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FLIGHT SIMULATION STUDY TO DETERMINE MLS LATERAL COURSE WIDTH REQUIREMENTS ON FINAL APPROACH FOR GENERAL AVIATION

(NASA-CR-137859) FLIGHT SIMULATION STUDY TO DETERMINE MLS LATERAL COURSE WIDTH REQUIREMENTS ON FINAL APPROACH FOR GENERAL AVIATION (Crumrine (Ralph J.)) 35 p HC $4.00 CSCL 17G G3/04

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TABLE OF CONTENTS

ABSTRACT

An investigation of the effects of various lateral course widths and runway lengths for manual CAT I Microwave Landing System instrument approaches was carried out with instrument rated pilots in a General Aviation simulator. Data are presented on the lateral dispersion at the touchdown zone, and the middle and outer markers, for approaches to 3,000, 8,000 (and trial 12,000 foot) runway lengths with full scale angular lateral course widths of ±1.19°, ±2.35°, and ±3.63°. The distance from touchdown where the localizer deviation went to full scale was also recorded. Pilot acceptance was measured according to the Cooper-Harper rating system.

I INTRODUCTION

The lateral course width (or deflection sensitivity) of the new Microwave Landing System (MLS) cannot be adjusted or monitored in the same manner as the present Instrument Landing System (ILS) localizer. Since the ILS is a fixed beam system its beam width can be adjusted on the ground to give the required (Cat II) full scale deflection of 350 feet to either side of the runway centerline at the threshold as shown in Fig. 1. This adjustment is made at each ILS installation so that regardless of runway length or localizer siting, the lateral deflection at the threshold is standardized.

The MLS is not a fixed beam system, but rather a narrow beam which is scanned over a wide horizontal angle (±10° to ±40° depending on the configuration). Hence, the MLS lateral course width cannot be adjusted or verified in the same manner as the ILS. The present U. S. MLS signal format proposes to implement a standardized lateral course width in the following manner. The ground radiated azimuth (localizer) preamble would include three bits for the azimuth deviation scale factor. This data would be coded to transmit the appropriate azimuth antenna-to-runway threshold distance to the airborne MLS receiver for the particular MLS siting as shown in Table 1.

It is proposed in Reference 4 that the airborne MLS receiver use this runway length data to alter the sensitivity of the lateral CDI deviation signal to produce the full scale deflections shown in the right hand column of Table 1. These course widths are a digitization of course widths used for CAT II localizer installations (reference 5). The purpose of this study was to determine the effect on General Aviation of different lateral course widths as a function of runway length. This data should provide insight to the need for and the suitability of the azimuth deviation scale factor quantization as shown in Table 1.

II SIMULATION STUDY

Simulation Description - The simulator chosen for this study was the Singer-Link GAT1-B flight simulator shown in Figure 2. This simulator is fully described in Reference 5. It is a 3 axis-of-motion simulator with full simulation of navigation aids.

The landing approach was modeled as shown in figures 3 and 4. The lateral course widths (as determined by full scale deflection) evaluated were: ±1.19°, ±2.35°, and ±3.63°. The runway lengths selected for test were: 3,000 and 8,000 feet. Some trial runs also included the 12,000 foot runway; however, the bulk of the statistical data reported here is limited to 3,000 and 8,000 foot runways. The wind conditions were: calm, 15 knots left, and 15 knots right. All runs were made with light-to-moderate turbulence included.

The localizer and glide slope deviation were displayed on the Narco VOA-9 indicator. Full scale localizer course width was adjusted to the end of either the blue or yellow scale arc and the arc length was approximately 5/8 inches left or right of center.

Pilot Selection - Twenty-nine pilots from all segments of the General Aviation community were invited to participate in this study; the only criteria being that each pilot was instrument rated and current according to FAA regulations. The occupations represented by the participants are listed in Table 2. Table 3 shows the distribution of pilots versus hours of pilot-incommand flight experience.

Test Procedure - Prior to the test flights each pilot received a description of the test objectives, the simulator, the task description, an approach plate (Figure 3), and a Cooper-Harper Handling Qualities Rating Description (Appendix A). At the time of the test each pilot was briefed orally about the task and about the simulator characteristics. The pilots were then familiarized with the simulator cockpit and allowed to fly typical training maneuvers including some approaches.

After familiarization each pilot flew a set of six runs for record. In each case the order of runs was drawn entirely at random. Crosswinds, when required, were also drawn at random. Fatigue and learning were thus distributed in a random manner over all the results.

During the tests, the pilots were instructed to keep the localizer and glide slope displays centered, while maintaining proper airspeed. At the minimum descent altitude of 332 feet the pilot transferred from the glide slope to barometric altimeter and maintained this altitude while continuing to center the localizer as long as possible. They were also instructed to maintain an average approach speed of 105 knots.

To simulate the normal pilot workload, light to moderate turbulence was added to the flight conditions and approach control and tower communications were simulated. All elements of the landing guidance system were operative; localizer, glide slope, marker beacon, and ADF.

Recorded Data - Analog traces of localizer deviation, crosstrack errors, airspeed, and barometric altimeter were recorded using a pair of HP 7046A X-Y/Y plotters. One pen was switched between glide slope and barometric altimeter in the vicinity of the middle marker; thus, in all five variables were recorded. Range was measured on the X axis from the localizer transmitter location as shown in Figure 1. Maximum recorded range was 7.5 nmi.

Cooper-Harper ratings (C-H ratings) and pilot opinion were obtained after each run. The Cooper-Harper rating is a measure of pilot acceptance ranging between 1 for excellent and 10 for unacceptable. The scale with descriptive material is included in Appendix A. It should be noted, that this was the first time any of the participating pilots had used the C-H rating system and that this lack of familiarity could affect the results.

III RESULTS

Pilot Opinion - Figure 5 summarizes the C-H ratings for the various combinations of runway length, lateral course width and wind conditions which were statistically studied. The conditions on the X-axis are arranged in order of increasing sensitivity. Notice that the C-H rating increases for both the very low sensitivity and very high sensitivity cases. It is also interesting to note that current ILS conditions exemplified by the 8,000 foot runway and 2.33° course width emerged with the best Cooper-Harper rating. This result indicates that experience may be a strong factor in influencing acceptability.

The increase in Cooper-Harper rating at the low sensitivities was due largely to a group of pilots with limited recent experience, that did not like it because course trends were slow to emerge and thus, these less practiced pilots were uncertain of themselves and their position and were led to take large heading changes just to cause something to happen in the localizer display.

At the other extreme, where pilot compensation would have been expected to be high due to the high deflection sensitivity of the 3,000 foot/1.19° sensitivity runs, the average C-H ratings are only mildly higher. This average was influenced downward by a group of keenly experienced pilots who found none of the runs particularly difficult, thus, giving all runs low C-H ratings. This group liked the fast response of the localizer display due to the narrow course width. This group was typically composed of air taxi pilots, flight instructors, and ex-Army helicopter pilots. It was generally acknowledged that short final straight-in approaches with large angle turn-ins would probably be troublesome with the narrow 1.19° course width. This was observed to be true in the case of the simulator runs as there were numerous occasions where the pilot missed his turn-in from a 45° intercept when using the narrowest course width; particularly when the cross wind was at his back.

Pilot comments were solicited after each run along with the C-H rating. The following conclusions can be drawn based on these comments:

1. The narrow (1.19°) course width is unacceptable at the short (3,000 foot) runway for a high percentage of the pilots due to the resultant high workload and overshoot during the 45° intercept of the localizer.

2. Increasing the course width from 1.19° to 2.35° for the 3,000 foot runway makes this combination acceptable.

3. The combination of the 8,000 foot runway and the nominal (2.35°) course width was rated best by the pilots and this reflects the pilot training/experience with the present 2.5°/8,000 foot nominal ILS.

4. The 3.63° course width was objectionable to several pilots due to the slow or insensitive response of the localizer display.

Lateral Dispersion - Figure 6 shows the cross track errors measured at the touchdown zone and middle and outer markers for the 8,000 and 3,000 foot runways. (See Appendix B for the detailed lateral dispersion tabular data.) The cross hatches represent the 2 σ deviations and the means are noted by the symbols. Notice the funneling effect typical of an angular guidance system.

Table 4 is a summary of the maximum allowable lateral deviation at the middle marker due to instrument saturation. A full scale CDI indication at the middle marker requires the pilot to initiate a go around for a CAT I approach, hence the lateral dimensions of Table 4 can be used as a criteria to compare to the actual lateral 2 σ deviations given in Figure 6 and summarized in Table 5 to establish the acceptability of the various runway length and course width combinations. Notice from the percentages of Table 5 that all of the combinations except the 3,000 foot runway/1.19° width with cross winds fall below the lateral deviation which could constitute a missed approach. Notice that the case which most resembles the present ILS (8,000 foot/2.35°) is within 70% of the full scale deflection limit. Hence, all but the shortest runway/narrowest course width appear to be satisfactory on the basis of cross track deviations at the CAT I decision height (middle marker).

Closest Approach - All simulator test runs were continued inside the middle marker with the instruction to continue tracking the localizer. Figure 7 shows the typical instability that is encountered close to the localizer transmitter. It was of interest to determine how far the approaches could continue before the sensitivity became so great that the display would saturate. The point at which this occurrs is referred to herein as the point of closest approach.

Figure 8 shows the distance of closest approach for each of the run conditions. The distance shown is the mean plus 2 σ deviation for each case. Three individual flights were not included in the two 3,000 foot runway/1.19° data because the localizer went full scale three to four times between the outer marker and the touchdown zone, and in fact, constituted a missed approach for these three flights prior to the middle marker.

Considering the above and the fact that Figure 8 shows that the closest approach occurs for the run with the widest course width and the longest runway, we see that the data trend is generally as expected. However, there are some unexplained comparisons for the 8,000 foot/runway 2.35° case of Figure 8. One clear conclusion from this portion of the data is that the shortest runway/narrowest course width (3,000 foot/1.19°)

case is unacceptable based on the three missed approaches out of 53 flights at these conditions. Even if these three data points are ignored, Figure 8 shows that the closest approach distance for the 3,000 foot/1.19° case with crosswind is very close to the middle marker distance of 7,867 feet. Hence making this case unacceptable. The closest approach for all the other conditions is acceptable since it is well inside the middle marker location.

Discussion - Although statistical data was not accumulated for the 12,000 foot runway case, the trial runs did not show any unusual problems. It is expected that the trends provided by the statistical data plotted in Figures 5, 6 and 8 can be extrapolated to the 12,000 foot runway case

The cases with the largest course width and shortest runway were not run statistically because the medium course width (2.35°) was completely acceptable. Statistical data was not obtained for the smallest course width for the 8,000 foot runway because the test runs with these conditions were acceptable and the medium 2.35° course width for this runway length was acceptable. Also Table 5 shows that in going from 8,000 to 12,000 foot runway lengths there is only a small percentage increase in the lateral distance at which full scale localizer deflection is encountered at the middle marker. Hence, the 50% increase in runway length does not result in a similar increase in acceptable lateral dispersion.

IV CONCLUSIONS

The goal of this study was to determine full scale angular deviation for pilot display on conventional localizer deviation indicators used with the Microwave Landing System (MLS). Of particular interest is the question of azimuth course widths for a short runway. For the middle marker location theoretical system gain variations of 5:1 were explored, taking into account runway lengths and course width changes.

Results for the narrowest course width ($\pm 1.19°$) applied to the short runway indicate a high workload. This is evidenced by the higher numerical C-H ratings, increased glide slope dispersion, by the several "missed approach" situations that occurred, and the numerous "missed turns on to course" for this case. On the average, localizer became too sensitive for continuing the approach prior to reaching the middle marker location if the "wild points" were included in this data.

Results for the $\pm 2.35°$ course width runs seem quite satisfactory including the approaches to the 3,000 foot runways. There is some degradation of glide slope dispersion between the 8,000 and 3,000 foot runway data. With this sensitivity ($\pm 2.35°$) the localizer was useable down past the middle marker and appears satisfactory for General Aviation approach to typical minimums.

The $\pm 3.63°$ course width produced several minor adverse results. Dispersions are unnecessarily aggravated by this larger course width angle. There are some adverse reaction to the slow display trends with this course width.

Results of this study tend to point to the fact that ±2.35° course width is acceptable for runway lengths in the range from 3,000 to 8,000 feet; and beyond to the maximum length runway anticipated if a minor increase in dispersion is acceptable. It, therefore, appears from these limited tests that it may not be necessary to vary the MLS azimuth course width as a function of runway length for this class of user.

REFERENCES

1. DO-148, A New Guidance System for Approach and Landing, RTCA SC-117, December 18, 1970.
2. DO-118, Standard Performance Criteria for Autopilot/Coupler Equipment, RTCA-79, March 14, 1963.
3. FAA Flight Inspection Manual.
4. MLS Signal Format Specification, FAA-ER-700-08A, May 30, 1975.
5. FAA Flight Inspection Manual, Tailored Localizer Course Width, pp. 18.
6. GAT I-B Maintenance Manual.

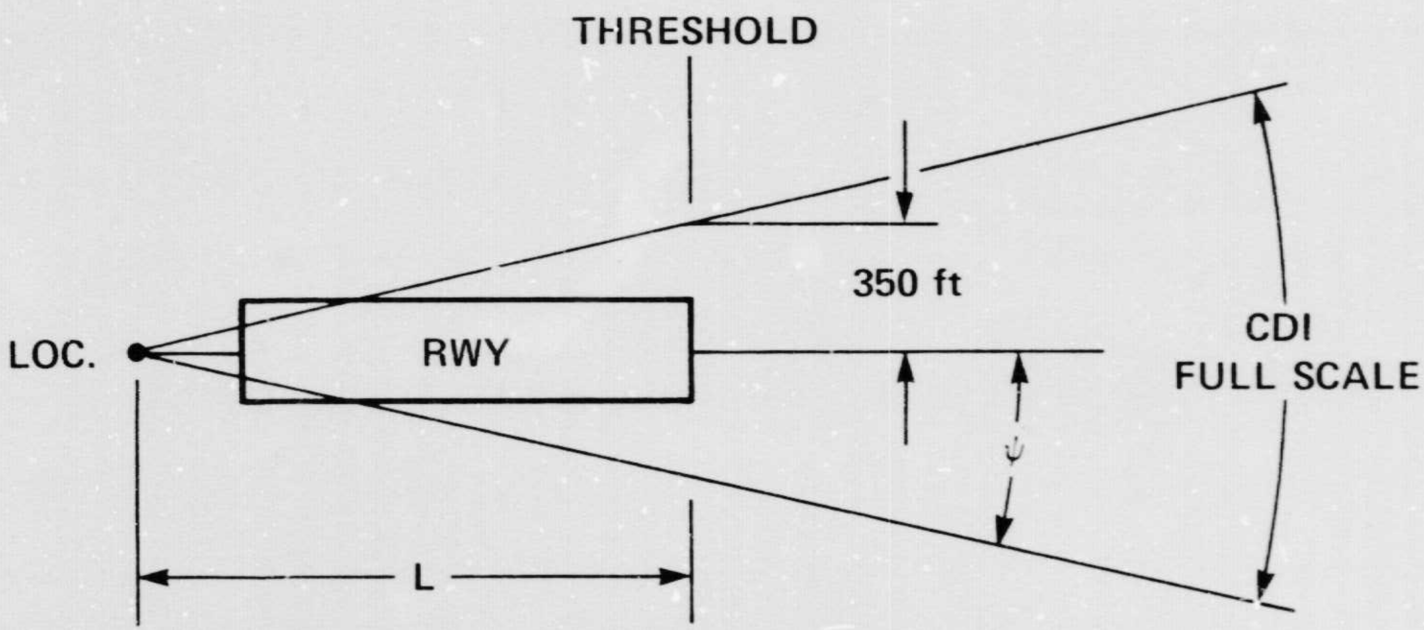


FIGURE 1. ILS LOCALIZER GEOMETRY

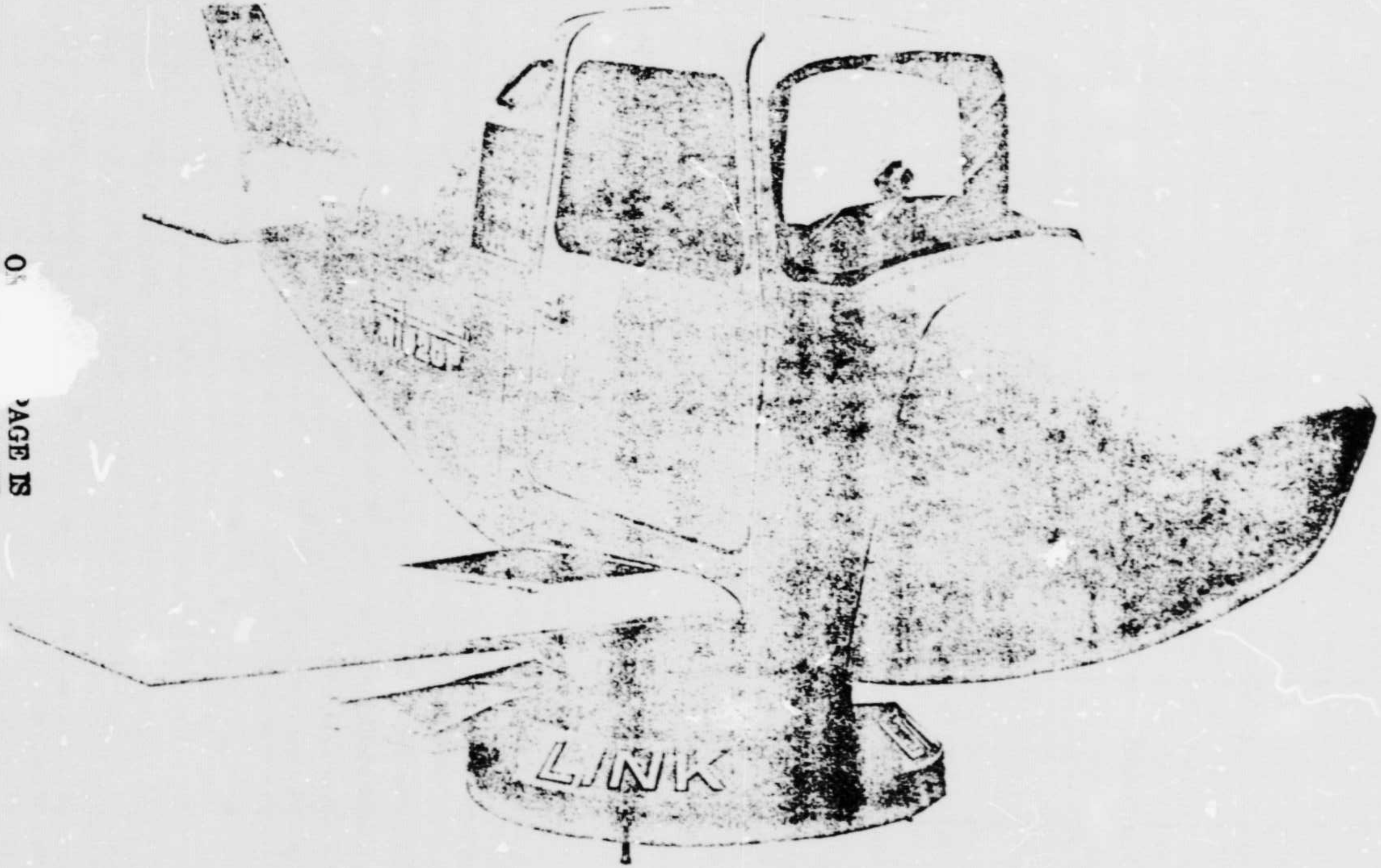


FIGURE 2. GENERAL AVIATION TRAINER

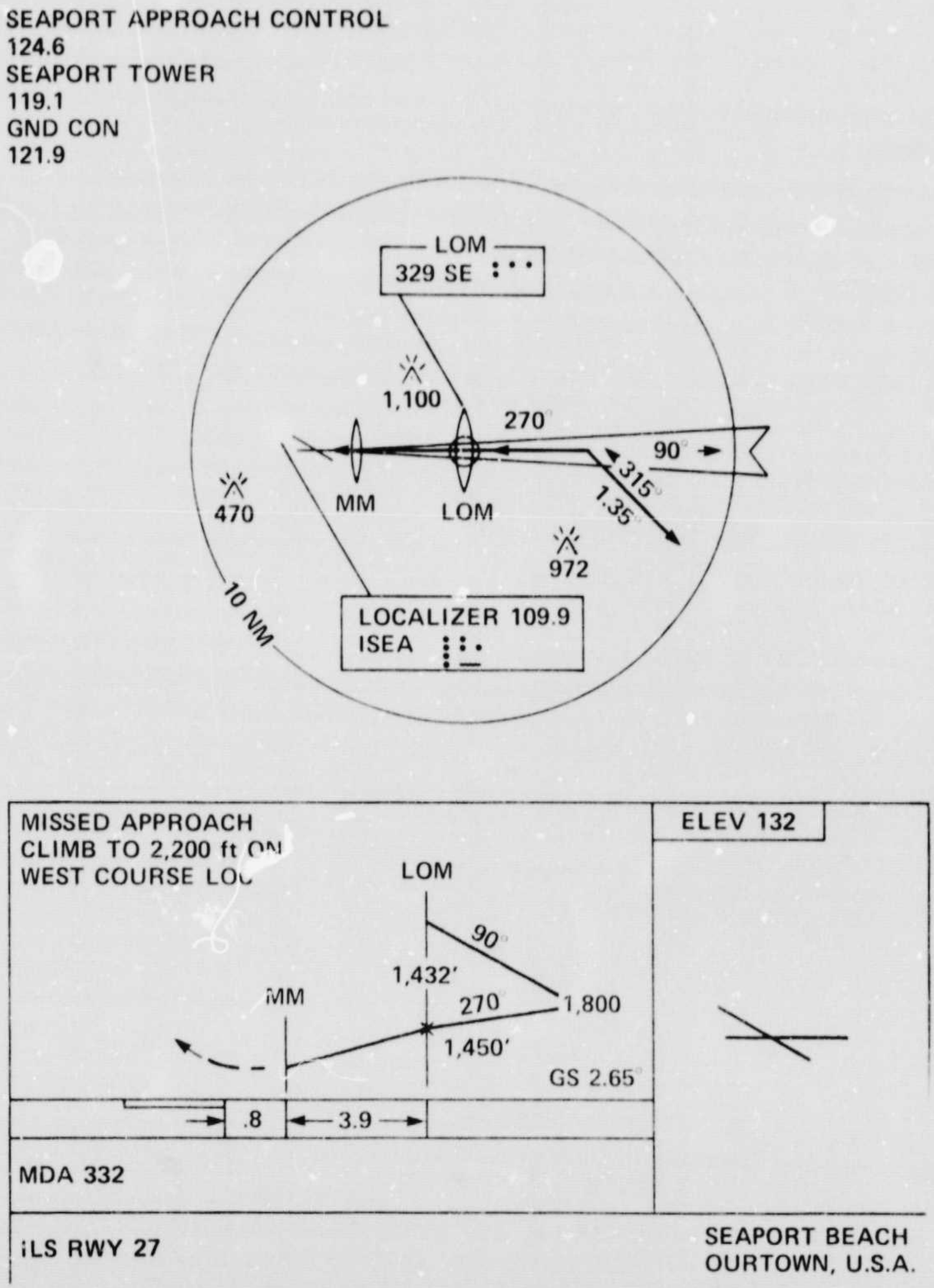


FIGURE 3. APPROACH PLATE USED FOR EVALUATION

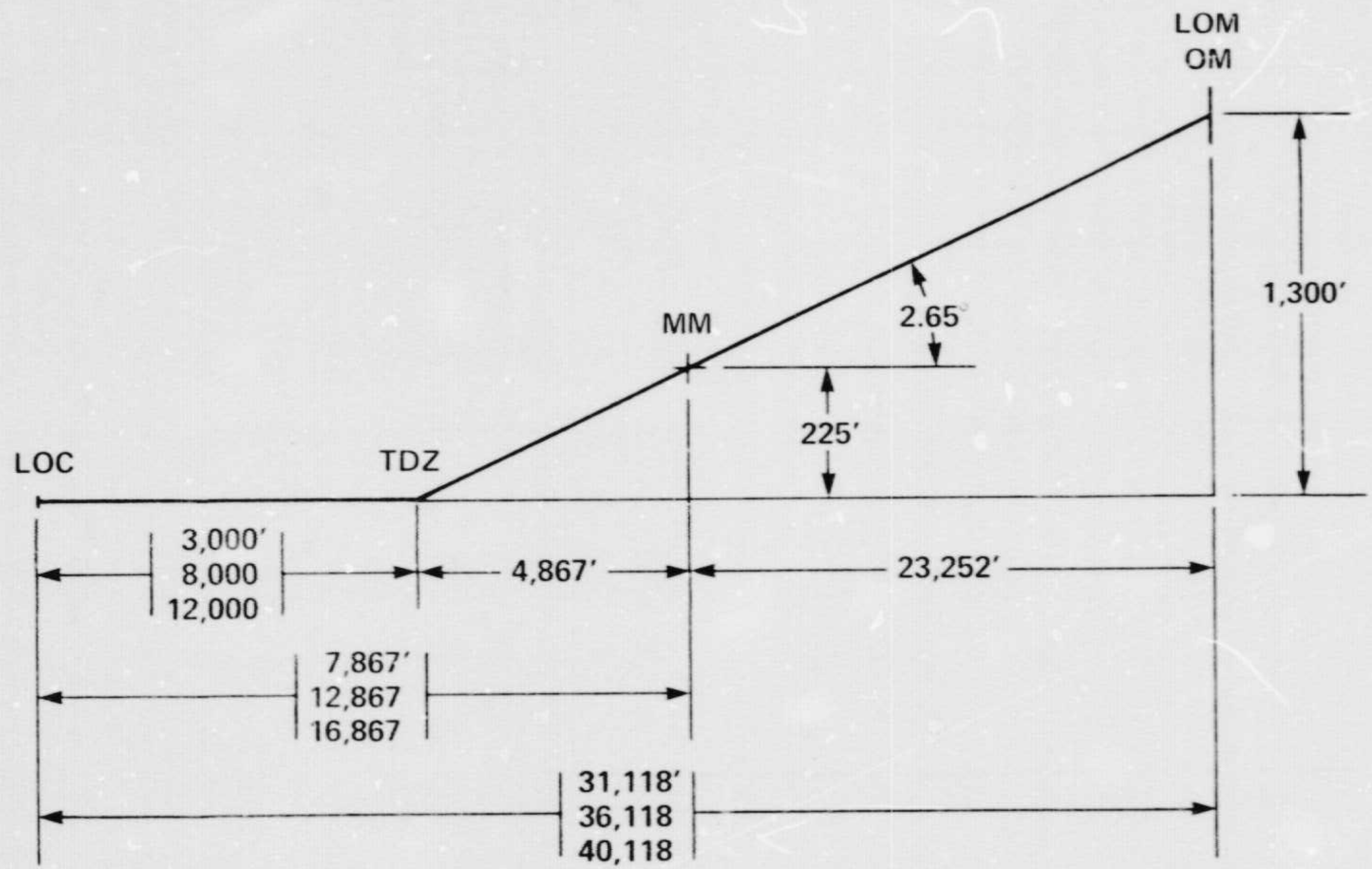


FIGURE 4. ILS TEST COURSE

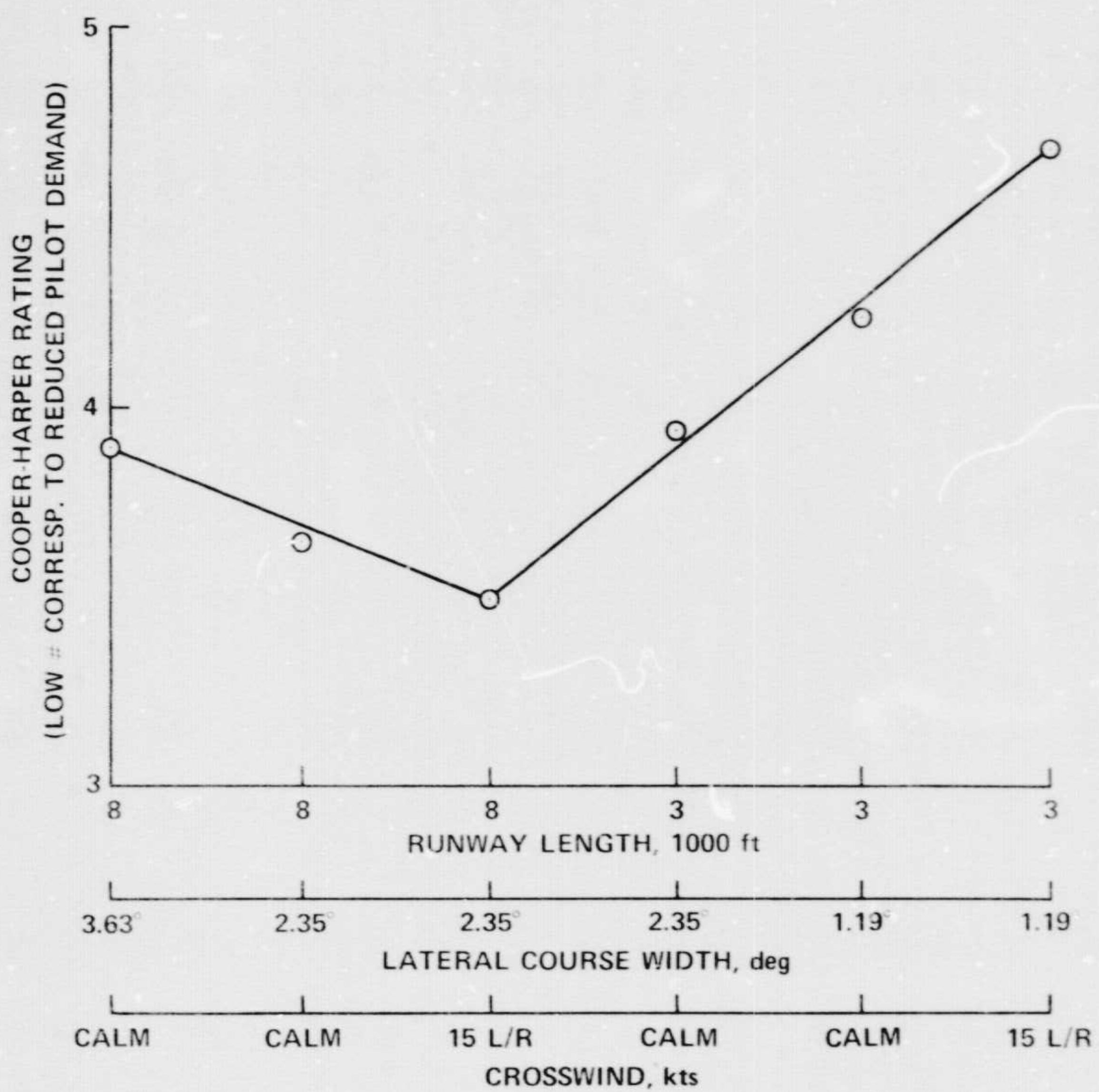


FIGURE 5. PILOT EVALUATION

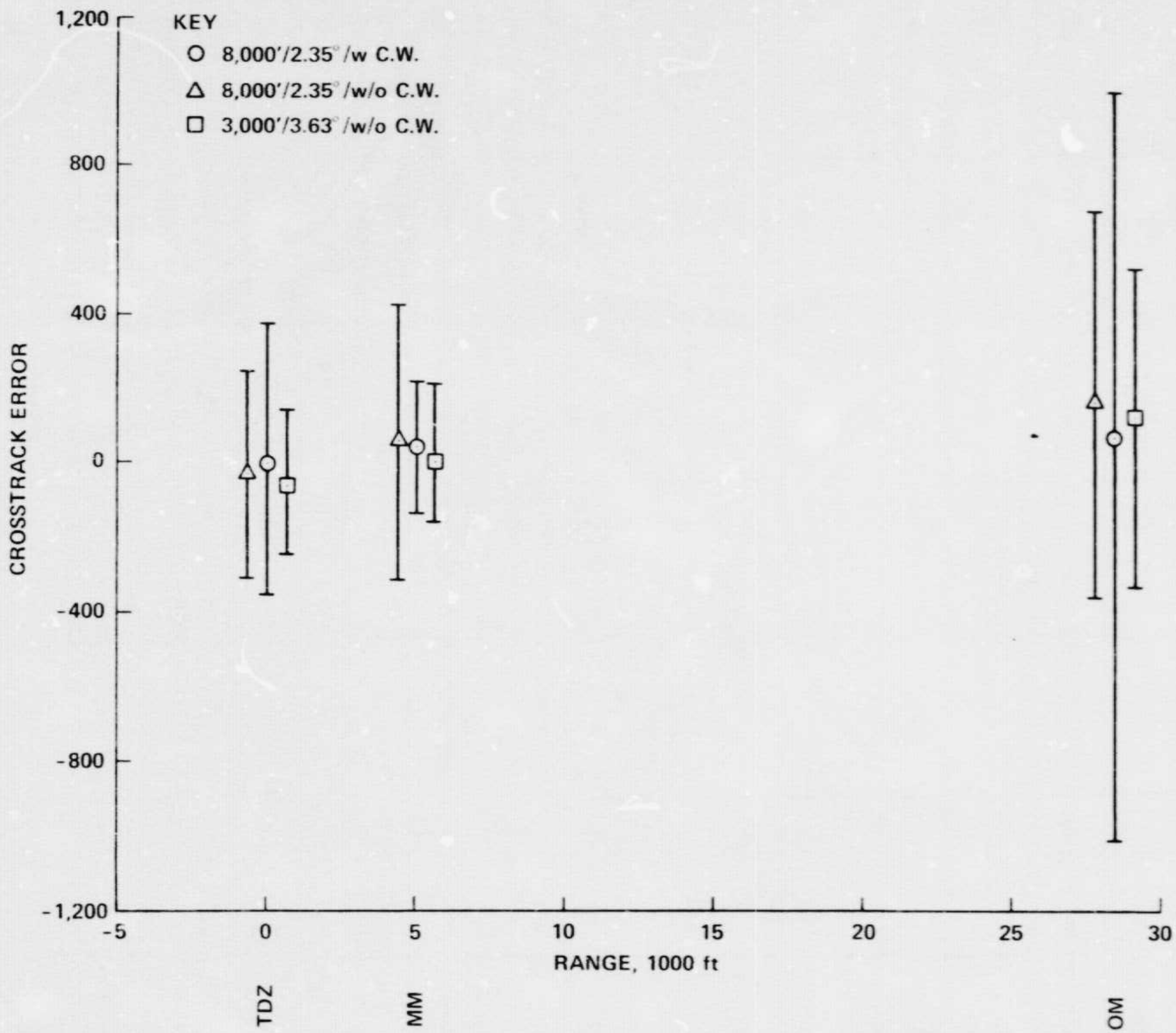


FIGURE 6. LATERAL DISPERSIONS

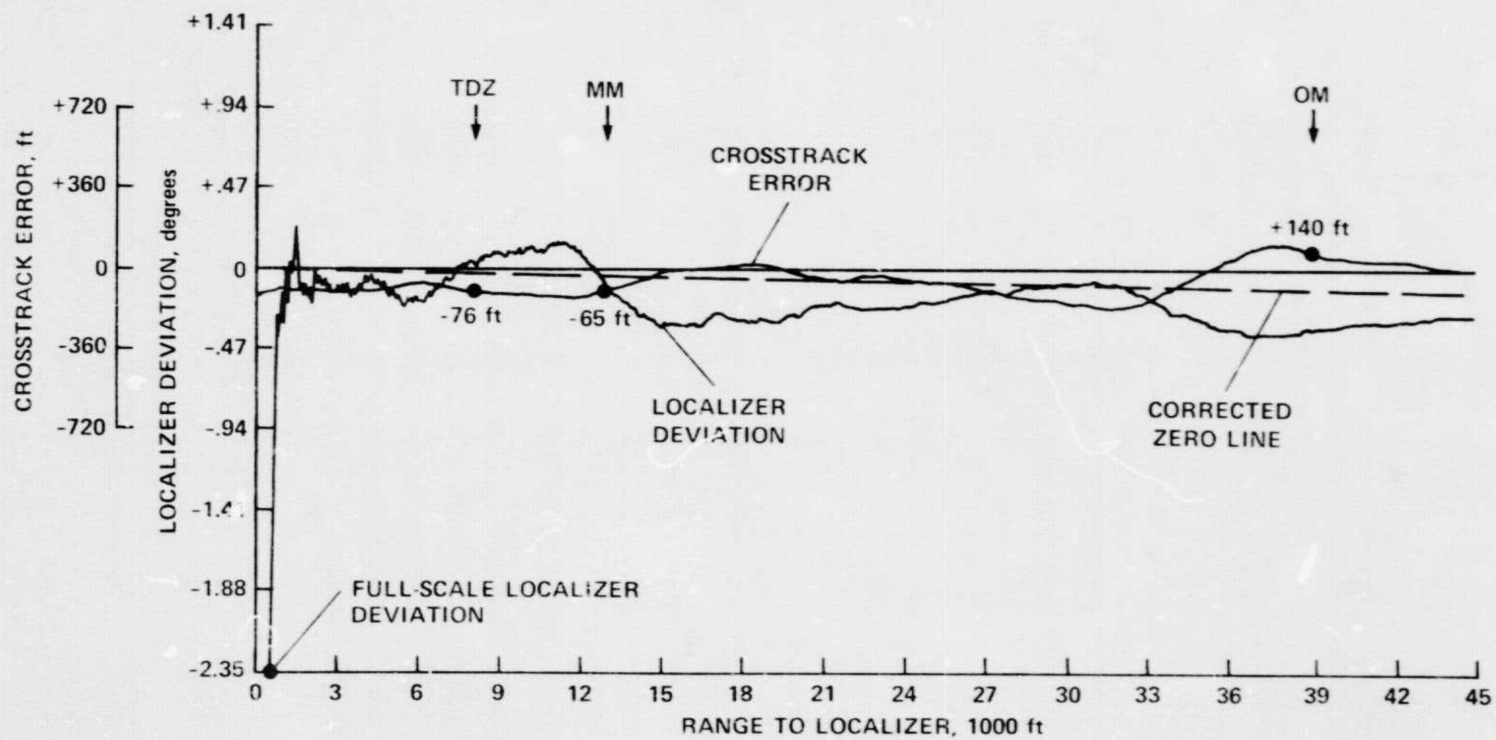


FIGURE 7. TRACKING PERFORMANCE AT ± 2.35° COURSE WIDTH AND 8,000 FT RUNWAY

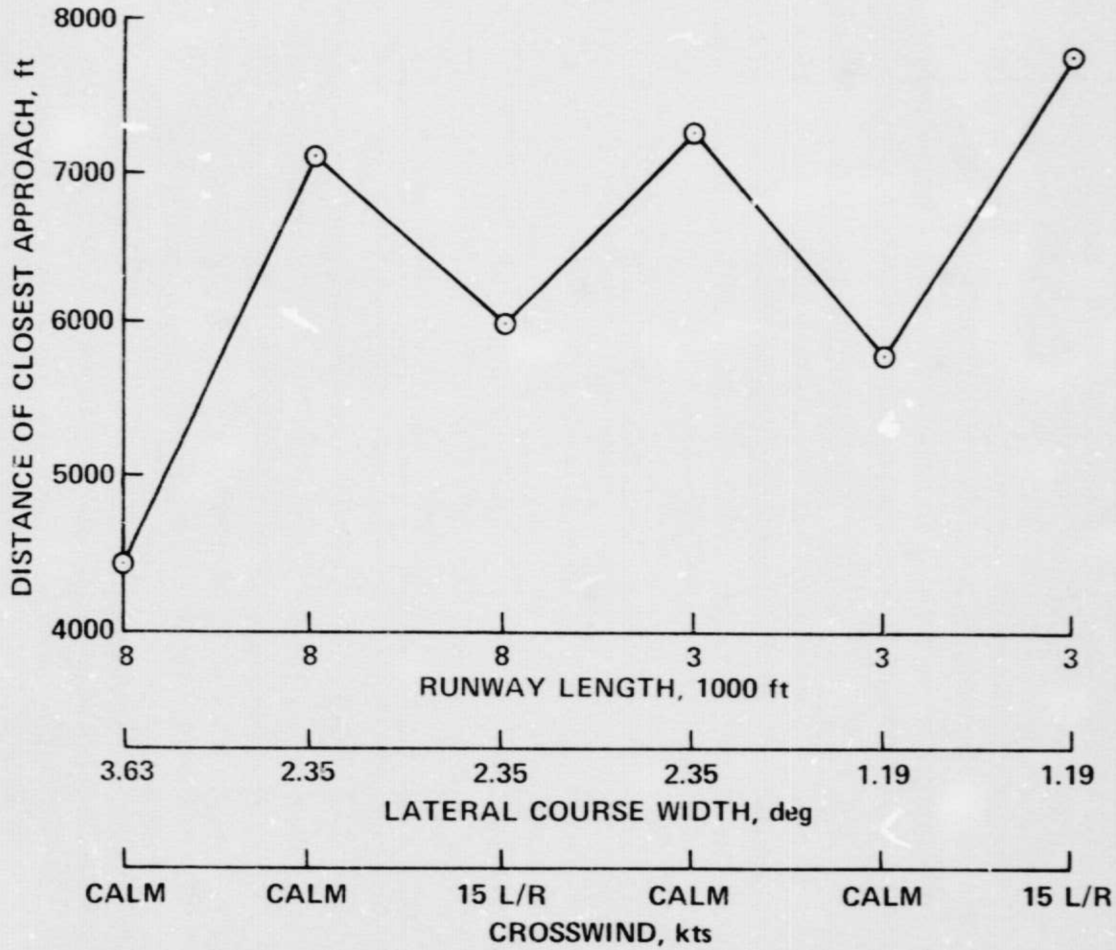
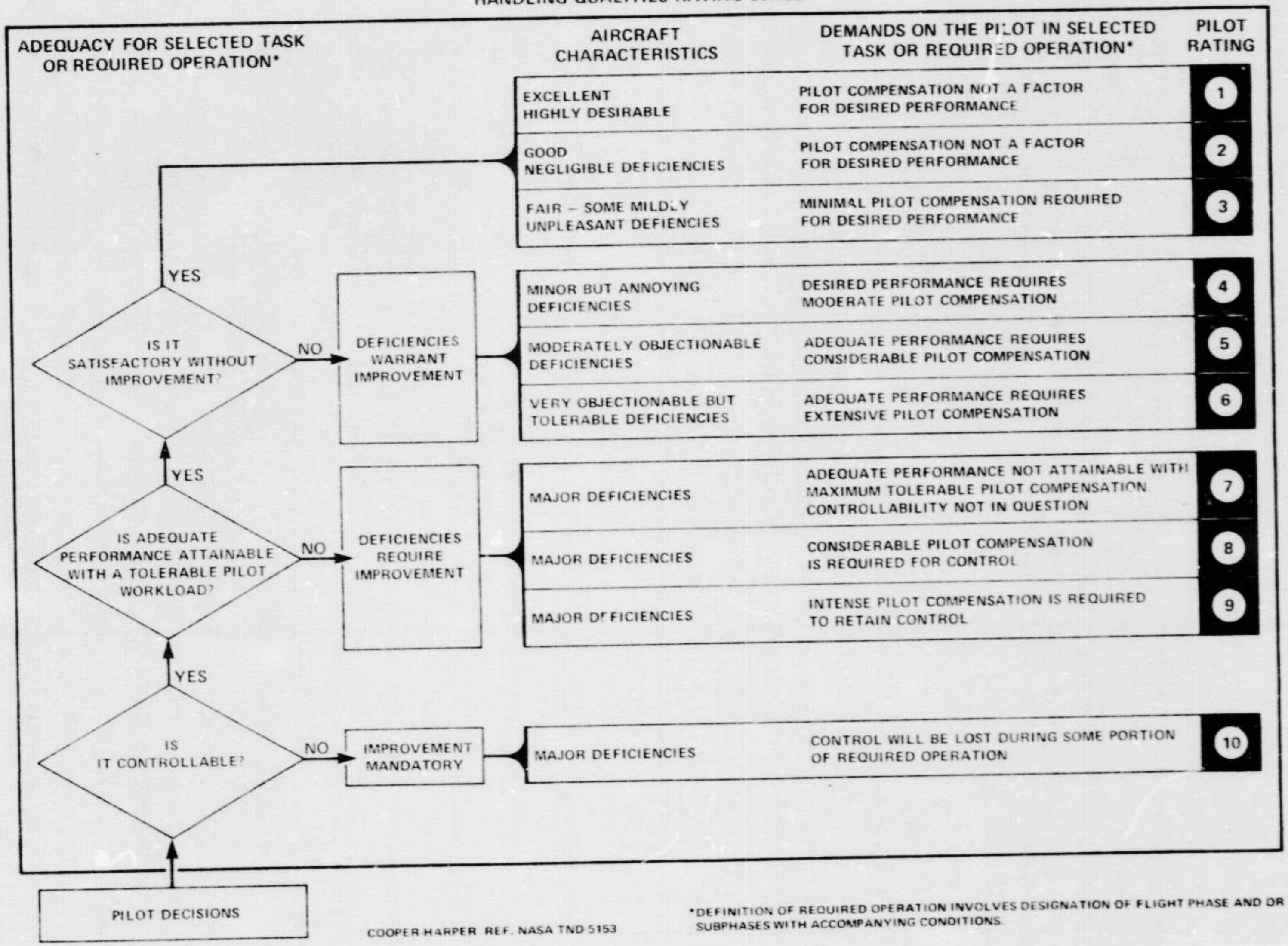


FIGURE 8. CLOSEST APPROACH

APPENDIX A

HANDLING QUALITIES RATING SCALE



COOPER HARPER REF. NASA TND 5153

*DEFINITION OF REQUIRED OPERATION INVOLVES DESIGNATION OF FLIGHT PHASE AND OR SUBPHASES WITH ACCOMPANYING CONDITIONS.

APPENDIX A

DEFINITIONS FROM TN-D-5153

COMPENSATION

THE MEASURE OF ADDITIONAL PILOT EFFORT AND ATTENTION REQUIRED TO MAINTAIN A GIVEN LEVEL OF PERFORMANCE IN THE FACE OF DEFICIENT VEHICLE CHARACTERISTICS.

HANDLING QUALITIES

THOSE QUALITIES OR CHARACTERISTICS OF AN AIRCRAFT THAT GOVERN THE EASE AND PRECISION WITH WHICH A PILOT IS ABLE TO PERFORM THE TASKS REQUIRED IN SUPPORT OF AN AIRCRAFT ROLE.

MISSION

THE COMPOSITE OF PILOT-VEHICLE FUNCTIONS THAT MUST BE PERFORMED TO FULFILL OPERATIONAL REQUIREMENTS. MAY BE SPECIFIED FOR A ROLE, COMPLETE FLIGHT, FLIGHT PHASE, OR FLIGHT SUBPHASE.

PERFORMANCE

THE PRECISION OF CONTROL WITH RESPECT TO AIRCRAFT MOVEMENT THAT A PILOT IS ABLE TO ACHIEVE IN PERFORMING A TASK. (PILOT-VEHICLE PERFORMANCE IS A MEASURE OF HANDLING PERFORMANCE. PILOT PERFORMANCE IS A MEASURE OF THE MANNER OR EFFICIENCY WITH WHICH A PILOT MOVES THE PRINCIPAL CONTROLS IN PERFORMING A TASK.)

ROLE

THE FUNCTION OR PURPOSE THAT DEFINES THE PRIMARY USE OF AN AIRCRAFT.

TASK

THE ACTUAL WORK ASSIGNED A PILOT TO BE PERFORMED IN COMPLETION OF OR AS REPRESENTATIVE OF A DESIGNATED FLIGHT SEGMENT.

WORKLOAD

THE INTEGRATED PHYSICAL AND MENTAL EFFORT REQUIRED TO PERFORM A SPECIFIED PILOTING TASK.

Azimuth Antenna to Threshold Distance	MLS Azimuth Deviation Scale Factor Bit Pattern	Proposed Lateral Course Width
0 - 6700	0 0 1	6°
6700 - 7650	0 1 0	5.6°
7650 - 8750	0 1 1	4.9°
8750 - 10,000	1 0 0	4.3°
10,000 - 11,450	1 0 1	3.7°
11,450 - 13,100	1 1 0	3.3°
More than 13,100	1 1 1	2.9°

TABLE 1

OCCUPATIONS OF SAMPLE PILOT GROUP

Occupation	No. of Pilots
Businessman	5
Engineer	7
Flight Inspector	2
Flight Instructor	3
Student	1
Airline Pilot	3
Charter Pilot	3
Military Officer	1
Teacher	1
Policeman	1
Air Traffic Controller	2
Total	29

TABLE 2

PILOT EXPERIENCE

Hrs. Pilot-on-Command	No. of Pilots
0 - 300	7
300 - 600	7
600 - 1200	4
1200 - 2400	4
2400 - up	7
Total	29

TABLE 3

RUNWAY LENGTH	LATERAL COURSE WIDTH					
	± 1.19°		± 2.35°		± 3.63°	
	LATERAL DEVIATION (2σ)	% OF FULL-SCALE LIMIT	LATERAL DEVIATION (2σ)	% OF FULL-SCALE LIMIT	LATERAL DEVIATION (2σ)	% OF FULL-SCALE LIMIT
3,000 ft	125′ (CALM)	77%	192′ (CALM)	59%	–	–
	194′ (WITH C.W.)	119%*	–	–	–	–
8,000	–	–	368′ (CALM)	70%	426′ (CALM)	52%
	–	–	174′ (WITH C.W.)	33%	–	–

TABLE 5. LATERAL DEVIATION AT MIDDLE MARKER

RUNWAY LENGTH	LATERAL COURSE WIDTH		
	± 1.19°	± 2.35°	± 3.63°
3,000 ft	± 162 ft	± 323 ft	± 500 ft
8,000	± 208	± 527	± 815
12,000	± 272	± 692	± 1070

TABLE 6. LATERAL DEVIATIONS CORRESPONDING TO FULL SCALE AZIMUTH (LOCALIZER) DEFLECTION (LIMIT FOR GO-AROUND)

APPENDIX B

TEST DATA SUMMARY

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RUN # 208L,R

Pilot #	CH #	OM XT	MM XT	TDZ XT	2 MILE MAX AT	2 MILE MAX XT	CLOSEST APP AT	CLOSEST APP XT	G: VX
1	3	0	+73	-32	13,000	+169	900	-73	+11
2	5	+1536	+231	-4	1700	+455	2,550	-108	+6[illegible]
3	3	+40	+94	+118	7,280	+230	2,700	-40	+16
4	4	0	+86	+43	12,000	+184	7,700	+70	-2[illegible]
5	4	+152	+87	0	10,800	-152	3,250	-65	+4
6	5	+198	-72	-86	6990	+318	4,500	0	-1[illegible]
7	3	-158	-50	+32	4,260	+168	3,000	-40	+4
8	3	+36	+104	+11	0	+104	[illegible]100	-59	+12
9	3	+198	-32.4	+36	13,000	+115	[illegible],000	+30	-9
10	4	+17	+162	-300	2,550	+387	11,500	-277	+4[illegible]
11	3	+302	+112	+36	9665	+684	11,500	-113	+1[illegible]
12	3	-85	-86	-76	400	-119	3,700	[illegible]	+9
13	4	-144	+112	+85	0	+112	1,[illegible]	-20	+1[illegible]
14	4	+353	+153	+147	2,250	+567	3,[illegible]00	+[illegible]3	+4
15	5	+277	+40	+101	11,500	-194	[illegible]00	-113	-[illegible]
16	3	-216	+115	-202	7,430	+205	7,[illegible]0	-[illegible]4	-3[illegible]
17	3	-20	+33	0	2,430	+205	.4[illegible]	-[illegible]	+2
18	3	-371	+86	-68	14,500 ~~4,300~~	+211 ~~+42~~	6,300	+40	-21
19	5	+475	-65	-76	0	-65	1,700	-107	-9
20	3	-176	-54	+4	12,000	+259	3,000	-90	+43
21	3	+77	-27	-240	5,375	+237	—	—	-2
22	3	+177	+78	+241	7,875	-365	[illegible]700	-96	-24
23	3	-300	-6	-36	11,700	+231	6,500	+36	-2
24	3	+271	+4	-36	12,000	+435	2250	-26	+[illegible]
25	3	-1524	-15	-273	9,995	+333	6,300	0	+[illegible]
26	4	+111	-7	-10	1,875	+84	4750	-18	+[illegible]
27	5	+377	+204	+6[illegible]	[illegible]875	+3[illegible]	12,250	+243	-[illegible]
28	3	+105	-27	+57	9,825	+156	5,500	-105	+1[illegible]
29	1	+435	+162	+72	1,770	+313	[illegible]400	-43	+1[illegible]
N	29	29	29	29	29	29	22	22	2[illegible]
Max(+)	[illegible]	+1531	+231	+290	13,000	+684	[illegible]	+[illegible]5	+6
Max(-)	3	-1524	-86	-300	0	-365	[illegible]	-277	-[illegible]
$\bar{X}$	3.51	[illegible]	+56.1	+7.7	[illegible]45	[illegible]	[illegible]	37.1	12
ST	.97	[illegible]	174	257	[illegible]34	[illegible]	3,900	177	57

RUN # 2070

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PLOT #	CH #	OM XT	MM XT	TDE XT	2 MILE MAX AT	2 MILE MAX XT	CLOSEST APP AT	CLOSEST APP XT	G: VX
1	3	-396	-30	+12	6420	+43	1,650	-68	+4
2	3	+1033	+720	-76	600	+725	—	—	+42
3	3	+151	+105	+323	12,000	+235	12,000	+170	-15
4	3	+360	-47	-136	12,000	-348	900	0	+4
5	3	+486	+131	-16	4,200	+331	3,900	+20	+15
6	4	+389	+18	+126	11,400	+124	7,200	+72	-7
7	4	+61	+39	0	7,200	+104	2,100	-59	-41
8	3	+90	-45	-36	4,020	-90	[illegible]700	-36	-9
9	3	+140	-65	-76	0	-65	[illegible]200	-97	+1[illegible]
10	3	+417	+130	-97	4,800	-281	[illegible]000	+3[illegible]	-1[illegible]
11	3	+158	+108	+18	8,730	+232	[illegible]	-44	+5
12	[illegible]	+40	+70	-176	12,000	+119	[illegible]	+18	+1[illegible]
13	3	+331	+37	-18	5,170	+173	2,650	-[illegible]0	+1[illegible]
14	4	+324	+72	-248	12,000	-407	[illegible]	-157	-2[illegible]
15	4	+104	+32	-223	9,710	+76	11,[illegible]	-[illegible]	-13
16	4	-50	-8	-72	4,530	+104	3,[illegible]	-52	-5
17	4	+360	+155	-209	7,080	+295	9,[illegible]	-50	-3
18	3	+97	+13	-90	5,160	+47	1,[illegible]	-79	-8
19	5	+310	+[illegible]0	+126	12,000	-126	3,[illegible]	-[illegible]9	-14
20	4	-93	-497	-101	0	-497	[illegible]	-[illegible]	-35
21	[illegible]	-230	+220	+163	4230	+515	—	—	+4[illegible]
22	3	+84	-45	+63	3635	-96	[illegible]	-72	+7
23	3	-132	-35	+60	6,275	+73	—	—	+8
24	[illegible]	+141	+246	+219	0	+246	—	—	+5
25	[illegible]	+165	-144	+51	12,000	-376	[illegible]000	[illegible]165	+8
26	4	+141	+31	0	7615	+90	[illegible]05[illegible]	-6[illegible]	+3
27	4	+276	+69	-24	12,000	-150	[illegible]	-9[illegible]	-8
28	3	+45	+165	+27	12,000	+195	4[illegible]5[illegible]	+15	-[illegible]
29	5	+81	+36	-405	12,000	+651	[illegible]	-96	+[illegible]
N	29	29	29	29	29	29	25	25	[illegible]
Max(+)	5	+1033	+720	+323	12,000	+725	12,000	+170	+[illegible]
Max(-)	3	-396	-497	-405	0	-576	900	-157	-[illegible]
X̄	[illegible]	+183.1	[illegible]	-71.1	[illegible]	58	[illegible]	-37	[illegible]
σ T	1.54	316.7	303.1	[illegible]	[illegible]	[illegible]	1,390	134.1	[illegible]

RUN # 2030

Pilot	CH	OM	MM	TDE	2 MILE MAX		CLOSEST APP		G:
#	#	XT	XT	XT	AT	XT	AT	XT	VX
1	3	+72	+18	-61	12,000	+77	1,500	-72	-3
2	7	+331	-252	-165	6,540	-1476	—	—	-32
3	3	+169	+115	-26	0	+115	3,900	-54	+47
4	5	+612	+155	-69	3,640	-26	600	-32	+7
5	4	+26	0	+14	2,880	+61	3,750	-18	+9
6	4	-115	+9	+47	5,250	1,260	3,600	+29	+8
7	4	+216	+93	-7	300	+97	1,800	-43	+48
8	3	+140	-57	-40	1,800	-72	2,400	-61	+9
9	4	+14	-18	-133	4,900	+97	1,300	-61	-9
10	3	+155	-43	-68	12,000	-392	1,500	-97	+2
11	3	+152	0	0	4,590	+79	4,200	-13	+16
12	3	+104	-22	-65	1,250	+72	2,400	-30	+18
13	4	-32	-8	-14	4,560	+101	3,300	-31	+20
14	3	+504	+94	-76	3,120	+518	1,800	-61	-28
15	4	+46	-47	-36	600	-51	3,500	-18	-33
16	4	+36	-121	-385	12,000	+191	7,800	-30	+16
~~17~~		~~+71~~	~~-104~~	~~-94~~	~~10,650~~	~~[illegible]~~	~~2,400~~	~~-36~~	—
17	3	-72	+115	-54	1,140	+141	2,400	-26	+15
18	3	+112	+43	-50	0	+43	2,300	-26	+3
19	4	+102	-43	-18	11,000	+122	5,100	-32	-20
20	5	+140	+144	-241	4,140	+573	4,100	-30	-15
21	4	-225	-72	-39	7,500	-170	2,350	-15	+48
22	3	-93	0	-15	10,375	+111	4,200	-15	+15
23	4	-183	-30	-66	6,328	-125	3,500	-36	-2
24	3	+309	-24	-42	11,700	-69	3,500	-51	+19
25	5	+537	+93	+216	7,950	+177	1,800	+90	-110
26	4	+183	+60	-57	9,700	+120	5,500	-57	+2
27	5	+70	+252	0	0	+252	11,800	-130	-25
28	5	+108	31	+31	7,975	-132	4,000	+48	-2
29	5	+113	-14	0	6,840	+227	2,850	+8	+47
N	29	29	27	27	27	27	22	22	27
Max(+)		+612	+257	+216	12,000	+573	11,800	+132	+47
Max(-)		-225	-252	-385	0	-1476	200	-130	-110
$\bar{X}$	3.93	+179	+10.2	-53.1	5,563	+26.9	3,998	-30.1	3.7
σT	1.92	391.4	191.5	192.9	3,317	636.1	3,791	112.1	33.3

RUN # 10.30

Pilot #	CH #	OM XT	MM XT	TDE XT	2 MILE MAX AT	2 MILE MAX XT	CLOSEST APP AT	CLOSEST APP XT	GS VXT
1	3	+126	-48	-39	14,700	[illegible]	2,100	-72	+26
2	3	+302	-154	-18	12,000	+3[illegible]	—	—	+91
3	4	+47	-4	-29	7,590	[illegible]	6,800	-54	+24
4	6	+35	-144	-133	300	-1[illegible]	4,400	-119	-37
5	4	-70	+18	-36	2,550	+30	4,250	-29	-11
6	6	-37	0	-130	16,600	+116	[illegible]700	+58	-23
7	3	+112	+7	-72	10,500	[illegible]	[illegible]500	-54	-21
8	5	-52	-27	-65	12,000	-176	[illegible]500	-51	-3
~~9~~		~~+140~~	~~-65~~	~~-91~~	~~0~~	~~[illegible]~~	~~[illegible]~~	—	—
10	5	+102	+36	-43	12,000	+110	1,100	-26	+51
9	4	+137	-45	-90	4,700	+76	[illegible]	-73	+7[illegible]
11	4	-101	-6	-97	6,000	+71	7,600	-30	+3[illegible]
12	4	+65	+14	-24	13,000	-77	4,200	-35	-5
13	3	+36	-13	-41	[illegible],240	+61	2,4[illegible]	-61	-6
14	5	+270	-16	-175	13,000	+233	5,[illegible]	-15	-7
15	4	57	-11	+30	6,900	+67	4,[illegible]	[illegible]	+18
16	4	-151	-94	-86	0	-94	2,[illegible]	-22	+31
17	4	+11	-104	-94	10,650	+307	3,1[illegible]	-16	-8
18	3	+54	+22	-77	5,010	+23	4,[illegible]	-56	-30
19	4	+77	+12	-47	5,790	+167	3,[illegible]	-36	+[illegible]
20	4	+79	+9	-128	1,940	+148	5,[illegible]	[illegible]	+53
21	3	+402	-117	-96	1,875	-161	[illegible]	-57	+8
22	6	-144	+70	-135	9,375	+144	7,500	+76	+2[illegible]
23	5	+162	-15	-66	3,875	-111	3,800	-72	+2[illegible]
24	3	+309	0	-144	12,000	+93	5,400	-33	+[illegible]
25	7	-102	+153	-543	7,500	+572	5,750	-128	-[illegible]
26	5	+51	+31	-33	2,550	+91	[illegible]200	-24	+[illegible]
27	3	+42	+24	+375	7,375	-157	3,200	+79	+[illegible]
28	1	-135	-37	+60	12,000	-114	9,500	-21	+3[illegible]
29	3	+[illegible]	-7	-22	1,000	+72	2,400	-29	+[illegible]
N	29	29	29	27	[illegible]	27	28	27	[illegible]
Max(+)	7	+402	+153	+375	16,600	+572	[illegible]	+76	-[illegible]
Min(-)	3	-151	-154	-543	0	-173	900	-128	-[illegible]
X̄	4.24	+61.3	-.54	-61.[illegible]	7665	[illegible]	[illegible]	-36.9	+14
ST	3.31	277	13.5	266	7715	241	4431	88.7	54

ORIGINAL PAGE IS
OF POOR QUALITY

RUN # 63 L/R

Pilot #	CH #	OM XT	MM XT	TDZ XT	2 MILE MAX AT	2 MILE MAX XT	CLOSEST APP AT	CLOSEST APP XT	GS VXT
1	4	+36 / +30	-67 / +46	+67 / +14	[illegible]	-13 / +13	3,200	+70 / +18	+6 / +7
2	5	+504	-77	-504	9,700	+201	2,200	-70	+81
3	3	+119	+126	+13	10,650	+176	1,500	-18	+14
4	7	+47	-51	-130	7,700	+73	7,400	-55	-26
5	5	+51	-61	-15	11,400	-112	3,150	-18	+3
6	6	-50	-62	-47	0	-68	6,300	+40	-10
7	5	+178	+101	+65	2,400	+138	4,500	+35	-1.5
8	6	-100	+18	-36	5,220	+90	2,400	-47	+8
9	6	-115	-40	-43	11,100	+155	[illegible]	-4[illegible]	+22
10	4	+173	+32	-43	12,000	+202	[illegible]	+4[illegible]	+6
11	5	+68	-32	-18	3,640	+115	[illegible]	-5[illegible]	-20
12	3	-137	-101	-32	10,200	-153	2,100	-72	-17
13	4	+65	+58	+11	11,600	+94	4,500	+18	+14
14	3	+33	+135	+18	11,200	+395	[illegible]	[illegible]	0
15	5	+137	+36	-25	3,730	+101	7,400	[illegible]	+29
16	5	-230	-75	-43	0	-75	[illegible]	-76	+45
17	6	-47	-108	-86	0	-108	7,600	-76	+6
18	3	+11	+35	-61	8340	+58	1,300	-54	-2
19	5	+97	+11	-36	7590	+54	3,300	-10	-6
20	[illegible]	-133	+205	-169	4110	-306	—	—	-31
21	4	+221	-50	-90	1,900	-227	3,600	-74	-58
22	[illegible]	-153	-75	-60	1750	-107	9,600	-51	+33
23	4	+81	+81	-65	2375	+133	—	—	-1
24	[illegible]	0	-18	-96	1850	+105	1,000	-6[illegible]	-13
25	[illegible]	-57	+318	+18	12,000	+405	[illegible]	[illegible]	+44
26	5	+8	+3	-66	8375	+77	1,000	-3[illegible]	0
27	—	—	—	—	—	—	—	—	—
28	5	+174	+33	-15	8625	-57	2,700	-36	+7[illegible]
29	4	+153	+12	-4[illegible]	[illegible]	+189	1,252	-31	+7
N	28	28	28	28	28	28	25	25	28
Max(+)	7	+504	+318	+65	12,000	+405	7,600	+70	+81
Max(-)	3	-230	-108	-504	0	-306	1,000	-76	-31
$\bar{X}$	4.71	+50.4	+15.2	-55.7	6622	+55.7	3,800	-38.1	+7.7
σ	3.17	302.4	144.2	881.3	8853	324.2	4915	77.2	60.1

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OF POOR QUALITY

RUN # 20L/R

Pilot	CH	OM	MM	TDZ	2 MILE MAX		CLOSEST APP		G
#	#	XT	XT	XT	AT	XT	AT	XT	VX
1							1090		
2							4290		
3							0		
4							840		
5							600		
6							900		
7							900		
8							3300		
9							810		
10							0		
11							0		
12							3450		
13							900		
14							490		
15							420		
16							3840		
17							1350		
18							570		
19							630		
20							2190		
21							1475		
22							2125		
23							1050		
24							1350		
25							5500		
26							0		
27							9975		
28							1250		
29							900		
N							29		
Max(+)							9975		
Max(-)							0		
$\bar{X}$							1916		
2σ							4299		

ORIGINAL PAGE IS
OF POOR QUALITY

RUN # 2070

Pilot	CH	OM	MM	TDZ	2 MILE MAX		CLOSEST APP		G
#	#	XT	XT	XT	AT	XT	AT	XT	V
1							0		
2							—		
3							6810		
4							600		
5							2640		
6							6720		
7							980		
8							1170		
9							840		
10							690		
11							960		
12							840		
13							810		
14							6870		
15							456		
16							450		
17							960		
18							0		
19							570		
20							780		
21							720		
22							775		
23							—		
24							600		
25							4900		
26							800		
27							6800		
28							875		
29							8100		
N							27		
Max(+)							8100		
Min(-)							0		
$\bar{X}$							2177		
2S							5084		

RUN # 2070

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OF POOR QUALITY

Pilot	CH	OM	MM	TDZ	2 MILE MAX		CLOSEST APP		G
#	#	XT	XT	XT	AT	XT	AT	XT	V
1							0		
2							—		
3							6810		
4							600		
5							2640		
6							6780		
7							900		
8							1170		
9							840		
10							690		
11							960		
12							840		
13							810		
14							6870		
15							450		
16							450		
17							960		
18							0		
19							570		
20							780		
21							720		
22							775		
23							—		
24							600		
25							4900		
26							800		
27							6800		
28							875		
29							8100		
N							27		
Max (+)							8100		
Max (-)							0		
$\bar{x}$							812.		
2σ							5084		

RUN # 2030

Pilot #	CH #	OM XT	MM XT	TDZ XT	2 MILE MAX AT	2 MILE MAX XT	CLOSEST APP AT	CLOSEST APP XT	GS VXT
1							840		
2							——		
3							690		
4							750		
5							630		
6							0		
7							1050		
8							690		
9							1080		
10							480		
11							930		
12							690		
13							930		
14							1110		
15							2460		
16							5940		
17							750		
18							570		
19							660		
20							12360		
21							1625		
22							750		
23							875		
24							675		
25							6300		
26							775		
27							7200		
28							975		
29							1590		
N							28		
Max (+)							12360		
Max (-)							0		
X̄							1906		
2σ							5975		

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OF POOR QUALITY

RUN # 3026

Pilot	CH	OM	MM	TDE	2 MILE MAX		CLOSEST APP		G:
#	#	XT	XT	XT	AT	XT	AT	XT	VXT
1							—		
2							—		
3							970		
4							0		
5							0		
6							0		
7							0		
8							0		
9							450		
10							9800		
11							0		
12							2940		
13							750		
14							0		
15							0		
16							0		
17							0		
18							1800		
19							0		
20							0		
21							0		
22							0		
23							1000		
24							0		
25							2050		
26							0		
27							2200		
28							0		
29							780		
N							27		
Rng(+)							9000		
Rng(-)							0		
$\bar{x}$							[illegible]		
2σ							3577		

RUN # 1030

Pilot #	CH #	OM XT	MM XT	TDZ XT	2 MILE MAX AT	2 MILE MAX XT	CLOSEST APP AT	CLOSEST APP XT	GS VXT
1							1860		
2							—		
3							2340		
4							5250		
5							1170		
6							3990		
7							1140		
8							1080		
9							750		
10							960		
11							2790		
12							1620		
13							930		
14							4410		
15							1740		
16							1650		
17							1830		
18							720		
19							2550		
20							3540		
21							750		
22							7000		
23							2100		
24							3325		
25							—		
26							925		
27							5325		
28							3375		
29							1300		
N							27		
Max (+)							7000		
Max (-)							166		
$\bar{X}$							2535		
σ							3237		

RUN #1034R

Pilot #	CH #	OM	MM	TDZ	2 MILE MAX		CLOSEST APP		G
		XT	XT	XT	AT	XT	AT	XT	VY
1							1020		
2							7320		
3							750		
4							810		
5							600		
6							2670		
7							4170		
8							1890		
9							1860		
10							660		
11							990		
12							7260		
13							2550		
14							1800		
15							540		
16							840		
17							2760		
18							810		
19							660		
20							12780		
21							1350		
22							2175		
23							1875		
24							1375		
25							—		
26							1375		
27							—		
28							2050		
29							1575		
							27		
							12870		
							540		
							2380		
							5324		

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OF POOR QUALITY

RUN # .63 L/R

Pilot #	CH #	OM XT	MM XT	TDZ XT	2 MILE MAX AT	2 MILE MAX XT	CLOSEST APP AT	CLOSEST APP XT	GS VXT
1	4	~~+36~~ ~~+30~~	~~-61~~ ~~-46~~	~~+27~~ ~~+14~~	~~[illegible]~~ ~~3,250~~	~~-13~~ ~~+95~~	~~6,000~~ ~~3,250~~	~~+70~~ ~~+18~~	~~+6~~ ~~+9~~
2	5	+504	-72	-504	2,700	+201	2,700	-70	+81
3	3	+119	+126	+13	10,650	+176	1,500	-18	+14
4	7	+47	-57	-130	2,700	+73	2,400	-55	-26
5	5	+51	-61	-15	11,400	-112	3,150	-18	+3
6	6	-50	-62	-47	0	-68	6,300	+40	-10
7	5	+198	+101	+65	2,400	+135	4,500	+35	-1.5
8	6	-100	+18	-36	5,220	+90	2,400	-47	+8
9	6	-115	-40	-43	11,100	+155	[illegible],000	-45	+22
10	4	+173	+32	-45	12,000	+202	[illegible],000	+45	+6
11	5	+68	-33	-18	3,040	+115	[illegible],100	-58	-20
12	3	-137	-101	-32	10,200	-155	2,100	-72	-17
13	4	+65	+58	+11	11,600	+94	4,500	-18	+14
14	3	+323	+135	+18	11,200	+245	3,750	-30	0
15	5	+131	+36	-25	2,750	+164	7,400	-18	+29
16	5	-230	-75	-43	0	-75	3,[illegible]00	-76	+45
17	6	-47	-108	-26	0	-108	7,600	-76	+6
18	3	+11	+25	-61	8340	+58	1,300	-54	-2
19	5	+97	+11	-36	7590	+54	3,[illegible]00	-40	-6
20	[illegible]	-133	+205	-169	4110	-306	—	—	-31
21	4	+221	-50	-90	1,900	-223	[illegible]00	-44	-58
22	[illegible]	-153	-75	-60	1750	-107	[illegible]	-51	+38
23	7	+81	+81	-63	2375	+133	—	—	-7
24	[illegible]	0	-19	-96	1850	+105	[illegible]000	-6[illegible]	-13
25	[illegible]	-57	+312	+18	12,000	+405	—	—	+44
26	5	+8	+3	-66	8375	+77	[illegible]	-3[illegible]	0
27	—	—	—	—	—	—	—	—	—
28	5	+174	+33	-15	8625	-57	2,700	-30	+72
29	4	+153	+12	-4[illegible]	[illegible],000	+179	1,750	-21	+7
N	28	28	28	28	28	28	25	25	28
Max(+)	7	+504	+312	+65	12,000	+405	7,600	+70	+81
Max(-)	3	-230	-108	-504	0	-306	1100	-76	-31
$\bar{X}$	4.71	+50.4	+15.9	-55.7	6623	+45.9	3,860	-28.1	+7.7
σ	1.17	318.4	194.5	301.3	[illegible]	3342	7715	77.3	66.1

(RUN # 2.03L/R

Pilot	CH	OM	MM	TDZ	2 MILE MAX		CLOSEST APP		G
#	#	XT	XT	XT	AT	XT	AT	XT	VX
1							1020		
2							4280		
3							0		
4							740		
5							600		
6							900		
7							700		
8							3300		
9							810		
10							0		
11							0		
12							3450		
13							900		
14							990		
15							420		
16							3840		
17							1350		
18							570		
19							630		
20							2190		
21							1475		
22							2125		
23							1050		
24							1350		
25							5500		
26							0		
27							9975		
28							1250		
29							900		
N							29		
Max(+)							9975		
Max(-)							0		
$\bar{X}$							1916		
2 J							4249		

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OF POOR QUALITY

RUN # 2070

Pilot	CH	OM	MM	TDZ	2 MILE MAX		CLOSEST APP		G
#	#	XT	XT	XT	AT	XT	AT	XT	V
1							0		
2							—		
3							6810		
4							680		
5							2640		
6							6780		
7							460		
8							1170		
9							840		
10							690		
11							960		
12							840		
13							810		
14							6870		
15							456		
16							450		
17							960		
18							0		
19							570		
20							780		
21							420		
22							775		
23							—		
24							600		
25							4900		
26							800		
27							6800		
28							875		
29							8100		
N							27		
Max (+)							8100		
Min (-)							0		
$\bar{X}$							2122		
2 S							5084		

RUN # 2070

Pilot #	CH #	OM XT	MM XT	TDZ XT	2 MILE MAX AT	2 MILE MAX XT	CLOSEST APP AT	CLOSEST APP XT	G Vi
1							0		
2							----		
3							6810		
4							600		
5							2640		
6							6770		
7							980		
8							1170		
9							840		
10							690		
11							960		
12							840		
13							810		
14							6870		
15							450		
16							450		
17							960		
18							0		
19							570		
20							780		
21							720		
22							775		
23							----		
24							600		
25							4900		
26							800		
27							6800		
28							875		
29							7100		
N							27		
Max (+)							7100		
Max (-)							0		
$\bar{x}$							312.		
2σ							5074		

RUN #2030

ORIGINAL PAGE IS
OF POOR QUALITY

Pilot #	CH #	OM	MM	TDZ	2 MILE MAX		CLOSEST APP		GS
		XT	XT	XT	AT	XT	AT	XT	VXT
1							840		
2							——		
3							690		
4							750		
5							630		
6							0		
7							1050		
8							690		
9							1080		
10							480		
11							930		
12							690		
13							930		
14							1110		
15							2460		
16							5940		
17							750		
18							570		
19							660		
20							12360		
21							1625		
22							750		
23							875		
24							675		
25							6300		
26							775		
27							7200		
28							975		
29							1590		
N							28		
Max (+)							12360		
Max (−)							0		
$\bar{X}$							1906		
2σ							5875		

RUN # 3026

Pilot #	CH #	OM XT	MM XT	TDZ XT	2 MILE MAX AT	2 MILE MAX XT	CLOSEST APP AT	CLOSEST APP XT	GS VXT
1							—		
2							—		
3							240		
4							0		
5							0		
6							0		
7							0		
8							0		
9							450		
10							9000		
11							0		
12							2940		
13							750		
14							0		
15							0		
16							0		
17							0		
18							1800		
19							0		
20							0		
21							0		
22							0		
23							1000		
24							0		
25							2050		
26							0		
27							2200		
28							0		
29							770		
N							27		
Max(+)							9000		
Min(-)							0		
$\bar{X}$							[illegible]		
2σ							3511		

RUN # 1030

Pilot #	CH #	OM XT	MM XT	TDZ XT	2 MILE MAX AT	2 MILE MAX XT	CLOSEST APP AT	CLOSEST APP XT	GS VXT
1							1860		
2							—		
3							2340		
4							5250		
5							1170		
6							3990		
7							1140		
8							1080		
9							750		
10							960		
11							2790		
12							1620		
13							930		
14							4410		
15							1770		
16							1650		
17							1830		
18							720		
19							2550		
20							3540		
21							750		
22							7000		
23							2100		
24							3325		
25							—		
26							925		
27							5325		
28							3375		
29							1300		
N							27		
Max (+)							7000		
Min (-)							[illegible]		
X̄							[illegible]		
2σ							3237		

RUN #1034/K

ORIGINAL PAGE IS
OF POOR QUALITY

Pilot	CH	OM	MM	TDZ	2 MILE MAX		CLOSEST APP		G
#	#	XT	XT	XT	AT	XT	AT	XT	VX
1							1020		
2							7320		
3							750		
4							810		
5							600		
6							2670		
7							4170		
8							1890		
9							1860		
10							660		
11							990		
12							7260		
13							2530		
14							1800		
15							540		
16							840		
17							2760		
18							810		
19							660		
20							12780		
21							1350		
22							2175		
23							1875		
24							1375		
25							—		
26							1375		
27							—		
28							2050		
29							1375		
							27		
							12870		
							540		
							2370		
							5324		