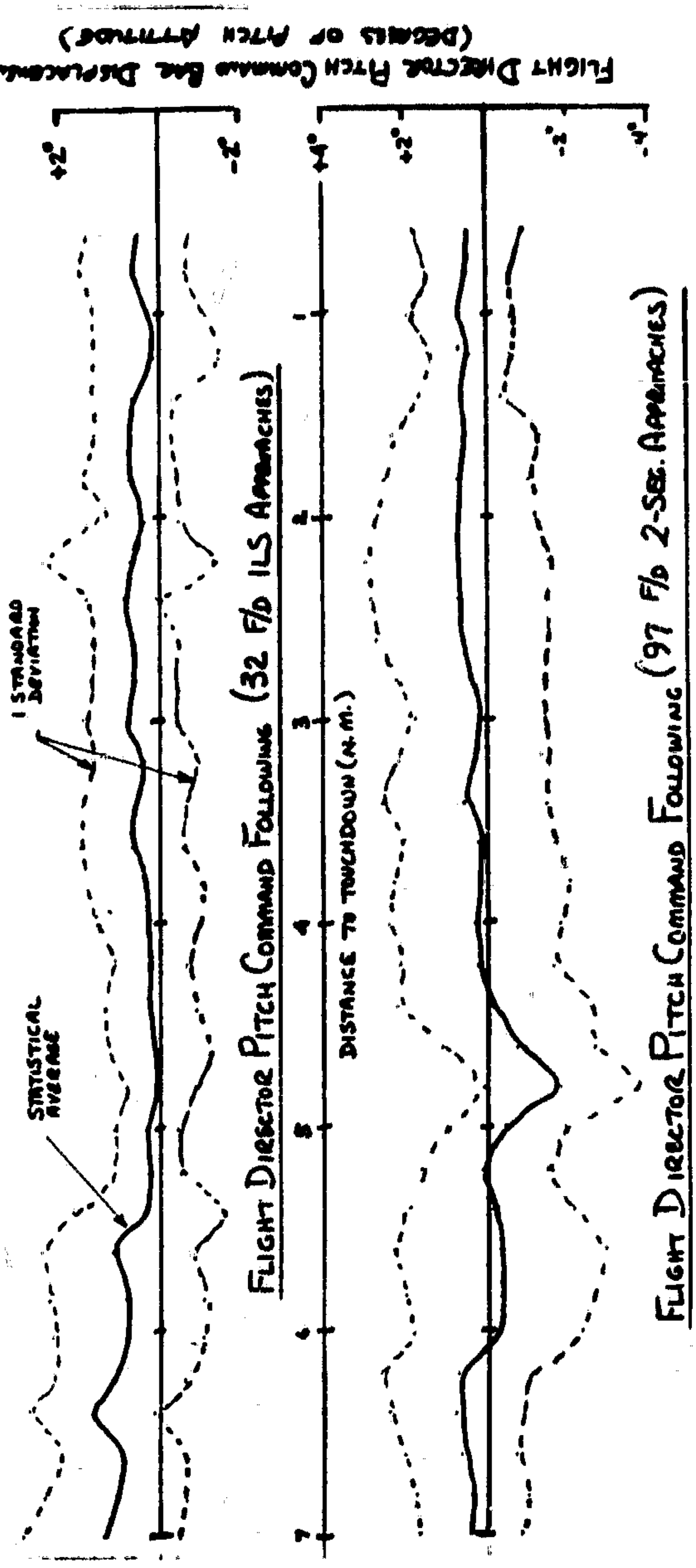
Flight Director ILS (First Approach) - As expected, the Group flew the flight director very tightly on the ILS approach from glideslope capture onward. In the 5-to-4-mile range, the smaller sample held their attitude slightly high (command bar slightly low) which accounts for the longer period to correct back to glideslope after initial overshoot discussed in the Plot 1 analysis. The larger sample (Plot 2A) on average, held a slightly lower attitude than commanded. In both cases, however, these are fractions of 1° for the entire approach.

Second Approach (First Two-Segment Flight Director) - This approach turned out very much as expected. From upper segment capture point (about 6 N.M.) onward to glideslope capture point, one sees the pitch attitude being held high. Plot 1 verifies the expected result in that the aircraft remains above upper segment all the way down. Also, as expected, the 1-sigma envelope is quite large until approximately 1.4 N.M., which is about the point at which the Group is back on the familiar "ground" of the ILS glideslope.

Third and Sixth Approaches (Second and Third Two-Segment F/D Approaches) The Group follows the flight director very well on these approaches in the upper segment regime. The hold-off after initial overshoot in the third approach, particularly, is of shorter duration than after the ILS overshoot. Both of the glideslope transitions show more of a reluctance to pick the nose up than on the second approach. Plot 1 shows the Group flying directly through the glideslope and



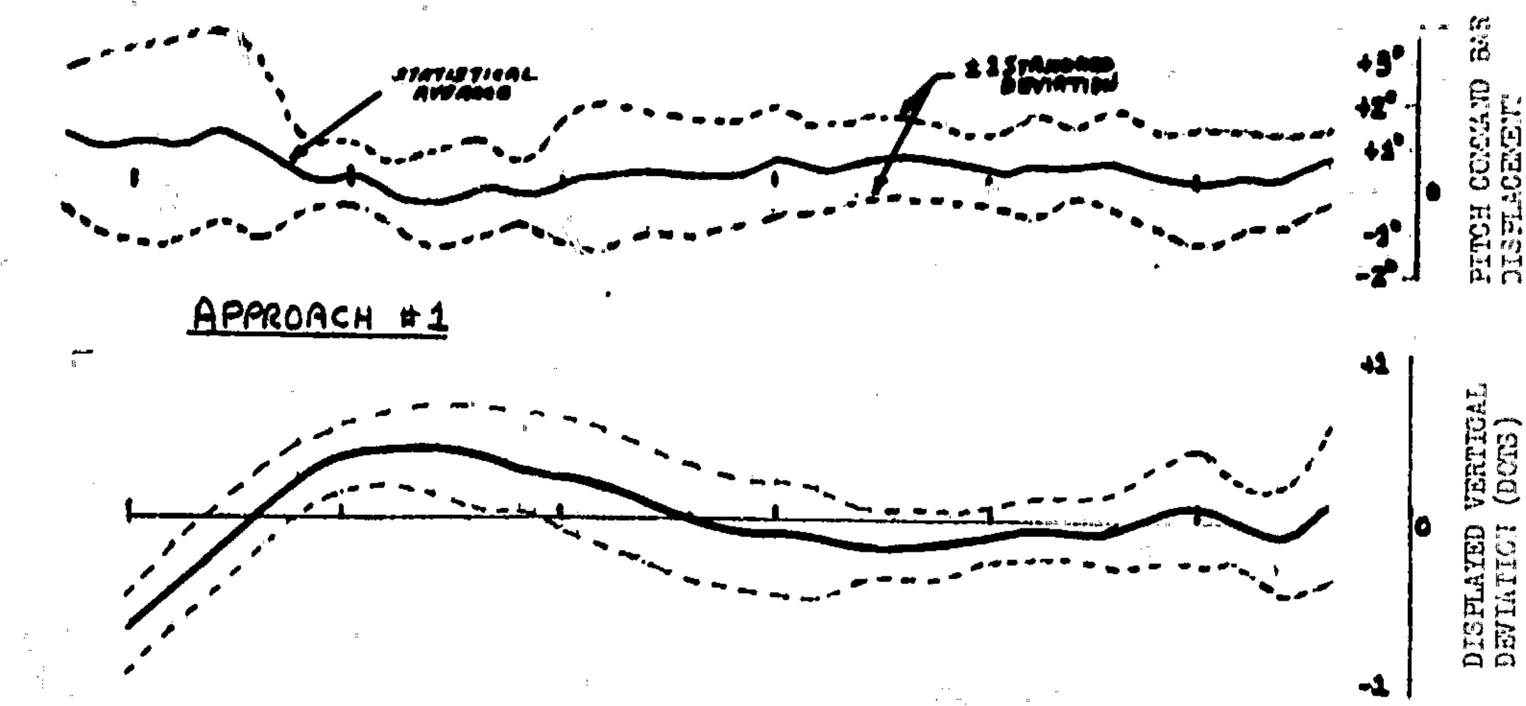
PLOT 2 - FLIGHT DIRECTOR PITCH COMMAND FOLLOWING



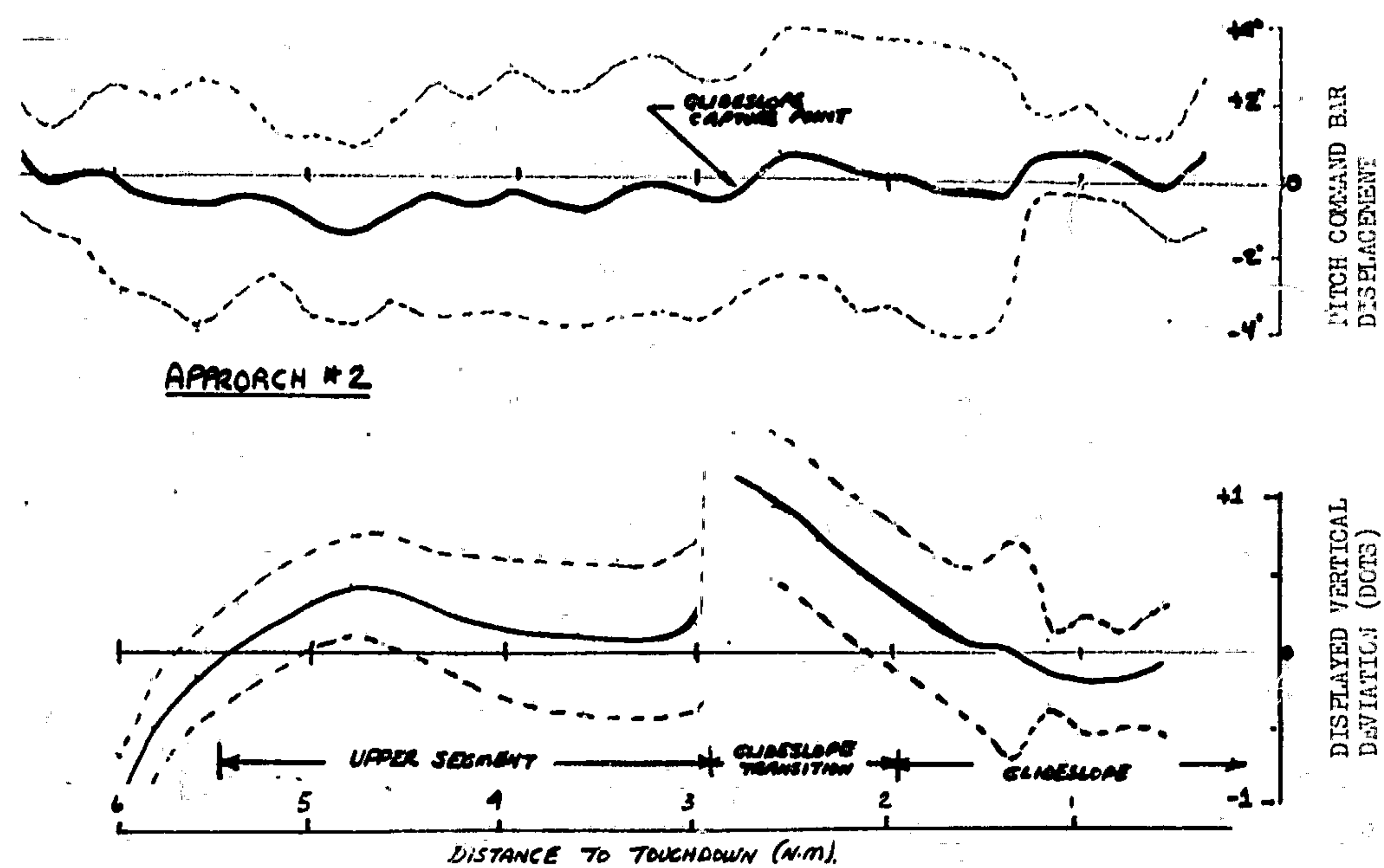
PLOT 2-A - FLIGHT DIRECTOR PITCH COMMAND FOLLOWING
(ALL F/D ILS & 2-SEG APPROACHES)

catching it with a smooth correction back toward center. The 1-sigma envelope on the third approach is particularly good. The sixth is very good from about mid-upper segment onward. Nothing elsewhere in the data explains the relatively large scatter in the 6-to-4.5-mile range. Plot 1, however, shows that despite this scatter, the profile was the best-flown of all (including the ILS) in this mileage regime.

Plots 2-B (1) and (2) - These plots bring the flight director following and aircraft vertical deviation plots together in order to show the approximate magnitude of the vertical deviation from profile which resulted from the Groups' flight director following errors. They are self-explanatory and will not be further analyzed.

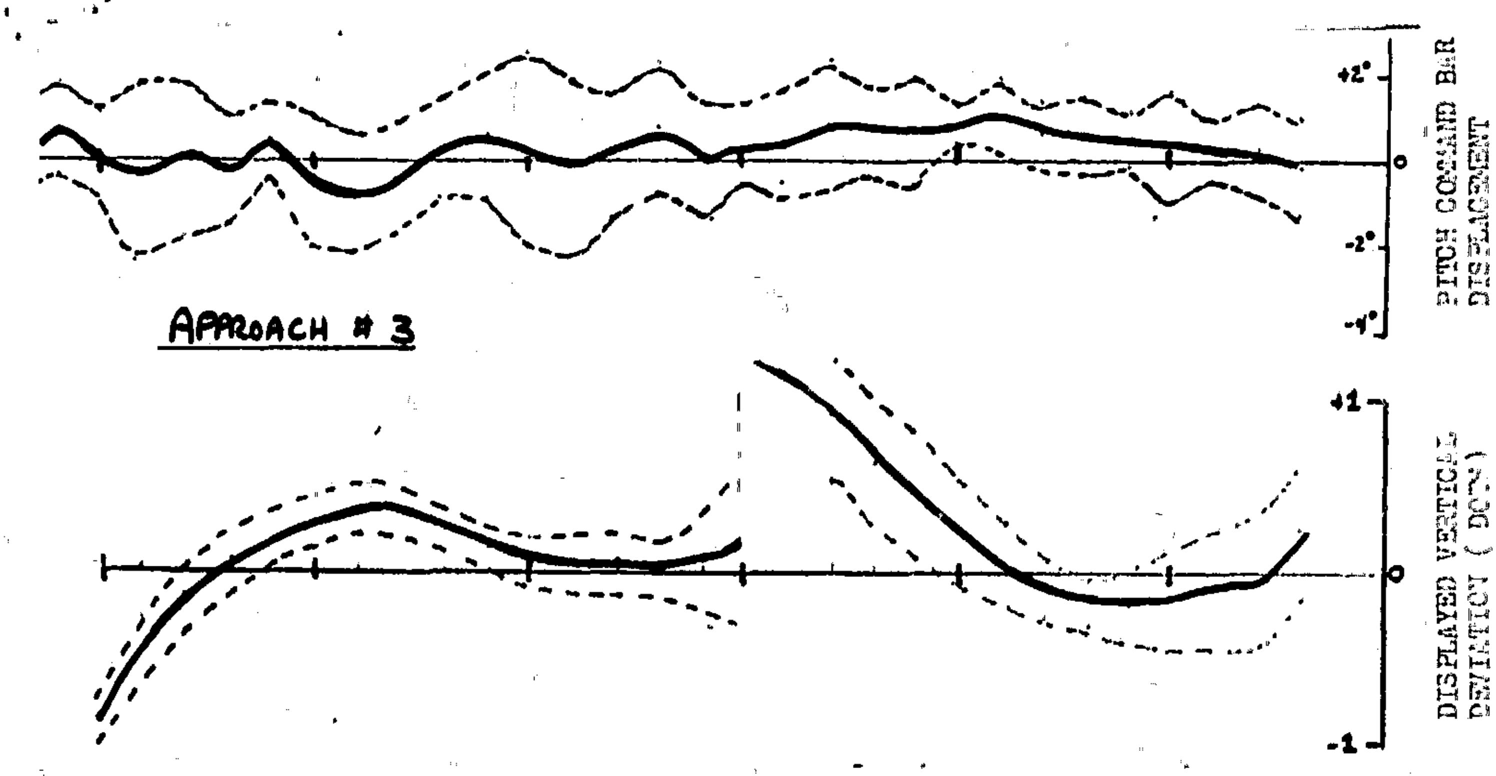


PITCH COMMAND BAR DISPLACEMENT vs DISPLAYED VERTICAL DEVIATION (FLT DIR ILS)

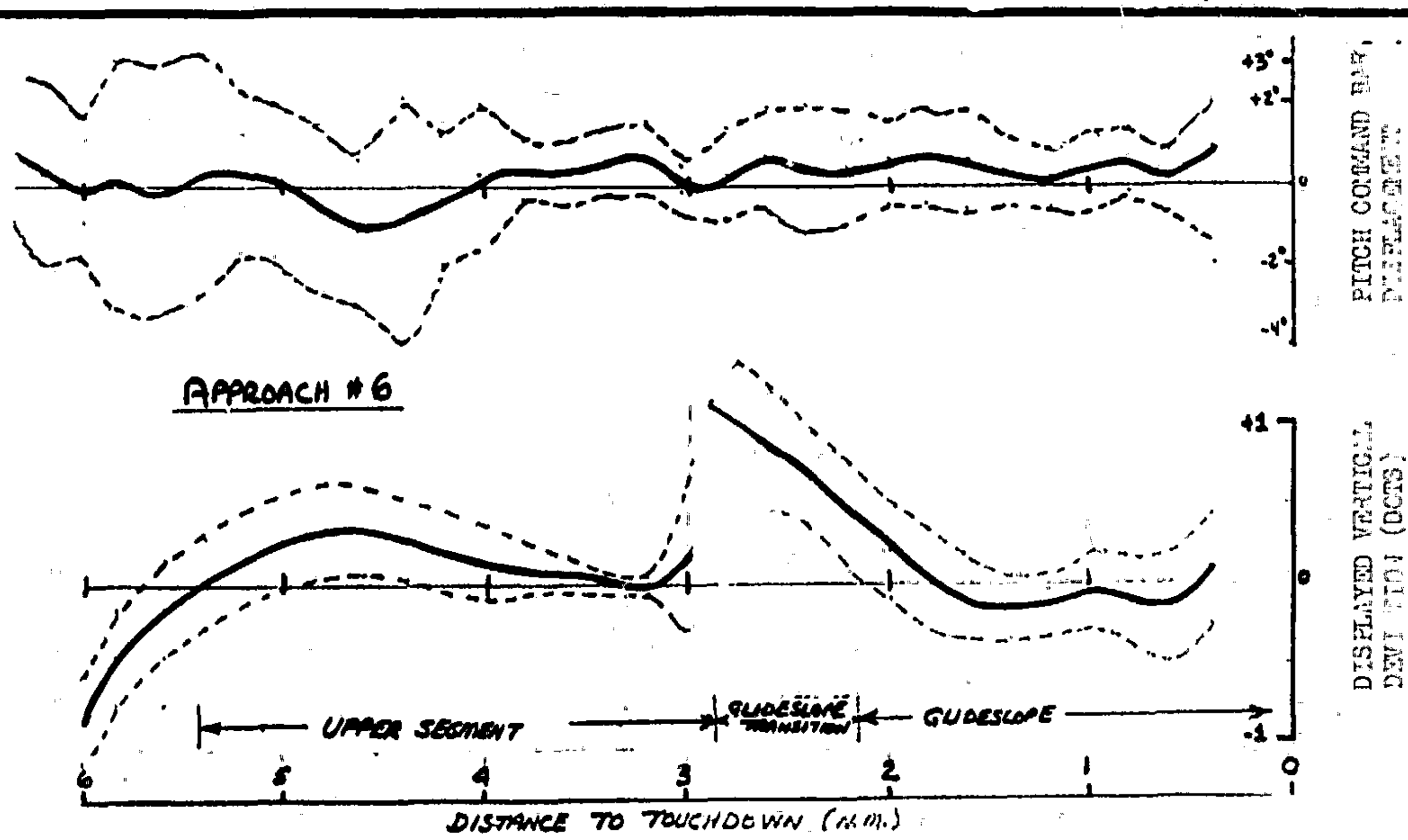


PITCH COMMAND BAR DISPLACEMENT vs DISPLAYED VERTICAL DEVIATION (FIRST 2-SEG)

PLOT 2-B(1)



PITCH COMMAND BAR DISPLACEMENT vs DISPLAYED VERTICAL DEVIATION (SECOND 2-SEG)



PITCH COMMAND BAR DISPLACEMENT vs DISPLAYED VERTICAL DEVIATION (THIRD 2- SEG)

PLOT 2-B(2)

CONCLUSIONS FROM PLOT 2 ANALYSIS

1. With very little practice in the procedure, the transition to upper segment can be well-flown. Likewise, tracking accuracies on upper segment compare favorably with ILS glideslope tracking.

2. Flight Director guidance throughout the profile appears to be correct and accurate.

3. The glideslope transition maneuver appears to be properly commanded. The Pilot Group, on average, flies very slightly through the glideslope but consistently corrects back and does not exceed Cat II vertical deviation criteria.

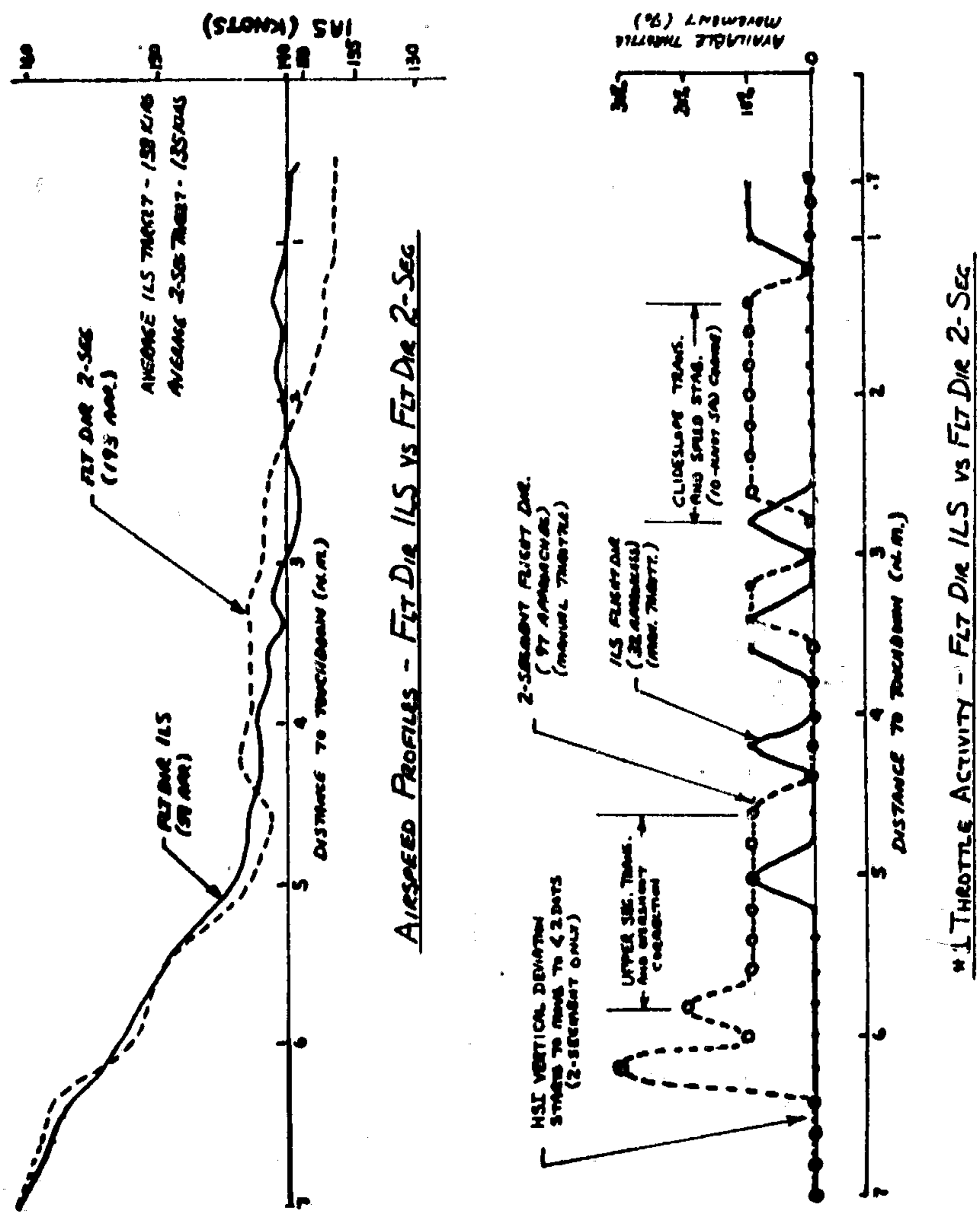
Plot 3 Airspeed Control and Throttle Activity

In light of the significant number of pilots who ranked airspeed control as being slightly more difficult in the two-segment approach than in the ILS, a comparison of power control demands between the ILS and two-segment approaches has been made in Plot 3. As with the pitch and roll activity comparisons, a finding that the two-segment approach significantly increased this part of of the pilot physical workload would influence the overall conclusions as to the safety of the procedure..

The airspeed profiles in Plot 3 show exactly what was to be expected. The pilots flew good ILS speed profiles. At the typical gross weights at which the ILS approaches were flown, target speed was about 140 KIAS. In the two-segment approaches (flown generally at lighter weights than the ILS), Vref was typically 137-135 KIAS. The profile shows good Upper Segment stabilization at Vref+10 with a good 10-knot bleed to Vref in the glideslope transition regime and slightly thereafter. For purposes of this analysis, it has been assumed that the pilots flew both types of approach to the same accuracy standard as regards airspeed scheduling. Differences in power control activity are therefore considered as an index of relative pilot physical workload as regards power control.

In interpreting the throttle activity portion of Plot 3, it should be recognized that this was summarized in 0.1 n.m. increments. The plotted values represent the sum total of the advancements and retardations which occurred in the previous 0.1 n.m. expressed in percent of available throttle movement. This was measured by a transducer on the throttle linkage and calibrated 0-100% between flight idle ad the position corresponding to 100%RPM.

The throttle activity plot is consistent with the special power control demands of the two-segment approach. The sudden rise at approximately 6.5 n.m. corresponds to the range at which the vertical deviation bar in the HSI starts to move downward from two dots. Although not plotted, a similar rise (which is less sustained) appears in the ILS data (Appendix III). Activity remains higher in the Upper Segment transition and stabilization than in the ILS which shows three distinct activity demand points between 5.2 and 3.2 miles. As is to be expected, power control activity rises again in the two-segment approach during the transition from Upper Segment to glideslope. It is important to recognize that this is the portion of the profile in which speed bleeds from Vref+10 to Vref on glideslope. A significant point is that after the 1.3-mile point onward, power control workload demands for the ILS exceed those of the two-segment approach.



PLOT 3 - AIRSPEED CONTROL & THROTTLE ACTIVITY

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Findings from Plot 3 Analysis

1. Power control pilot workload in the Upper Segment transition of the two-segment approach is higher and more sustained than the transition to glideslope in the standard ILS.

2. The power control workload factor again exceeds the demands of the ILS in the glideslope transition from Upper Segment. This is to be expected since no such maneuver is required in the ILS after initial transition.

3. Based on this data, the pilot group diverted more activity to power control in the final portion of the ILS than in the two-segment approach to maintain the same speed control performance. (Note: Data cut-off is at 0.7 n.m. because, as stated earlier, of the 60 approaches considered, power applications for go-around occurred in the great majority of cases in the 0.4-0.7 n.m. range).

4. After the large power adjustment at about 6.5 miles, the magnitude of power control activity is no larger than that for the ILS except that it is more sustained in the two transition areas.

5. After initial overshoot correction, power and speed stabilization on upper segment are excellent. In this range, the group encountered considerable power control activity on the ILS, this being 2-3 miles after glideslope transition.

Pitch and Roll Activity

These two parameters were recorded in the evaluation in order to determine the relative physical effort expended by the pilot in flying the ILS and the two-segment approaches.

Plots 1 and 1-A have shown that the group tracked the vertical profile of the two-segment approach as well as they tracked the ILS profile. A comparison of localizer tracking performance (Appendix III shows negligible differences in lateral tracking performance. For purposes of this analysis, it has therefore been assumed that pilot tracking performance is substantially the same on both types of approach. A comparison of pitch and roll activity between the ILS and two-segment approach therefore becomes an index of the relative physical workload in flying the two approaches to the same performance standard.

Plots 4, 4-A, and 4-B make this comparison. Pitch activity is expressed in degrees-seconds. Control column movement from trimmed zero (in either direction) times the number of seconds the column is displaced; have been summed in 0.1 NM increments in Appendix III. Roll activity has been similarly derived using control wheel angular displacement.

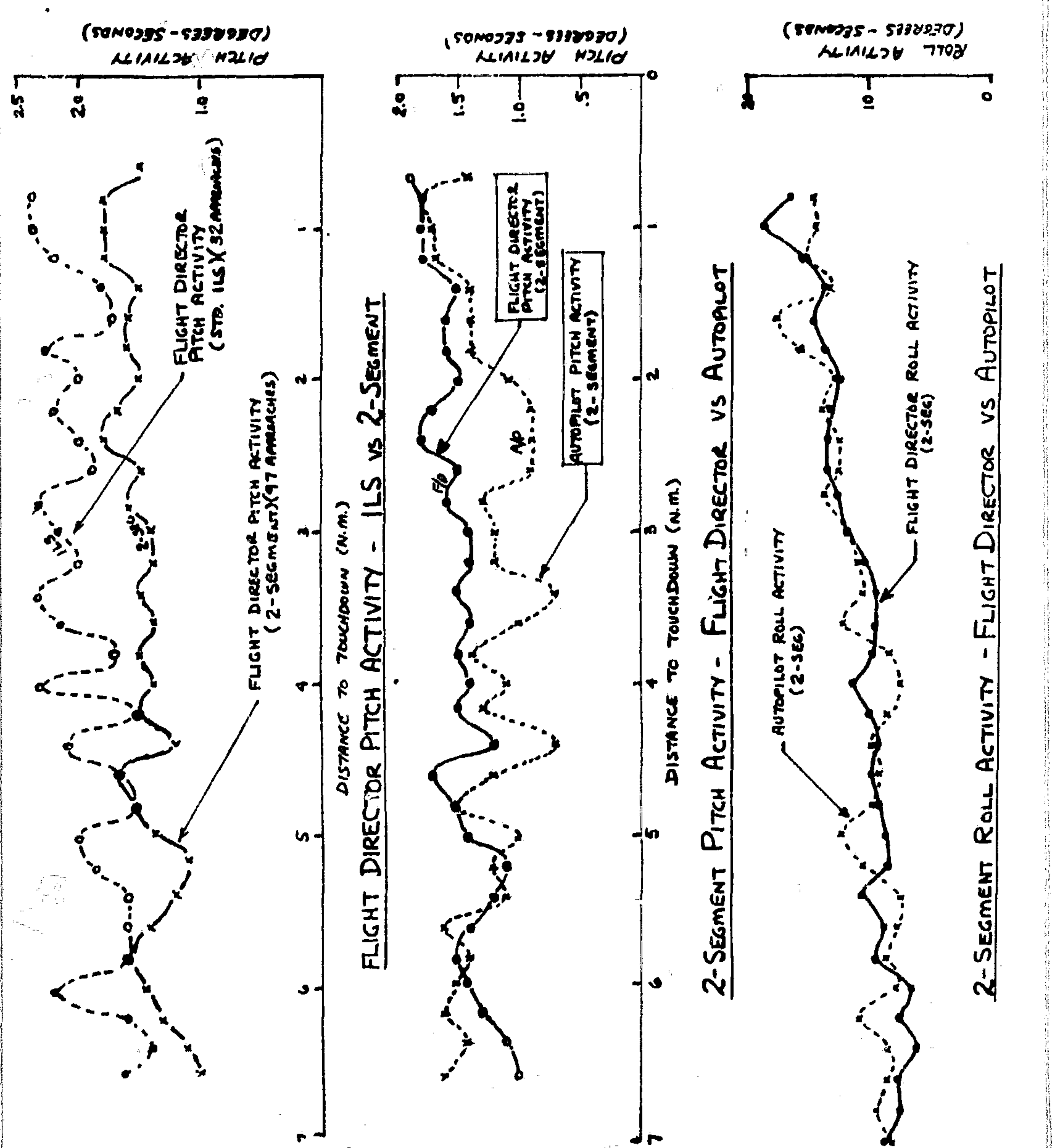
Given the assumption that the group tracked both profiles with substantially the same accuracy, a comparison of pitch and roll activity levels between the two types of approach (flight director ILS and flight director two-segment) will be used as a factor in the conclusions regarding the safety of the procedure. Any significant increase in overall workload (or in some specific portion of the approach) will be reflected as having a potential impact on safety. By the same token, negligible differences will be interpreted as indicating that the two-segment approach does not impact safety relative to the ILS approach from the pilot workload standpoint.

Plot 4 Analysis

Plot 4 makes two separate pitch activity comparisons and one roll activity comparison. In interpreting the two pitch activity plots, it is important to recognize the very small scale factor. This scale has been blown up to facilitate plotting and visual comparison. It is one-tenth the scale used on the roll activity plot.

Flight Director Pitch Activity - ILS vs Two-Segment (Plot 4)

One important point is shown in this plot. This is that the average pitch activity for the two-segment approach is consistently less than that required for the standard ILS. It can also be seen that, except for the two points on the two-segment approach where increased activity would be expected (upper segment and glideslope transitions), the



PLOT 4 - PITCH AND ROLL ACTIVITY

activity level is very stable throughout until about the 1.4 NM point at which time it rises. It should be noted that activity on the ILS also rises at this point and that the rise in ILS activity is nearly double that shown for the two-segment in the same portion of the approach. It should also be recognized that this rise is characteristic of a precision approach in which the beam is narrowing and the pilot concentrates more heavily on maintaining very small deviations.

Two-Segment Pitch Activity - Flight Director vs Autopilot (Plot 4)

This plot is consistent with the differences noted in Plot 1-A. Activity is substantially the same in both cases until correction back to upper segment after initial overshoot. At this point, the flight director pitch activity is stable but slightly higher than autopilot pitch activity. This accounts for the earlier correction back to upper segment shown for the flight director than the more deliberate autopilot correction shown in 1-A. Flight director activity is considerably higher in the glideslope transition portion, but this is also consistent with Plot 1-A which appears to reflect a slightly more rapid transition when being hand flown than when on autopilot. Glideslope stabilization and approach completion levels are nearly identical both in magnitude of activity increase and in general level.

Two-Segment Roll Activity - Flight Director vs Autopilot (Plot 4)

Two points can be made from this plot. The first is that there is a characteristic rise in activity as the aircraft gets nearer to touchdown. This is principally the result of the narrowing of the localizer beam. This is true of both the autopilot and flight director plots. The second point is that there is no significant general (or specific) difference between the hand-flown flight director and autopilot activity throughout the approach.

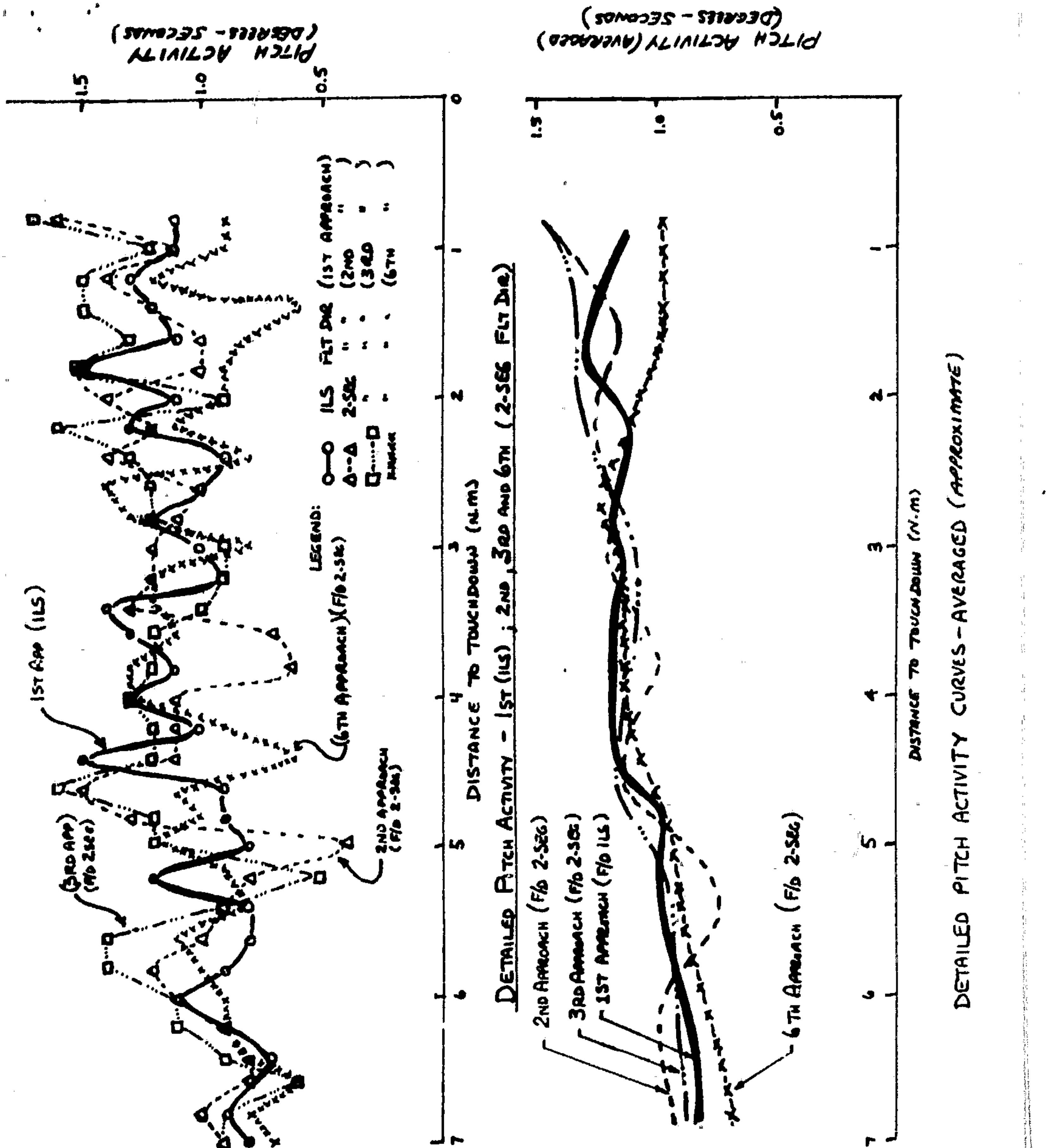
Detailed Pitch Activity - 1st, 2nd, 3rd and 6th Approaches (Plot 4-A)

The complexity of the detailed pitch activity plot of the four approaches must be considered in light of the greatly expanded degrees-seconds scale which it was necessary to use to separate the plots from each other. The approximately averaged curves appears below the detailed plot.

The important facts which this plot shows are:

(1) The general level of pitch activity of the ILS and the two-segment approaches is generally the same throughout the approaches.

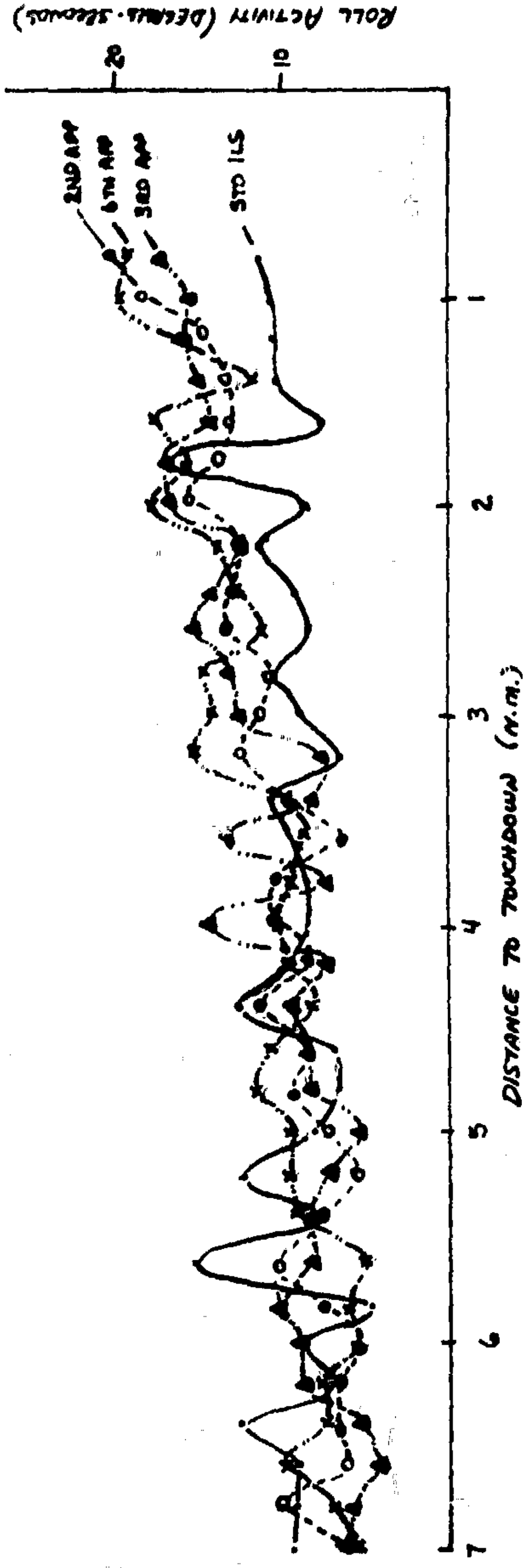
(2) There is a characteristic rise in pitch activity from commencement of all of the approaches to the point at which the approaches were broken off for a go-around.



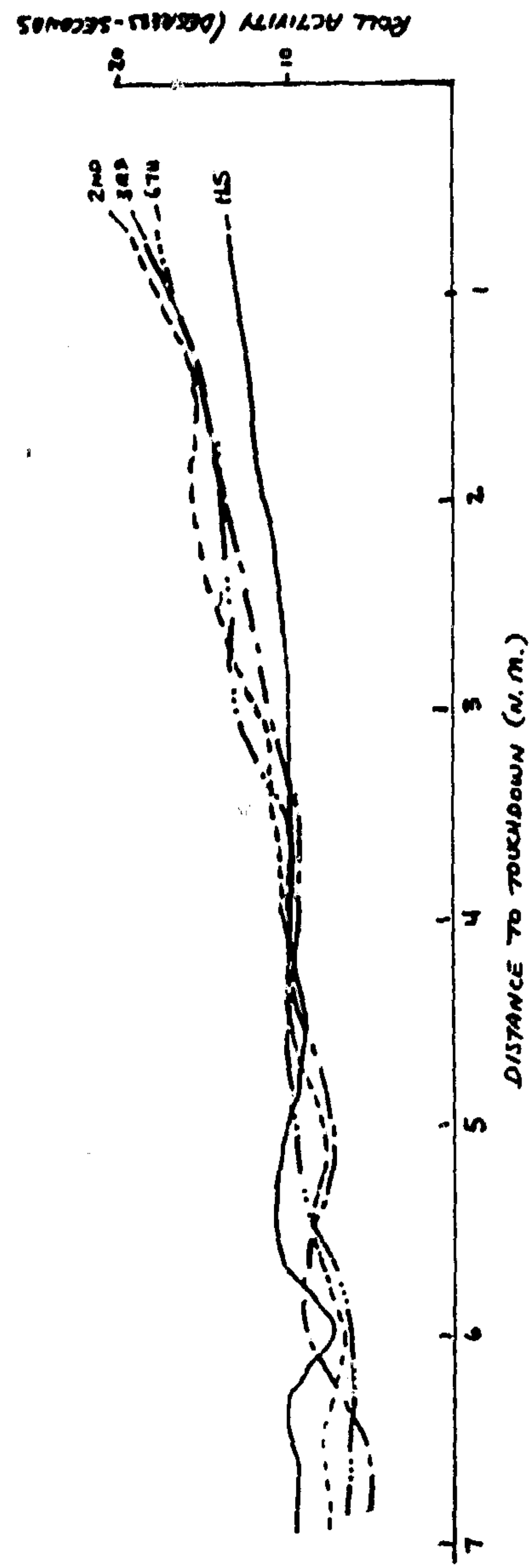
PLOT 4-A - PITCH ACTIVITY, 1ST, 2ND, 3RD & 6TH APPROACHES

Detailed Roll Activity - 1st, 2nd, 3rd, and 6th Approaches (Plot 4-B)

This plot compares the roll activity levels of the flight director ILS and the three flight director two-segment approaches flown by the 19-pilot statistical sample used for the 1st-2nd-3rd-6th approach analysis. It shows a somewhat higher roll activity level for the two-segment approach inside of approximately glideslope capture point (about 3 NM). Some of this is the result of data scatter of the smaller statistical sample. If the roll activity of the larger sample in Plot 2 is superimposed on this plot, the activity is still slightly higher than the ILS, but only very slightly.



DETAILED ROLL ACTIVITY - 2-SEG FLT DIR. AND ILS (1ST-2ND-3RD-6TH APP)



ROLL ACTIVITY (AVERAGED) - FLT DIR 2-SEG & ILS (1ST-2ND-3RD-6TH APP)

PLOT 4-B - ROLL ACTIVITY, 1ST-2ND-3RD-6TH APPROACHES

Findings from Plot 4, 4-A, 4-B Analysis

1. The two-segment approach does not significantly impact pilot physical workload in controlling the airplane's pitch attitude in performing to substantially the same vertical and lateral deviation standards as in the ILS. Since the two-segment approach effectively entails an intercept from below and followed by a second intercept from above, it is felt that this factor would show significant overall differences in pitch control activity if it were demanding more pilot attention than the ILS.

2. Roll activity is slightly higher in the two-segment than the ILS in the final portion of the approach. It can only be surmised that the sum total of pitch change and airspeed control in the glideslope transition regime demanded more of the pilot's attention than would normally be demanded in the ILS.

Conclusions Regarding Overall Safety of the Two-Segment Approach Procedure

1. The procedure is acceptably safe.

2. The system as evaluated provides adequate guidance for use in IFR.

3. The two-segment approach crew procedures and techniques are not significantly different from the standard ILS in any way which degrades safety.

4. The profile transitions are safe and easy to fly. At these points, pilot workload is slightly higher in power and attitude control than in the ILS; however, this increase does not result in any apparent unsafe tracking performance or in undue diversion from other essential cockpit duties.

5. Typical engine power settings required for upper segment tracking under representative conditions are acceptable. Under some above-the-surface tailwind conditions (which exceed permissible surface tailwind components for landing), engine power might be too low for full anti-ice capabilities, without the use of moderately assymetrical engine power. Under such conditions, the procedure would probably not be recommended.

6. Upper segment descent rates are acceptable except under some above-the-surface tailwind conditions. As with 5 above, these conditions would be for winds exceeding permissible landing tailwind components.

7. Glideslope transition and stabilization altitudes are safe and acceptable. (Note: Several pilot comments related to this factor indicated that the altitudes used in the procedure were safe but that lower altitudes than these would not be acceptable.)

IS THE TWO-SEGMENT SYSTEM AND PROCEDURE OPERATIONALLY PILOT-ACCEPTABLE

EVALUATION CRITERIA GENERAL

~~IS THE TWO-SEGMENT PROCEDURE OPERATIONALLY PILOT-ACCEPTABLE?~~

Two principal objectives were involved in the Guest Pilot Evaluation. The first was to establish that the procedures were safe for use in the six-month in-service evaluation which was to follow. The second was that the group should evaluate the procedure from the standpoint of whether they, as pilots, felt that the procedures would be operationally acceptable to the general pilot community.

It was recognized that the pilots would be making their judgments from a "test tube" environment which lacked many of the every-day elements of air carrier operations (revenue passengers aboard, interfacing with other scheduled traffic in a heavy-traffic ATC environment, etc.). It afforded the best opportunity, however, to "try it on for size" before going into the in-service evaluation where these missing elements would be present.

No two pilots were expected to use exactly the same "yardstick" for accepting (or not accepting) the procedure. Question 4-A was framed to elicit each pilot's comments regarding whether it was operationally sound and acceptable. Its companion question (4-B) was intended to show the principal basis upon which he had judged the procedure as operationally acceptable (or lacking). Questions 5 and 6 were extensions of the broader question 4. It was felt that the transition maneuvers and the inter-transition portion of the profile (to which questions 5 and 6 were addressed) represents most of what was new and un-familiar, and would therefore yield comments bearing on conclusions regarding acceptance by the Guest Pilots. Pilot responses to questions 4-A-B, 5 and 6, along with the Part I responses, therefore form the principal basis for conclusions related to pilot acceptance.

As with the preceding safety analysis, certain performance data derived from Appendix III will be given appropriate weight in any conclusions to which the data pertains.

Because the basis for comment (particularly in question 4-A) is potentially very broad, an attempt to categorize the comments under a few general headings has been made. The verbatim comments (and any subsequent correspondence) are contained in Appendix I. The general categories and their rationale are:

(1) Pilot Workload and/or Physical Cockpit Activity - In the preceding analysis of safety, certain indicators of the level of this activity were considered as bearing indirectly upon safety if they reflected an undue diversion of the pilot's attention from other essential cockpit activity. In this analysis, these and other factors will be treated as having a direct relationship to pilot acceptance, on the premise that any pilot workload and/or physical cockpit activity demands which are markedly increased by the two-segment procedure would make the procedure less pilot-acceptable.

(2) External Factors - This category will relate principally to any external factors with which the pilot must cope in his approach to landing. The extent to which the effect of these factors is different in the two-segment approach from the ILS approach will be given appropriate weight in the conclusions.

(3) Profile And Procedures Considerations - Comments relating to profile geometry or to approach procedures will be placed in this category.

(4) Miscellaneous - Comments not appropriate to any of the above categories will be placed in this category.

QUESTION 4 A-B SUMMARY AND ANALYSIS
(37 Simulator; 45 Aircraft Questionnaires)

QUESTION 4-A - Do you feel the two-segment approach you have flown can be flown in normal line operation?

4-B - What factors are involved in your answer to 4-A?

Question 4 A-B Response Summary

	SIMULATOR	AIRCRAFT
"Yes" (With no classifiable comment)	3	7
"Yes" (With classifiable comment)	33	36
"No"	0	0
Classified by content as "No"	1	2
Total	37	45

The "Yes" with classifiable comments category is broken down below. The totals exceed the number of pilots because many responses to 4-A and 4-B introduced more than one idea in a single response.

Pilot workload/Cockpit Activity

	SIMULATOR	AIRCRAFT
Workload increased (particularly on Flight Director.	0	1
Workload not increased (or not appreciably higher than Standard ILS).	5	5
Good instrumentation/guidance	1	2
As easy/easier than ILS	0	9
Total	6	17

External Factors		
Procedure has icing/tailwind limitations	9	3
Procedure more pilot/passenger acceptable in windshear/turbulence conditions.	1	2
Acceptable with appropriate operational and weather limitations	5	10
Total	15	15
Profile and Procedures		
Profile/procedures simple, easy to fly	12	9
Good transitions/stabilization/power/descent rates	6	6
Good profile if glideslope stabilization is 500'(AFL) or higher	3	2
Total	21	17
Miscellaneous		
Acceptable procedure with adequate training/familiarity in line use.	10	9
Needs On-Line evaluation/greater pilot sample	3	1
Total	13	10
Total ("Yes"-classifiable)	55	59

Classified "No" by Content		
Potential safety problems in two-segment; can't foresee all problems at this time	1	0
Sink rate/lookout poor	0	1
Crew fatigue-potential safety factor	1	0
Compromises safety for noise abatement	0	1
Total	2	2

Question 4 A-B Analysis:

The general tenor of pilot responses to Question 4-A is that the two-segment approach procedures are operationally pilot-acceptable. Only in a few specific areas is there a significant number of comments which allude to limitations as to its use in normal line operations:

(1) Icing and tailwind limitations.

(2) Its use down to appropriate minimums and appropriate operating limitations.

(3) Training and/or sufficient use to permit the pilot to gain familiarity with the procedures and/or system management.

Question 4 A-B Findings:

1. The two-segment approach procedure can be flown in normal line operations with appropriate limitations related to the external factors which affect the use of any approach procedure.

2. The procedure is pilot-acceptable from the workload and cockpit activity standpoint.

3. The profile geometry is good. The procedure is easy to fly.

QUESTION 5 - RESPONSE, SUMMARY AND ANALYSIS
(37 Simulator; 45 Aircraft Questionnaires)

QUESTION 5: What is your opinion of the transition to upper segment?

Question 5 was intended to explore pilot reaction to the entire upper segment transition maneuver. This included:

(a) Pre-transition annunciation and instrument cues which the pilot needs for proper configuration and energy management.

(b) Differences between this transition and the standard ILS transition as regards configuration, speed and power control.

(c) Differences in the ease of following flight director commands in the upper segment transition as compared to the standard ILS transition.

(d) Same as (c) above for auto-coupled transition.

(e) Differences in crew workload to establish speed and power for stabilized upper segment tracking as compared to the same activity in the standard ILS.

(f) Is the transition too abrupt? Too "lazy"?

(g) Is the transition maneuver pilot-acceptable?

One of the principal criteria used in the procedures development was that from the pilot technique standpoint, the two-segment approach would be as similar in all respects to the standard ILS as possible. The differences between the upper segment and ILS transitions are more a matter of degree than of technique, the principal differences being in the amount of attitude change required, the substantially lower power settings and slight differences in flap management.

QUESTION 5 RESPONSE SUMMARY

An examination of the Question 5 verbatim responses in Appendix I will show numerous short and succinct comments such as "smooth - no problem", "excellent", etc. For purposes of this analysis, such comments are interpreted as reflecting the pilot's opinion that the transition maneuver is acceptable. The assumption has been made that he would not have selected such a term if he felt otherwise.

	SIMULATOR	AIRCRAFT
No response	6	1
Acceptable ("smooth", "no-problem", "excellent")	17	21
Acceptable (with comment)	14	23
Unacceptable	0	0
Total	37	45

The "acceptable with comment" category is broken down below. Some responses introduced more than one idea in a single response.

	SIMULATOR	AIRCRAFT
Pre-capture configuration necessary/needed earlier.	7	4
No unusual techniques/trim.	1	1
Ok with practice.	-	3
Transition fast/faster than expected.	4	3
Transition "lazy".	0	2
Transition comparable or better than ILS.	0	3
Transition is speed critical.	4	6
Transition "not so good".	1	0
Plenty of time to stabilize on UPPER.	1	-
Better on manual throttles/power management.	0	3
Workload increases (particularly if fast).	-	1
Ok day VFR - potential problem night/IFR.	-	1
Total	18	27

QUESTION 5 ANALYSIS

The comments indicate very little problem with the upper transition. The detailed comments point up the need for slightly earlier pre-capture configuration cues, the criticality of proper entry speeds and the fact that in a number of cases the transition was faster than the pilot had expected or thought it should be.

The configuration cue problem was recognized early; however, under the circumstances, it was felt necessary to accept this penalty in favor of a realistic deviation gain (250'/dot) which was necessary for good upper segment tracking. A gain switch after capture from about 500'/dot (to give better pre-configuration cues) to 250'/dot for tracking was found impracticable and unacceptable because a sudden deviation excursion at gain switchover point was virtually impossible to attain without very significant equipment modifications.

QUESTION 5 FINDINGS

1. The upper transition is pilot acceptable.

2. Pre-capture configuration cues are slightly later than they might be to be optimum.

3. Small variations in entry speeds make significant differences in the ease with which the transition is accomplished.

QUESTION 6 SUMMARY AND ANALYSIS

(37 Simulator - 45 Airplane Questionnaires)

QUESTION 6 - WHAT IS YOUR OPINION OF THE TRANSITION TO THE GLIDESLOPE?

Earlier evaluations and various published statements gave the indication that the transition from Upper Segment to ILS Glideslope (or Lower Segment) was considered the most safety- and pilot acceptance-critical portion of the two-segment procedure. The Project Pilot group conducted a very detailed investigation into the individual and interdependent variables that are involved in this portion of the approach. Question 6 was written as a completely free-form question in order to elicit Guest Pilot opinion on anything involved in the maneuver from commencement at Glideslope Capture Point to Glideslope stabilization point.

As with the Question 5 summary and analysis, such comments as "smooth", "gradual and smooth" etc. have been interpreted to mean that the pilot considers the maneuver acceptable. In addition to this type of comment, there are several comments which reflect pleasant surprise at the maneuver. In the absence of some additional specific statement to the contrary, these have been interpreted as an indication of the pilot's acceptance.

QUESTION 6 RESPONSE SUMMARY

COMMENT CATEGORY	SIMULATOR	AIRPLANE
No Response	-	1
Acceptable (without qualifying comment)	21	26
Acceptable (with comment)	16	18
Unacceptable	-	-
Total	37	45

The nature of the comments made in the responses are broken down as follows:

Good with proper guidance	-	1
Guidance is good	-	1
Power control/ trim easy	1	1
Prefers manual throttles	1	1
Workload not increased	-	1
Workload higher in speed/power/scanning	1	4
Good if stabilized for entry	1	2
Likes constant speed transition	1	1
Likes 10-knot increment on Upper	3	1
Good with proper training/familiarity	4	1
Improvement over earlier procedures	1	-
Flight Director better than Autopilot	1	1
Good if commenced by 1000'-Stab. on G/S by 500'	1	2
Transition starts too high/takes too much alt.	1	1
Transition starts too low	2	-
Good in VFR	-	1
"Only segment in complete program that gives me concern"	-	1

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QUESTION 6 FINDINGS

1. The glideslope transition maneuver is pilot-acceptable. There is no statement either in this question or in question 3 which would indicate that any pilot in the group considers the lower transition unsafe.

2. The maneuver as evaluated appears to have allayed earlier concerns as regards high sink rates, glideslope undershoot and engine spool-down at low altitudes.

PILOT QUESTIONNAIRE PART I ANALYSIS

The Part I questionnaire analysis appears in the preceding discussion on safety of the procedure, and will therefore not be repeated in this section. (See pp 34-35)

As explained earlier, the Part I responses were treated as indirect factors in the conclusions regarding safety. In the following findings, they have been considered as bearing directly on pilot acceptance.

FINDINGS FROM PART I ANALYSIS AS IT RELATES TO PILOT ACCEPTANCE

1. The two-segment approach procedure does not have a significantly greater impact on pilot cockpit activity than the standard ILS procedure.

2. Instrument scanning and airspeed control are slightly more difficult in the two-segment approach. These factors do not constitute an unacceptable workload increase over the standard ILS workload requirements.

COCKPIT INSTRUMENT DISPLAYS AND ANNUNCIATIONS

(3) COCKPIT ANNUNCIATOR AND INSTRUMENT DISPLAYS AND ANNUNCIATIONS

The responses to Questions 1 and 2 and any applicable written comments on Part I of the questionnaire constitute the principal sources upon which the conclusions regarding instrument and annunciator displays are based. Generally, the pilot either approved of these displays or recommended changes which he specified in his responses.

The following tables summarize the responses to these questions:

Question 1 Summary and Analysis

This summary is based on 37 simulator and 45 aircraft questionnaires.

Question 1 - Would you like to see any changes made to the existing annunciator display? If yes, what changes?

Question 1 Summary	Simulator	Aircraft
No change recommended	29	26
Annunciator changes/additions recommended:		
(a) 2-seg switch "on/2-seg" armed" lite	-	3
(b) 2-seg "fail" lite	1	1
(c) "Airport elevation set" annunciator	1	1
(d) Annun "Alt Hold" and/or A/T modes	4	2
(e) Add Radalt visual/aural warning at 1000'-800'(AGL)	-	1
(f) Illuminate "upper segment" and "glideslope" amber at same time	1	1
(g) Extinguish "upper segment" green at "glideslope" green	1	3

Question 1 Summary, Cont.

Relocations or logic changes recommended:	Simulator	Aircraft
(a) Place Approach Progress Display immediately above ADI	-	2
(b) Inhibit "glideslope" amber until at least 1000' below U/S capture	-	1
(c) Move 2-seg selector switch or make it different from marker beacon switch	-	1
(d) Make 2-seg selector switch engageable only if all valids are present	1	1
(e) (Comment) Blank "U/S" distracting on standard ILS	1	1
(f) Display F/D modes in HSI	1	-

Question 2 Summary and Analysis

Question 2: Would you like to see any change in the instrument display? If yes, what changes?

RESPONSE SUMMARY

	Simulator	Aircraft
No change recommended	20	21
Recommended changes:		
(a) Display raw G/S on HSI and computed data on ADI	4	5
(b) Investigate feasibility of (a) above	1	2
(c) Display computed data on ADI on U/S and switch to raw G/S at G/S capture	3	6
(d) Display raw G/S on HSI	-	5

Question 2 Summary, Cont.

		Simulator	Aircraft
(e)	Dampen sudden switch of vertical deviation bar on HSI at G/S capture	2	-
(f)	Place 2-seg selector switch on F/D mode selector panel	-	1
(g)	Group all 2-seg switches/controls together	1	3
(h)	Improve HSI visual configuration cues	1	-
(i)	Heading bug color (hard to read)	-	1
(j)	ASI hard to read/ASI scale orientation	1	1

DISCUSSION OF PILOT RECOMMENDATIONS

The recommendations relating to extinguishing the "upper segment" annunciation at glideslope capture were carefully considered. It was felt that this would not be consistent with the established progress display light convention wherein once illuminated, that light is not extinguished so long as the procedure continues normal progress through the subsequent steps.

A total of eleven comments (sim and aircraft) were made concerning separate annunciation of the two-segment on/armed/fail and annunciating the altitude hold and autothrottle modes. The original equipment design proposed by Collins included a "two-segment approach-normal" and a "two-segment fail-below glideslope" annunciator. These annunciators were deleted from the system for two principal reasons:

(1) A light should be added to the panel only if its message is such that safety is compromised in the time lapse which might be involved in the pilot's recognizing and interpreting this message from a less obvious source and/or (2) it is required by regulation

or is considered operationally necessary for some reason different from (1) above. In this particular case, the "two-segment-normal" light was functionally little more than a switch position indicator light. The "fail" light was considered redundant because failure of the system, while it is serving as the vertical guidance source, disconnects the autopilot and/or biases the command bars from view. The two-segment system, even when selected "ON", does not alter the operational logic of any of the flight director or autopilot modes other than the auto approach modes. Any two-segment failure affecting the usability of either system is therefore manifested to the pilot in a manner already proven adequate and reliable under such conditions.

Considerable comment was received (8 simulator, 18 aircraft) relating to raw data versus computed vertical deviation data on the ADI and HSI. Several combinations were mentioned. This matter was discussed at length in the system design phase. It is felt that the divergent opinions were principally the result of different airline instrumentation concepts, differences in pilot backgrounds and training and differences in individual fleet configurations. The decision to display raw ILS glideslope on the primary instrument was based on several important factors: (1) Raw ILS glideslope information which is unswitched and not processed through the two-segment system, should be available to the pilot. The addition of glideslope and LOC deviation displays in the ADI attest to the importance of this information in the primary attitude/guidance instrument. (2) This information must be immediately available to the pilot next to his flight director command bars in the most critical phase of the approach. As designed, the unswitched and unprocessed raw information is displayed in the ADI. (3) Raw glideslope display in the ADI is an additional safe-guard against a computational error which might mis-position the upper segment. There is no proper situation on upper segment in which the aircraft is on upper segment and below glideslope at the same time. (4) As presented, the display is the same as the pilot sees when capturing ILS glideslope from above in a standard ILS.

It should be recognized that if this system were retrofitted into the various air carrier fleets, any display combination which an individual carrier might desire could be incorporated through interface and minor equipment modifications.

Conclusions Regarding Two-Segment Annunciator and Instrument Displays

A. The annunciator display and sequencing are acceptable.

B. The vertical guidance display is acceptable.

C. Differences exist regarding the combination of raw and computed vertical deviation displays on the ADI and HSI. These differences can be accommodated by interface and minor equipment modifications.

D. The cockpit location of system controls, annunciators and switches is acceptable for a single-system installation.

GENERAL SUMMARY

The Guest Pilot Evaluation successfully accomplished the objectives for which it had been designed.

The participants represented a well-balanced cross section of experienced industry pilots. Their evaluations provided the confidence that the equipment and procedures could (and should) be evaluated in the regular air carrier environment by Line Pilots who became involved as the result of normal line bidding procedures. Accordingly the system was installed in a UAL B727-222. The FAA issued a Supplemental Type Certificate for evaluation of the equipment and procedures in revenue service. This evaluation was conducted during the period 28 April-29 October 1973.