FAA-74-5

REPORT NO. FAA-RD-74-81

HUMAN FACTORS EXPERIMENTS FOR DATA LINK
Interim Report No. 4

Edwin H. Hilborn

APRIL 1974
INTERIM REPORT

Prepared for
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research and Development Service
Washington DC 20591

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-RD-74-81		

4. Title and Subtitle	5. Report Date
HUMAN FACTORS EXPERIMENTS FOR DATA LINK Interim Report No. 4	April 1974
	6. Performing Organization Code
7. Author(s) Edwin H. Hilborn	8. Performing Organization Report No. DOT-TSC-FAA-74-5
9. Performing Organization Name and Address Department of Transportation Transportation Systems Center Kendall Square Cambridge MA 02142	10. Work Unit No. (TRAIS) FA413/R4145
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington DC 20591	13. Type of Report and Period Covered Interim Report June 1972-Dec. 1973
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Eight two-man crews of FAA/NAFEC test Pilots made four runs each in a GAT-2 simulator to evaluate four displays presenting short-message ATC commands and advisories. The counterbalanced experimental design was later replicated with eight crews of airline and ALPA pilots; and a single crew of AOPA pilots provided further data.

Response-time measurements were taken with each display. This information was supplemented by a questionnaire administered to each crew member at the completion of his experimental runs.

The use of a display limited to seven characters, or another employing a NIMO CRT was ruled out from further evaluation. Pilot opinion was generally favorable to the use of a display presenting three lines of seven LED characters each, and a linear display of 32 plasma characters

17. Key Words	18. Distribution Statement
· Air Traffic Control · Data Link · Message Coding · Simulators · Human Engineering	DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22151.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	118	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

The present report is one of a continuing series describing laboratory and simulator tests of concepts and prototype equipment for Digital Data Link. The goal of these studies is to obtain information which can reduce the number of devices which will eventually require flight testing.

No effort of the magnitude described in the present report could take place without contributions from many people. Valuable contributions throughout the planning and running of the experiment were made by Dr. P. Abramson and R. Wisleder.

Design and fabrication of the experimental hardware involved efforts by J. Gakis, W. Murphy, B. Nagy, B. Patten, B. Ressler, J. Sabath and J. Vrabel, all of DOT/TSC. The experiment was conducted at FAA/NAFEC with efforts by W. Crook, L. Dvorsky, D. Fehr, H. Halversen, D. Larson, A. Madge, W. Stevens and A. Swezeny.

Simulated flights were made by the following FAA/NAFEC Test Pilots: F. Auer, J. Bailey, A. Bazer, T. Billen, I. Budoff, C. Covert, R. Grace, K. Johnson, E. Krawiec, R. Lamprecht, J. Presley, R. Powell, J. Ryan, J. Terry, W. Tranter and H. White.

Airline and ALPA pilots who participated included D. Best (UAL), R. Cole (TWA), W. Cotton (ALPA-UAL), K. Eck (ALPA), R. Gerber (ALPA-PAA), D. Gold (EAL), L. Horton (UAL), V. Laursen (TWA), J. Murphy (ALA), J. Nichols (ALPA-BNA), P. Roitsch (PAA-SAE), J. Ruddy (ALPA), J. Russell (UAL), C. Schild (UAL), W. Williams (PAA), and J. Wooster (UAL).

M. Huck and M. Karant represented AOPA in the evaluation. J. Diehl of ARINC assisted in arranging for the services of the airline and ALPA pilots.

The author acknowledges the extensive and substantial effort of J. Benjamin in the preparation of this document.

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1. INTRODUCTION

This is the fourth in a series of Interim Reports, all titled "Human Factors Experiments for Data Link,"* which describe laboratory and simulator evaluations of concepts and prototype equipment for the digital transmission of air traffic control information. The previous report in this series (FAA-RD-73-69) described the evaluation of four such display types in a GAT-1 simulator at the Department of Transportation/Transportation Systems Center at Cambridge, Mass. Following this series of tests, minor modifications were made to three of the displays, and all were re-evaluated in a GAT-2 simulator at FAA/NAFEC using two-man crews. The present report documents the results of these latest tests.

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*Hilborn, E.H., "Human Factors Experiments for Data Link." Report #FAA-RD-72-150. Interim Report #1. November 1972.
Hilborn, E.H. and Devanna, L.R., "Human Factors Experiments for Data Link. Interim Report #2." Report #FAA-RD-73-55. April, 1973.
Hilborn, E.H. and Wisleder, R.W., "Human Factors Experiments for Data Link. Interim Report #3." Report #FAA-RD-73-69. August, 1973.

2. EXPERIMENTAL CONDITIONS

2.1 THE PROTOTYPE DISPLAYS

The four displays have been described fully in the previously referenced report. Their salient characteristics are presented in Table 2-1. For the GAT-2 tests, four modifications were made: (1) an automatic scrolling feature was incorporated into the 7-Window display so that up to three lines of seven characters each could be presented sequentially, (2) a storage register was built into the 3x7-Window display to provide scratchpad call-up of heading, altitude and speed commands on demand, (3) dimming controls were added, and (4) 12 character spaces on the right hand side of the 32-Window display were reserved for continuous display of heading, altitude and speed commands, thereby limiting other messages to a maximum of 20 characters. Figures 2-1 thru 2-4 depict the four displays, and Figure 2-5 shows the display location in the cockpit of the GAT-2.

As in the previous experiment, messages were generated from punched tape through a TSC-constructed interface box which provided the required decoding, storage and control functions. Figure 2-6 is a block diagram of the system.

TABLE 2-1. DISPLAY CHARACTERISTICS

	7-Window	3x7-Window	32-Window	NIMO*
No. of lines	1	3	1	3
characters/line	7	7	20 + 12	6
display technology	incandescent	LED	plasma	CRT
color	white	red	orange	green
character height	0.42"	0.35"	0.20"	0.165"
font	segmented	dot matrix	dot matrix	stencil
brightness	400 ft-L	300 ft-L	25 ft-L	100 ft-L

*NIMO is a trademark of Industrial Electronic Engineers.

Figure 2-1. The 7-Window Display

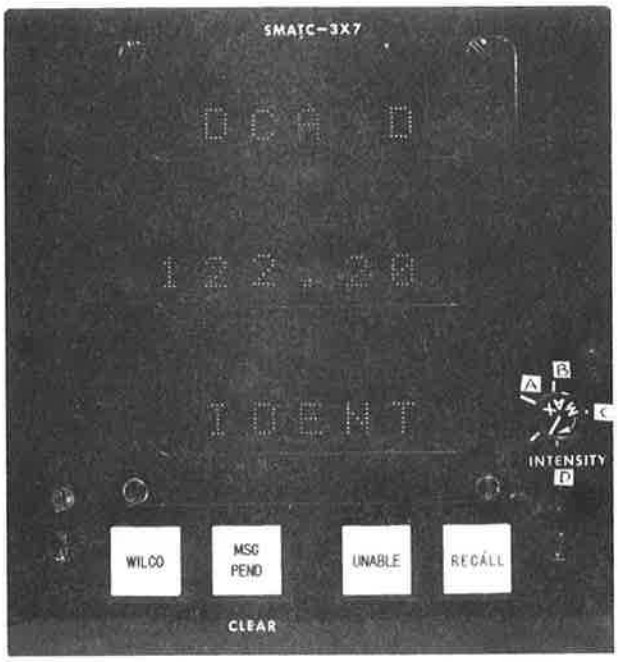

Figure 2-2. The 3 x 7-Window Display

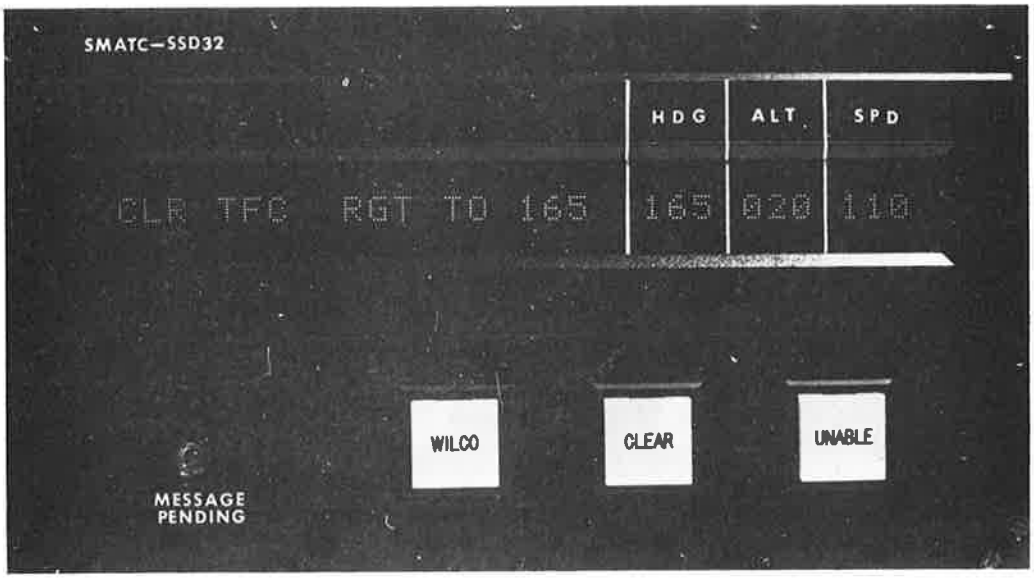

Figure 2-3. The 32-Window Display

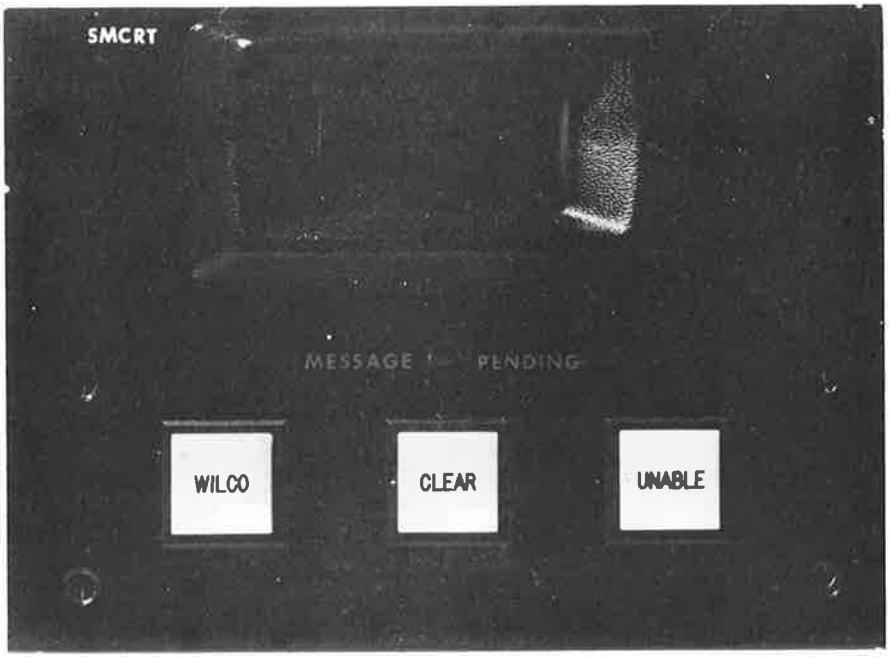

Figure 2-4. The NIMO Display

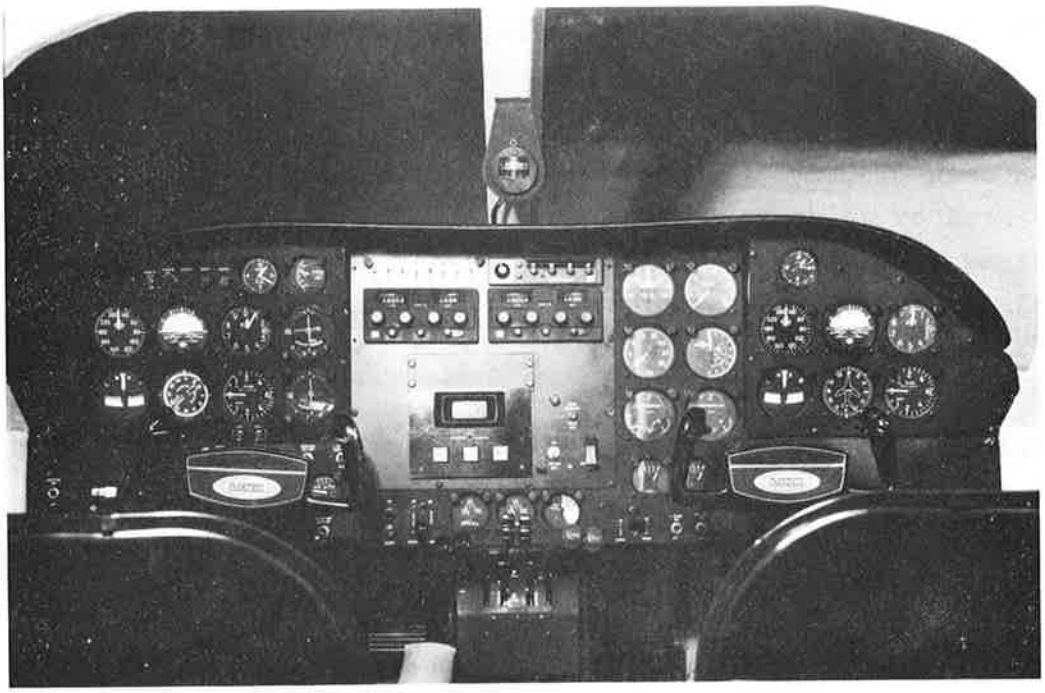

Figure 2-5. Cockpit Installation of Display

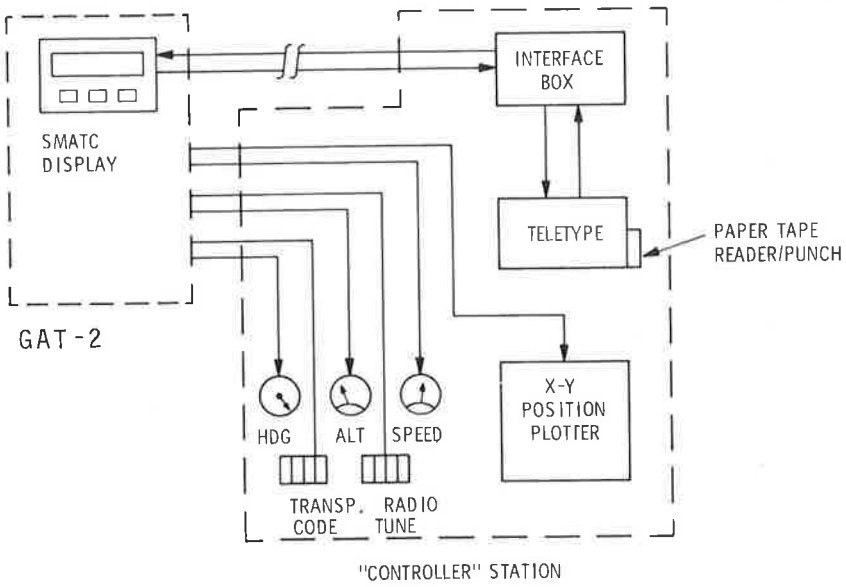

Figure 2-6. GAT-2 Simulation Block Diagram

"Wilco" and "Unable buttons were located on each of the displays. Additionally, "Wilco" buttons were located on the two control columns of the simulator.

On each display, the appearance of a new message was accompanied by an audio alert consisting of a beep repeated twice per second with 50% duty cycle, which continued until a response was made.

2.2 EXPERIMENTAL DESIGN

The eight pilots who had previously participated in the tests on the GAT-1 simulator were divided into four teams, identified as "A" thru "D". Four additional teams, "E" thru "H" were composed of FAA/NAFEC pilots with no previous Data Link experience. The experimental design used to counterbalance for practice effects is presented in Table 2-2, where the numbers 1, 2, 3 and 4 represent respectively the 7-Window, 3x7-Window, the 32-Window and NIMO displays, "D" and "N" represent day versus night conditions and "I" and "II" the two scenarios which were flown. The design was later replicated with eight crews composed of Airline and ALPA pilots (henceforth referred to simply as airline pilots.) Additional data were collected from one crew of AOPA pilots.

TABLE 2-2. EXPERIMENTAL DESIGN

	Teams			
Sequence of Tests	A,E	B,F	C,G	D,H
	1DI	3NII	4NI	2DII
	3DII	1NI	2NII	4DI
	4NII	2DI	1DII	3NI
	2NI	4DII	3DI	1NII

2.3 THE SCENARIOS

Scenario A presented the commands required for a flight from JFK Airport to Atlantic City, with departure on Runway 13R, radar vectors to V-16, further vectors to avoid traffic, departure from

Coyle via 039 radial to Gretna intersection and an eventual landing on Runway 31 at NAFEC. Scenario B represented a simulated flight from Philadelphia to LaGuardia, with departure on Runway 27R, vectors to V-157, a hold at Robbinsville and an eventual landing on Runway 13. The complete scenarios and the format in which the commands were presented on the several displays are reproduced in Appendix A. Figures 2-7 and 2-8 indicate the nominal flight paths flown. The numbers on these figures indicate where the commands listed in Appendix A were issued.

Both of the scenarios contained occasional impossible commands to force the crews to interpret the meaning of messages rather than responding with an automatic "Wilco" response.

2.4 EXPERIMENTAL SUBJECTS

Questioning of the FAA/NAFEC, Airline, ALPA, and AOPA pilots concerning their experience was limited to the determination of their age and their total flying hours in all types of aircraft. These data for the test pilots and airline pilots are reproduced in Table 2-3. Data for the two AOPA pilots are presented in Section 3.1.13 of this report for reasons given in that section.

2.5 EXPERIMENTAL PROCEDURES

Each of the crews made four simulated flights, lasting about one hour each, alternating as pilot and co-pilot on the runs. All four simulated flights for a crew were completed in a single day.

Prior to the flights, the crews were given copies of the instructions reproduced in Appendix B. They were allowed a brief practice period to familiarize themselves with the flying qualities of the simulator, and they were instructed as to the particular features of each of the four displays.

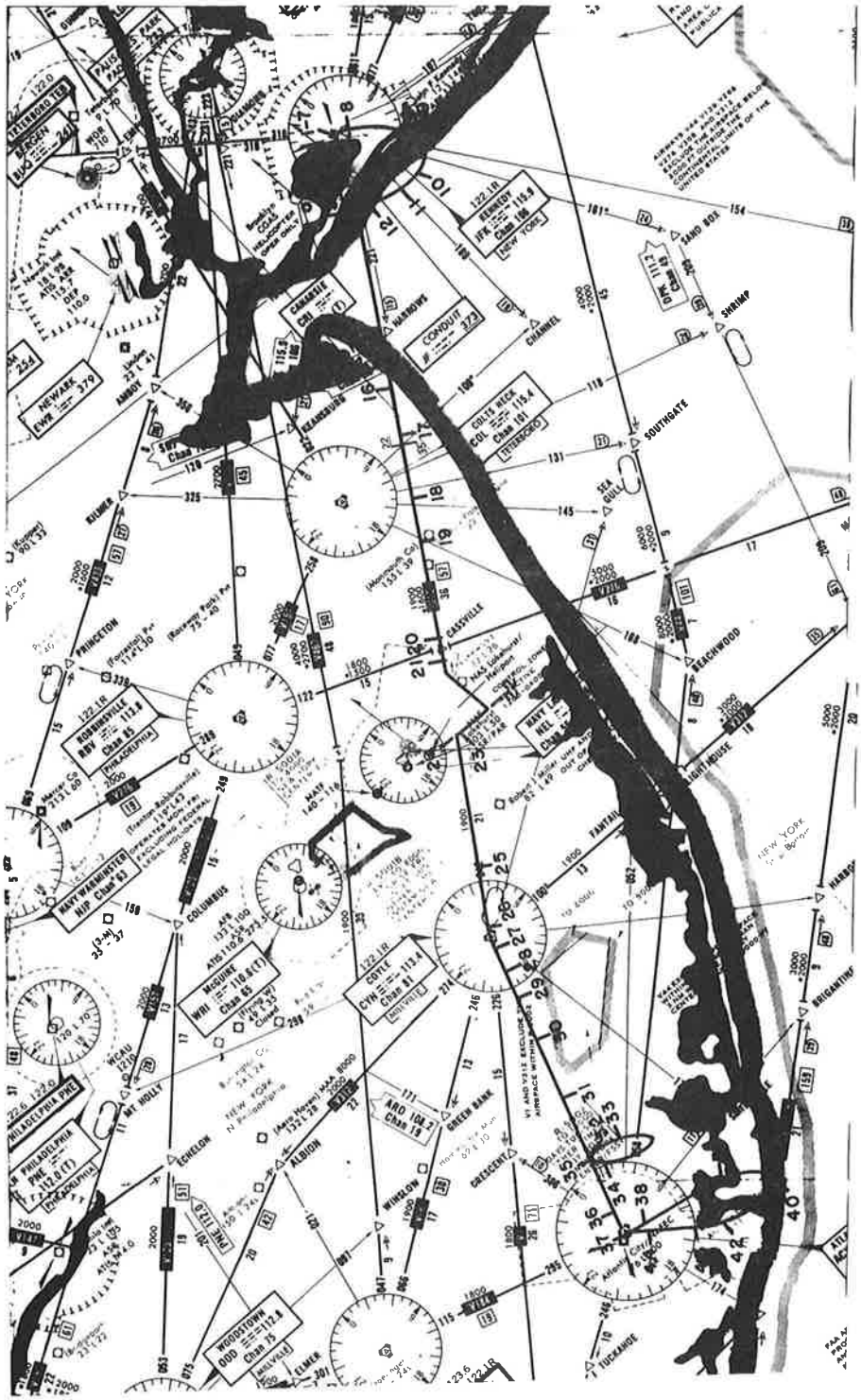

Figure 2-7. Nominal Flight Path for Scenario A

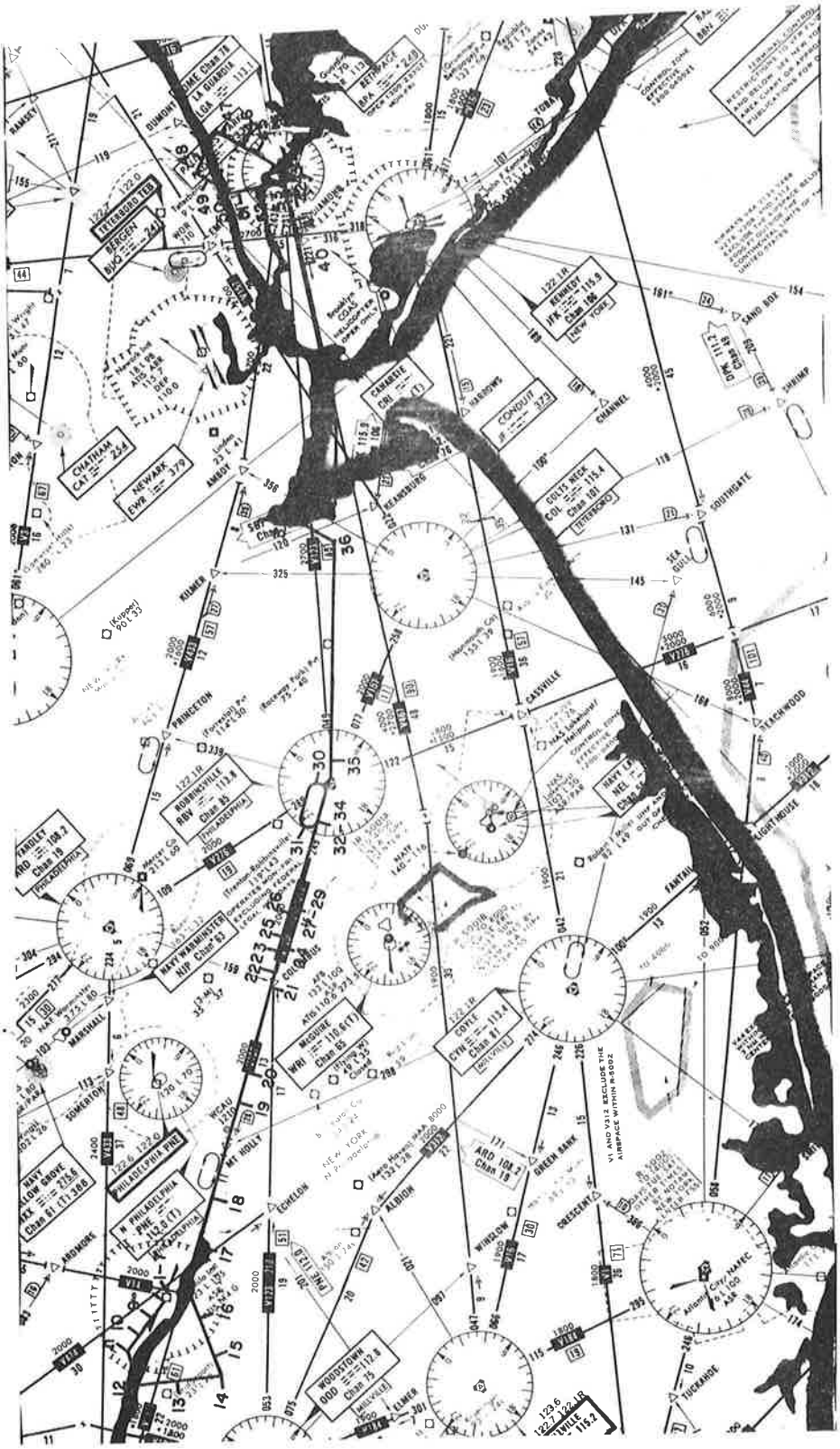

Figure 2-8. Nominal Flight Path for Scenario B

TABLE 2-3. AGE AND EXPERIENCE OF EXPERIMENTAL SUBJECTS

FAA/NAFEC Pilots				Airline & ALPA Pilots			
Crew	Pilot	Age	Total Flying Hours	Crew	Pilot	Age	Total Flying Hours
A	# 1	45	8,000	I	#17	30	2,700
	2	53	10,000		18	40	6,050
B	3	47	8,300	J	19	30	800
	4	53	10,500		20	54	17,000
C	5	51	20,000	K	21	39	5,000
	6	51	18,000		22	46	11,000
D	7	49	7,000	L	23	37	5,500
	8	48	13,000		24	46	16,000
E	9	51	18,000	M	25	55	25,000
	10	51	8,000		26	56	3,500
F	11	48	11,000	N	27	45	15,000
	12	45	4,242		28	32	3,900
G	13	51	5,000	O	29	42	7,000
	14	51	15,500		30	42	13,500
H	15	50	13,650	P	31	29	5,500
	16	54	9,000		32	37	7,000
Mean		50	11,200			41	9,000

3. EXPERIMENTAL RESULTS

The results reported in this section are divided into response time data and data abstracted from the questionnaire. The response time data are further subdivided to indicate differences resulting from individual pilots, crews, displays, scenarios, day versus night conditions, and message types and lengths, as well as "Unable" responses.

While response time to the presentation of a new message should not be considered the sole criterion for judging the adequacy of a display, it does provide a measure which is easily quantified, as well as permitting a comparison with subjective opinions of display quality. While response time data are covered first in this report, any apparent priority given to these data should be considered only as a means for the orderly presentation of information.

3.1 RESPONSE TIME DATA

Response time to all commands was recorded to the nearest tenth of a second. The equipment used further provided means for determining whether a "Wilco" response was made using the button on the display case, or on the pilot's or co-pilot control column. However, it was not possible to determine which of the two crew members made responses using the "Wilco" button on the display case. This deficiency will be corrected in future experiments.

3.1.1 Individual Pilots

The data of Table 2-3 indicated that the FAA/NAFEC test pilots represented a much more homogeneous population than the airline pilots. The age range for the NAFEC pilots was 45 to 53 as compared with an age range of 30 to 56 for the airline pilots. Flying experience of the NAFEC test pilots varied from 4,200 to 20,000 hours while the experience of the airline pilots ranged from 800

to 25,000 hours. On the average, the NAFEC test pilots had some 2,200 extra hours of experience over that of the airline pilots. For this reason, it does not seem desirable to attempt to combine the data of the two groups even though the experiment was replicated for the second group.

In the previous experiment in this series, reported in FAA-RD-73-69, there appeared to be a positive correlation between flying experience and speed of response and no such correlation between age and speed of response, but the small subject population used makes it questionable to attach any statistical significance. It therefore seems desirable to examine the data of the present experiment.

First, one should expect some correlation between age and flying experience in that no 30 year old pilot could be expected to have accumulated 20,000 flying hours. For the restricted age range of the NAFEC pilots, there is no such apparent correlation, as indicated in Figure 3-1. For the somewhat greater age range of the airline pilots, this correlation is quite noticeable, as indicated in Figure 3-2. The data presented here are limited to control column responses, and since with some crews, one crew member made all or nearly all of the responses, the data from the non-participating crew member are not included.

For both groups, however, there was not a strong correlation between reaction time and age, or reaction time and flying experience, as indicated in Figures 3-3 thru 3-6, with the possible exception of a slight correlation between age and reaction time for the NAFEC pilots, and in the anticipated direction since reaction time tends to increase with age.

3.1.2 Crew Differences

The examination of response time differences among crews is somewhat meaningless, since it combines data from crew members whose individual characteristics may vary widely, paired in an

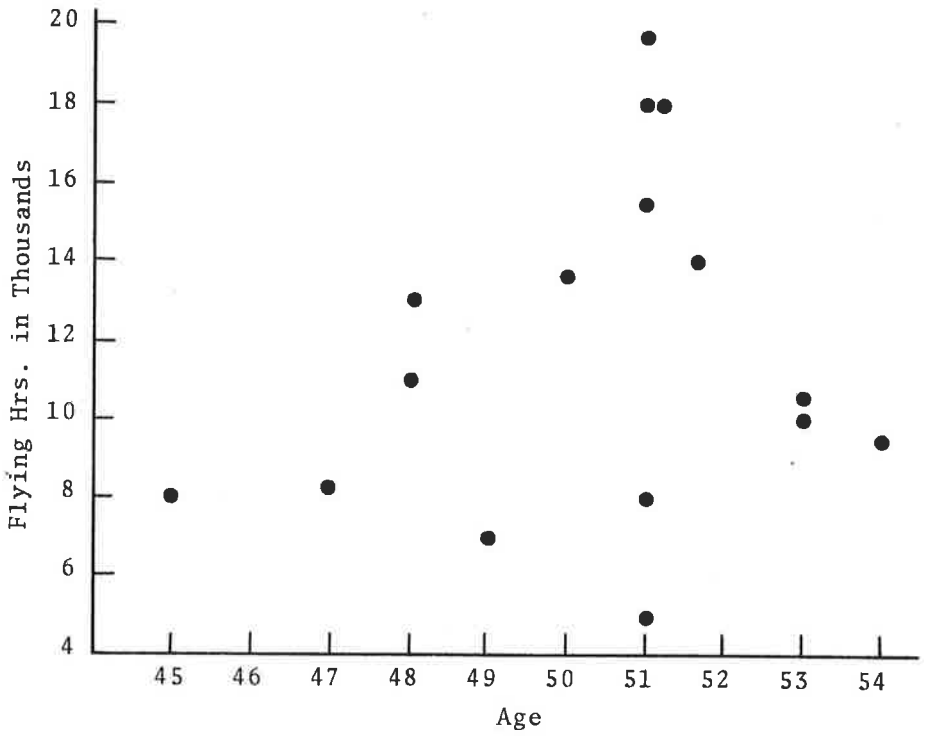

Figure 3-1. Flying Experience as a Function of Age: FAA/NAFEC Pilots

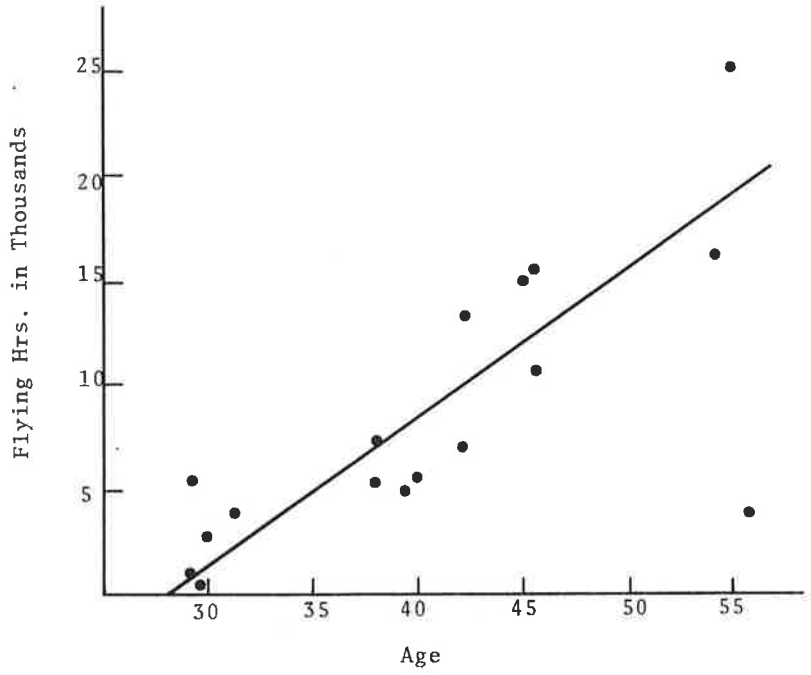

Figure 3-2. Flying Experience as a Function of Age: Airline Pilots

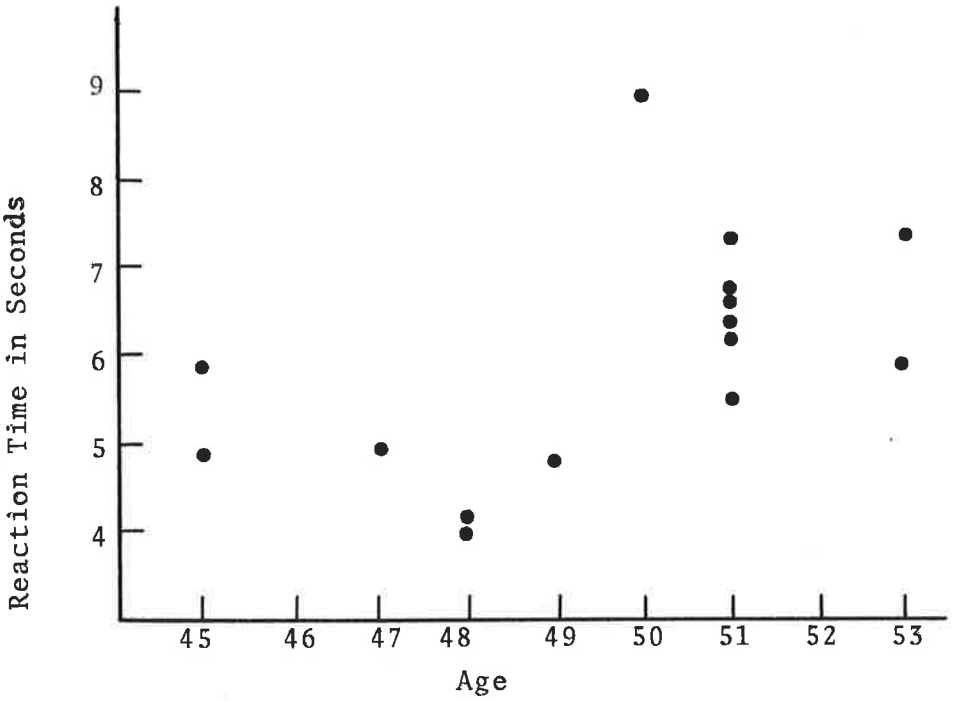

Figure 3-3. Reaction Time as a Function of Age: FAA/NAFEC Pilots

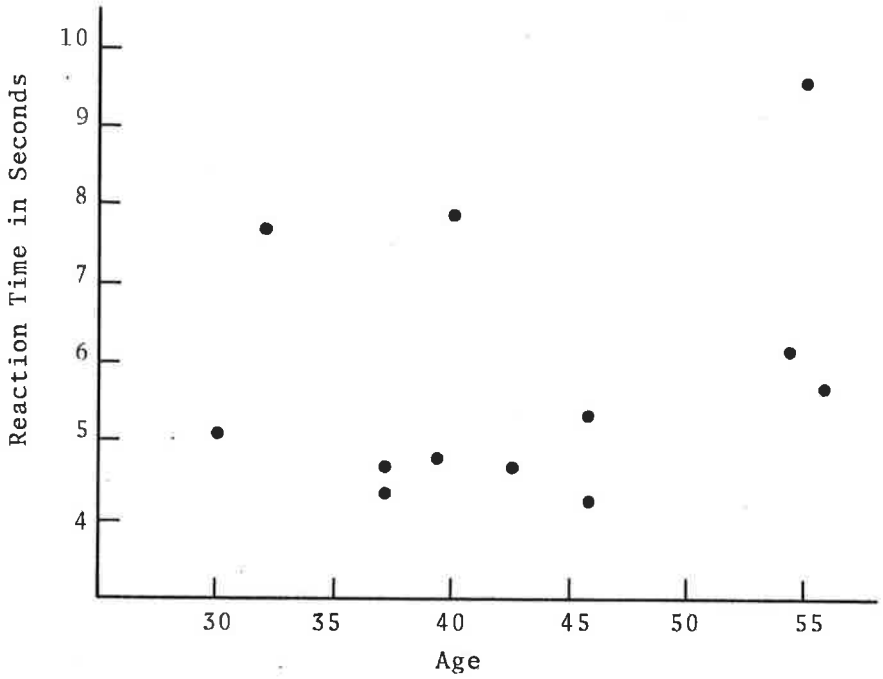

Figure 3-4. Reaction Time as a Function of Age: Airline Pilots

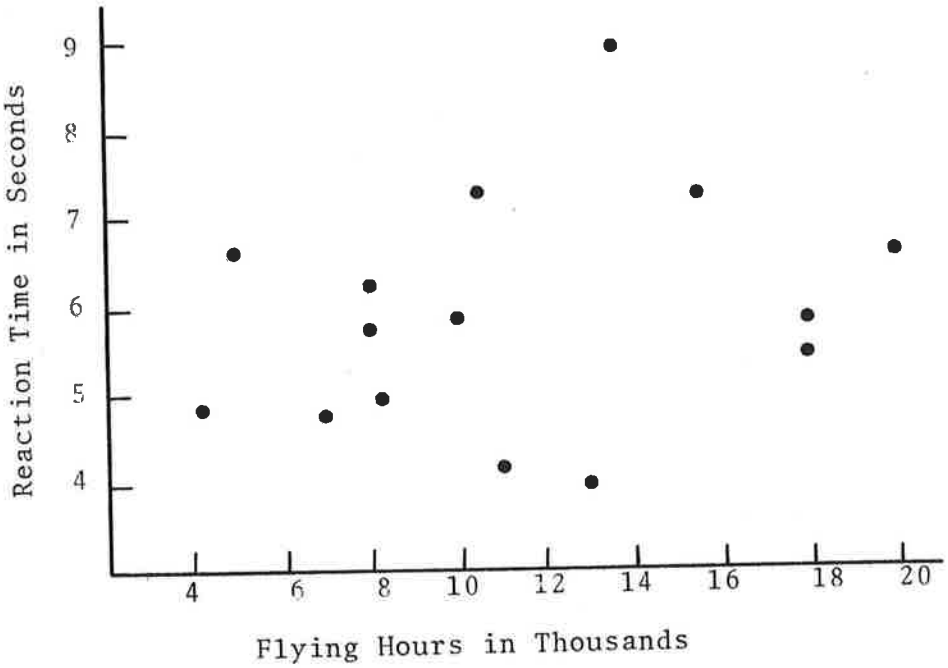

Figure 3-5. Reaction Time as a Function of Flying Experience: FAA/NAFEC Pilots

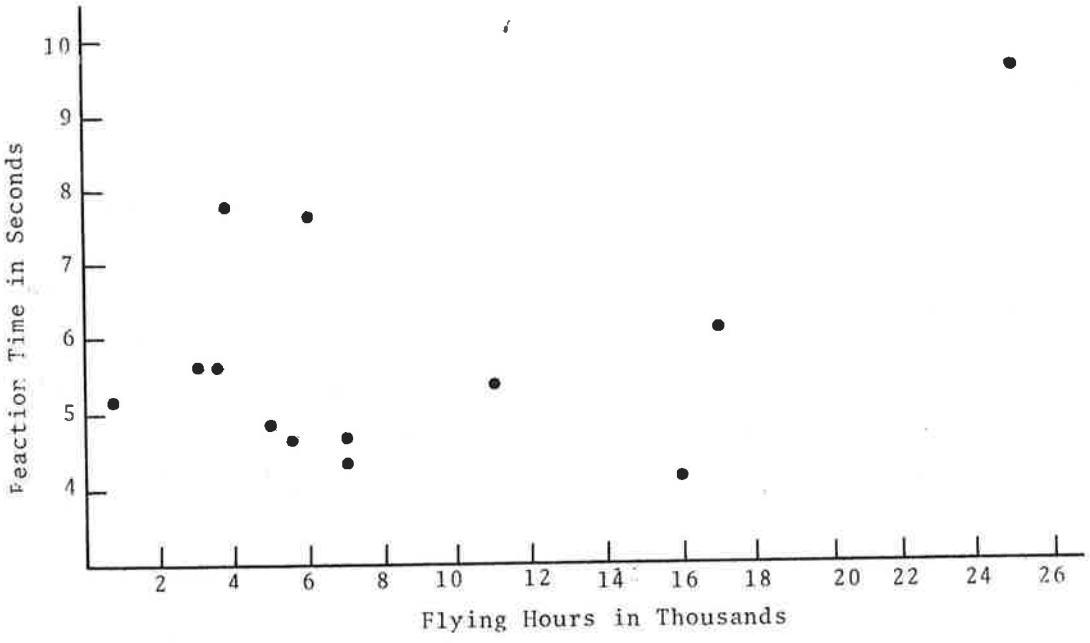

Figure 3-6. Reaction Time as a Function of Flying Experience: Airline Pilots

uncontrolled manner. For completeness, the mean response times of the several crews are presented in Tables 3-1 and 3-2 without additional comments.

TABLE 3-1. MEAN RESPONSE TIME IN SECONDS FOR FAA/NAFEC CREWS

Crew	Response Time
A	6.2
B	8.5
C	7.3
D	5.1
E	5.8
F	5.6
G	7.8
H	7.3
Mean	6.7

TABLE 3.2 MEAN RESPONSE TIME IN SECONDS FOR AIRLINE CREWS

Crew	Response Time
I	6.1
J	6.9
K	5.8
L	4.3
M	9.3
N	6.6
O	5.2
P	4.7
Mean	6.1

It appears more appropriate to examine the manner in which the several crews handled Data Link responses. Under usual commercial procedures, the co-pilot is responsible for the majority of communications transactions, while the pilot handles control of the aircraft. During the experiment, the crews were given no instructions as to which crew member had responsibility for Data Link, and different crews interpreted Data Link on their own as either a control or communication function, even though they alternated as pilot and co-pilot. There were no apparent differences in performance as a result of this when reaction time is taken as the criterion. Tables 3-3 and 3-4 indicate the total number of responses made on the pilot's "Wilco" button on the control column, that of the co-pilot and that on the display case. Note that crews "C" and "K" handled Data Link almost solely as a control function, whereas crews "D", "E", "G" and "L" clearly considered Data Link to be a communication function. Failure to record which crew member made responses on the display makes it impossible to determine with any certainty how the remaining crews handled Data Link.

TABLE 3-3. NUMBER OF RESPONSES MADE ON "WILCO" BUTTONS OF PILOT, CO-PILOT AND DISPLAY. TEST PILOTS

Crew	Pilot	Co-Pilot	Display	Total
A	9	71	66	146
B	11	70	77	158
C	111	7	39	157
D	0	142	12	154
E	8	110	37	155
F	16	78	64	158
G	5	143	9	157
H	31	11	111	153
Total	191	632	415	1238

TABLE 3-4. NUMBER OF RESPONSES MADE ON "WILCO" BUTTONS OF PILOT, CO-PILOT AND DISPLAY. AIRLINE PILOTS

Crew	Pilot	Co-Pilot	Display	Total
I	1	10	146	157
J	6	24	86	116
K	101	1	3	105
L	13	140	1	154
M	15	89	50	154
N	39	0	116	155
O	5	60	84	149
P	0	37	116	153
Total	180	361	602	1143

Differences in the total number of responses recorded for different crews in Tables 3-3 and 3-4 are attributable to the lack of a requirement of acknowledging messages such as "Radar Contact," by occasional failures by the experimenter to record a response, and in the case of Crews "J" and "K", to time constraints which did not permit them to complete all of the runs.

In most cases, some reasonable number of responses were made by both the pilot and co-pilot, and since crew members alternated in these positions, it seems desirable to examine any response time differences at these two positions. These data are presented in Tables 3-5 and 3-6. Despite the alternation of cockpit seating, crew members were remarkably consistent in having shorter response times while serving as co-pilot. Some definition of Data Link function is indicated in the instructions for crews in future experiments.

3.1.3 Display Differences

The two previous subsections of this report have provided data as to pilot and crew variability. We are now ready to concern ourselves with the quantitative data on performance differences with the different displays. The accumulation of such data was the principle reason for running the simulator evaluations.

Tables 3-7 and 3-8 indicate the mean reaction times in seconds for each crew with each scenario under day and night conditions. The mean reaction times of crews in these tables does not always agree with the means of the previous two sub-sections, since the data for responses made with the "Wilco" button on the display case are now included.

Tables 3-7 and 3-8 indicate how the experimental design provided an orderly examination of all combinations of display, scenario and day versus night conditions with a minimum of experimental runs, but further interpretation without recombination of the data is difficult.

Recombined data are presented in Tables 3-9 and 3-10 for the test pilots and airline pilots respectively. For both groups, mean response times were fastest with the 3x7-Window and NIMO displays, somewhat slower with the 32-Window display and slowest for the 7-Window display.

The variability of response time among crews is more easily noted in Tables 3-11 and 3-12 which present the ratio of reaction time of each crew on each display to the mean reaction time of

TABLE 3-5. MEAN RESPONSE TIMES OF PILOTS AND CO-PILOTS USING CONTROL COLUMN "WILCO" BUTTONS. TEST PILOTS

Crew	Serving as Pilot			Serving as Co-Pilot		
	No. of Resp.	Total Time	Mean Time	No. of Resp.	Total Time	Mean Time
A	9	54.5	6.1	71	354.0	4.7
B	11	127.2	11.6	70	391.3	5.6
C	111	688.2	6.2	7	32.5	4.7
D	0	0	- -	142	625.6	4.4
E	8	54.0	6.8	110	624.2	5.7
F	16	66.6	4.2	78	379.9	4.9
G	5	75.5	15.1	143	1024.8	7.0
H	31	308.2	10.0	11	71.0	6.5
Total	191	1374.2	7.2	632	3483.0	5.5

(TIME IN SECONDS)

TABLE 3-6. MEAN RESPONSE TIMES OF PILOTS AND CO-PILOTS USING CONTROL COLUMN "WILCO" BUTTONS. AIRLINE PILOTS

Crew	Serving as Pilot			Serving as Co-Pilot		
	No. of Resp.	Total Time	Mean Time	No. of Resp.	Total Time	Mean Time
I	1	10.2	10.2	10	79.2	7.9
J	6	39.3	6.6	24	136.9	5.7
K	101	729.8	7.3	1	3.2	3.2
L	13	50.9	3.8	140	619.1	4.4
M	15	200.6	7.6	89	688.5	7.7
N	39	300.6	4.0	0	- -	- -
O	5	19.8		60	299.5	5.0
P	0	- -		37	161.2	4.3
Total	180	1150.6	6.4	361	1997.6	5.5

(TIME IN SECONDS)

TABLE 3-9. MEAN REACTION TIME OF CREWS TO EACH DISPLAY: TEST PILOTS (TIME IN SECONDS)

	CREW								
DISPLAY	A	B	C	D	E	F	G	H	MEAN
NIMO	4.2	6.4	5.9	6.0	4.3	4.8	8.6	6.7	5.9
7-W	8.3	12.4	10.7	5.9	8.0	7.1	5.9	10.0	8.5
3x7-W	6.3	5.1	6.9	3.7	4.5	4.4	9.3	6.7	5.9
32-W	6.0	8.9	5.7	4.8	6.8	6.2	7.1	5.8	6.9
MEAN	6.2	8.2	7.3	5.1	5.8	5.6	7.7	7.3	6.7

TABLE 3-10. MEAN REACTION TIME OF CREWS TO EACH DISPLAY: AIRLINE PILOTS (TIME IN SECONDS)

	CREW								
DISPLAY	I	J	K	L	M	N	O	P	MEAN
NIMO	5.8	5.4	4.8	5.2	6.2	5.7	5.2	4.8	5.4
7-W	7.8	7.9	5.6	4.7	11.4	7.9	5.2	4.9	6.9
3x7-W	4.6	5.4	5.9	4.1	5.7	4.8	5.7	4.7	5.1
32-W	6.2	7.4	7.0	3.4	13.6	8.0	4.0	4.9	6.8
MEAN	6.1	6.9	5.8	4.3	9.2	6.6	5.0	4.8	6.1

all crews to that particular display. Here, the great variability in performance among crews for each individual display should be noted. For the test pilots, at least one crew performed poorly on each of the displays and two crews (B and G) performed poorly on two of the displays (but different displays) as indicated by the underlined numbers in Table 3-11. Only one crew (F) performed better than average on all four of the displays.

For the airline pilots (Table 3-12), there was much greater consistency in performance on the NIMO and 3x7-Window displays. One crew performed poorly on the 7-Window display, and that same crew "M" performed poorly on the 32-Window display, with a response

TABLE 3-11. RATIO OF THE MEAN RESPONSE TIME OF EACH CREW ON EACH DISPLAY TO THE MEAN RESPONSE TIME OF ALL CREWS ON THAT PARTICULAR DISPLAY. TEST PILOTS

	CREW								
DISPLAY	A	B	C	D	E	F	G	H	RANGE
NIMO	.71	1.08	1.00	1.02	.73	.81	1.46	1.14	.75
7-W	.98	1.46	1.26	.69	.94	.84	.69	1.18	.71
3x7-W	1.07	.86	1.17	.63	.76	.75	1.58	1.14	.95
32-W	.94	1.40	.84	.75	1.06	.97	1.11	.91	.65

TABLE 3-12. RATIO OF THE MEAN RESPONSE TIME OF EACH CREW ON EACH DISPLAY TO THE MEAN RESPONSE TIME OF ALL CREWS ON THAT PARTICULAR DISPLAY. AIRLINE PILOTS

	CREW								
DISPLAY	I	J	K	L	M	N	O	P	RANGE
NIMO	1.07	1.00	.89	.96	1.15	1.06	.96	.89	.26
7-W	1.13	1.14	.81	.68	1.65	1.14	.75	.71	.97
3x7-W	.90	1.06	1.16	.80	1.12	.94	1.12	.92	.36
32-W	.91	1.04	1.03	.50	2.00	1.18	.59	.72	1.50

time twice as great as the mean. On the other hand, crew "L" had a response time on the 32-Window display which was only half of the mean value for all crews. The above results all indicate the need to use several crews in the evaluation of any given display if meaningful data are to be obtained.

3.1.4 Control Column Versus Display "Wilco" Buttons

Tables 3-13 and 3-14 indicate the performance differences between use of the "Wilco" buttons on the control column and on the display for the test pilots and airline pilots respectively. With thirteen out of the sixteen crews, performance was faster using the control column "Wilco" button, indicating the importance of permitting crews to respond in this manner thereby avoiding a need to reach out to the panel.

TABLE 3-13. MEAN RESPONSE TIMES FOR USE OF THE "WILCO" BUTTONS ON THE CONTROL COLUMN AND ON THE DISPLAY. TEST PILOTS (TIME IN SECONDS)

CREW	CONTROL COLUMN	DISPLAY
A	5.0	6.6
B	6.4	10.6
C	6.1	10.6
D	4.4	13.0
E	5.7	6.1
F	4.8	6.7
G	7.4	13.0
H	9.0	6.6
MEAN	6.2	7.8

TABLE 3-14. MEAN RESPONSE TIMES FOR USE OF THE "WILCO" BUTTONS ON THE CONTROL COLUMN AND ON THE DISPLAY. AIRLINE PILOTS (TIME IN SECONDS)

CREW	CONTROL COLUMN	DISPLAY
I	8.1	5.9
J	5.8	7.3
K	5.2	26.1
L	4.3	5.8
M	8.5	9.3
N	7.7	6.2
O	4.9	5.1
P	4.5	4.8
MEAN	5.8	6.7

3.1.5 Scenario Differences

If variability among crews on their performance with a given display is to be minimized, it is important that the scenarios be equated for difficulty insofar as possible, since with an incomplete block experimental design as in the present experiment, all crews did not evaluate each display with each scenario.

Tables 3-15 and 3-16 indicate the mean performance of each crew with each scenario. The overall means indicate that the scenarios were well equated for difficulty even though certain crews did better on one scenario than on the other.

TABLE 3-15. MEAN PERFORMANCE OF CREWS ON SCENARIOS "A" AND "B". TEST PILOTS (TIME IN SECONDS)

CREW	SCENARIO	
	A	B
A	6.2	3.7
B	7.0	9.9
C	8.3	6.5
D	6.0	4.3
E	5.7	6.2
F	5.2	6.0
G	7.3	8.2
H	8.3	6.3
MEAN	6.8	6.4

TABLE 3-16. MEAN PERFORMANCE OF CREWS ON SCENARIOS "A" AND "B". AIRLINE PILOTS (TIME IN SECONDS)

CREW	SCENARIO	
	A	B
I	5.4	6.8
J	6.4	6.7
K	7.0	6.5
L	5.0	3.8
M	9.8	8.8
N	6.5	6.8
O	5.2	4.9
P	4.9	4.5
MEAN	6.1	6.1

3.1.6 First Versus Second Runs on a Scenario

The generation, coding and testing of a scenario requires appreciable time and money, and for this reason, it is desirable to minimize the number of scenarios that are used in a given experiment. At the same time, the ability of a crew to anticipate a command thru previous practice with that scenario must reduce the validity of data acquired under this condition.

Tables 3-17 and 3-18 show the change in performance of crews between first and second runs on a scenario. For both scenarios, there was appreciable reduction in reaction time on the second exposure. On future experiments, no crew should fly the same scenario more than twice, and ideally a scenario should be used only once by a crew.

Since each crew flew each display only once, we would not anticipate improvements in performance due to practice effects with the displays. For the four runs, mean reaction times for the test pilots were 6.7", 6.4", 6.9" and 6.2" respectively. For the airline pilots, the figures were 6.8", 7.1", 5.4" and 5.0". The performance changes here are apparently completely due to some familiarity with the scenarios on their second runs.

3.1.7 Day Versus Night Differences

Since the displays differed in brightness and contrast, one might expect performance differences between the night and day conditions even though the "daylight" conditions approximated that of a well-lighted office due to limitations in the ability to position high intensity lights in the area of the GAT-2. Tables 3-19 and 3-20 indicate the mean reaction times with each display under "day" and "night" conditions. For the test pilots, reaction times with the NIMO and 32-Window displays were comparable under the two conditions. Performance was appreciably faster with the 7-Window and 3x7-Window displays under daylight conditions. Airline pilots performed better with the 3x7-Window display in daylight, but the daylight condition yielded poorer performance with the 7-Window and 32-Window displays with this subject group.

TABLE 3-17. MEAN REACTION TIME OF CREWS ON 1ST AND 2ND RUNS ON EACH SCENARIO. TEST PILOTS

CREW	SCENARIO "A"		SCENARIO "B"	
	1st Run	2nd Run	1st Run	2nd Run
A	6.0	6.3	3.0	4.3
B	8.9	5.1	13.4	6.4
C	5.9	10.7	7.2	5.7
D	6.0	6.0	3.7	4.8
E	6.8	4.5	8.0	4.3
F	6.1	4.2	7.1	4.8
G	8.6	5.9	9.3	7.1
H	6.6	10.0	6.7	5.8
MEAN	6.9	6.6	7.3	5.4

(TIME IN SECONDS)

TABLE 3-18. MEAN REACTION TIME OF CREWS ON 1ST AND 2ND RUNS ON EACH SCENARIO. AIRLINE PILOTS

CREW	SCENARIO "A"		SCENARIO "B"	
	1st Run	2nd Run	1st Run	2nd Run
I	6.2	4.6	7.8	5.8
J	7.4	5.4	7.9	5.4
K	4.8	5.6	5.9	7.0
L	5.2	4.7	4.1	3.4
M	13.6	5.9	11.4	6.2
N	8.1	4.8	7.9	5.7
O	5.2	5.2	5.7	4.0
P	4.8	4.9	4.7	4.3
MEAN	6.9	5.1	7.0	5.2

(TIME IN SECONDS)

TABLE 3-19. REACTION TIME DIFFERENCES BETWEEN DAY AND NIGHT CONDITIONS. TEST PILOTS (TIME IN SECONDS)

DISPLAY	DAY	NIGHT	MEAN
NIMO	5.9	5.7	5.8
7-W	8.2	9.2	8.7
3x7-W	4.9	6.8	5.8
32-W	6.4	6.4	6.4
MEAN	6.4	6.9	6.7

TABLE 3-20. REACTION TIME DIFFERENCES BETWEEN DAY AND NIGHT CONDITIONS. AIRLINE PILOTS (TIME IN SECONDS)

DISPLAY	DAY	NIGHT	MEAN
NIMO	5.3	5.6	5.4
7-W	7.8	6.4	7.0
3x7-W	4.7	5.5	5.1
32-W	7.8	5.7	6.7
MEAN	6.4	5.8	6.1

3.1.8 Message Types and Lengths

All of the displays except the NIMO had the capability for displaying multiple commands such as a heading and altitude change, either simultaneously or, in the case of the 7-Window display, by scrolling. The use of such multiple transmissions of information could increase the efficiency of Data Link, since the long string of characters required to establish sync, aircraft I.D., parity etc. would require transmission only once, while the message *per se* could provide multiple units of information, a "Unit of Information" in this case being defined as any single discrete command or advisory. Such an increase in transmission efficiency must, however, be predicated on the ability of the crew to assimilate such multiple messages readily. Tables 3-21 and 3-22 present response times to the several displays as a function of units of information in messages, for test pilots and airline pilots respectively, and indicate that the response time is increased only modestly when two information units are presented.

TABLE 3-21. RESPONSE TIMES AS A FUNCTION OF NUMBER OF INFORMATION UNITS IN MESSAGE. TEST PILOTS (TIME IN SECONDS)

DISPLAY	NO. OF INFORMATION UNITS	
	1	2
NIMO	5.2	---
7-W	9.1	11.8
3x7-W	5.5	5.5
32-W	5.9	7.4
MEAN	6.3	8.3

TABLE 3-22. RESPONSE TIMES AS A FUNCTION OF NUMBER OF INFORMATION UNITS IN MESSAGE. AIRLINE PILOTS (TIME IN SECONDS)

DISPLAY	NO. OF INFORMATION UNITS	
	1	2
NIMO	5.0	---
7-W	6.3	5.9
3x7-W	4.9	5.2
32-W	4.8	6.3
MEAN	5.3	5.9

Earlier GAT-1 tests had indicated that the transmission of multiple messages became confusing when radio frequency setting and transponder code settings were involved, since, with this number of digits, the pilot preferred to make the appropriate settings before responding, to insure that he did not lose the message. With the 2-man crews of the present experiment, this condition became less critical. Tables 3-23 and 3-24 indicate the mean reaction times to the several displays with radio frequency and transponder code messages eliminated.

It should be noted that the differences from the previous two tables are extremely small.

TABLE 3-23. MEAN REACTION TIME AS A FUNCTION OF UNITS OF INFORMATION. R.F. & TRANSPONDER SETTINGS ELIMINATED. TEST PILOTS (TIME IN SECONDS)

DISPLAY	NO. OF INFORMATION UNITS	
	1	2
NIMO	4.7	---
7-W	9.0	10.8"
3x7-W	5.3	5.4
32-W	5.4	7.2
MEAN	6.1	7.9

TABLE 3-24. MEAN REACTION TIME AS A FUNCTION OF UNITS OF INFORMATION. R.F. & TRANSPONDER SETTINGS ELIMINATED. AIRLINE PILOTS (TIME IN SECONDS)

DISPLAY	NO. OF INFORMATION UNITS	
	1	2
NIMO	5.3	---
7-W	6.5	7.4
3x7-W	4.9	5.1
32-W	6.1	6.2
MEAN	5.7	6.4

3.1.9 "Unable" Responses

Throughout the experiment, occasional impossible messages such as "Turn right to a heading of 540°" were inserted to force the crews to interpret the meaning of messages instead of making an automatic "Wilco" response. As might be anticipated, response times to such "Unable" messages were somewhat longer than for "Wilco" messages, since the crews had to think "Could this be a possible message?" and then to reach out to the panel to respond. For test pilots, the mean response time to "Unable" messages was 7.7 seconds as compared with 6.7 seconds for "Wilco" responses. For the airline crews, these figures were 10.0 seconds and 6.1 seconds respectively.

3.1.10 Differences Between Test Pilots and Airline Pilots

The test pilots, on the average, were a somewhat older and more experienced group than the airline pilots. Additionally, test pilots have, over the years, been forced to adapt to a large variety of aircraft and to frequent changes in instrumentation in any given aircraft. For these reasons, we should expect certain response differences between the pilot groups.

The two groups handled Data Link responses in a somewhat different manner. With the test pilot group, a majority of the responses were made by the co-pilot using his control column response button. With the airline pilots, the largest number of responses were made directly on the display panel. Despite this difference in the manner of response, the two groups were remarkably consistent in their relative ranking under the several conditions studied. Airline pilots were slightly faster in their overall responses. With both groups, reactions to the NIMO and 3x7-Window displays were fastest and approximately equal, followed by the 32-Window, with the 7-Window slowest. The crew member serving as co-pilot made faster responses than when serving as pilot for both the test pilot and airline pilot groups, responses were consistently faster using the control column "Wilco" than the display "Wilco", and there was improvement in performance on the second run of a scenario. The test pilots performed slightly better under daylight conditions and the airline pilots under night conditions for unknown reasons. As might be expected, both groups showed increased reaction time when multiple unit messages were presented. Table 3-25 summarizes these data.

3.1.11 "Old" Versus "New" Pilots

Eight of the test pilots who served as subjects in this experiment had previously participated in the GAT-1 tests described in FAA-RD-73-69, and thus had some previous familiarity with the Data Link equipment. This did not, however, result in performance faster than that of the "new" test pilot group. Mean reaction time for the "old" test pilot group was 6.8 seconds as compared with 6.6 seconds for the "new" pilots.

TABLE 3-25. SUMMARY OF RESPONSE DIFFERENCES BETWEEN TEST PILOTS AND AIRLINE PILOTS

	Test Pilots	Airline Pilots
% Responses:		
By Pilot	15.4	15.7
By Co-Pilot	51.1	31.6
On Display	33.5	52.7
Response Times		
Mean	6.7	6.1
NIMO	5.9	5.4
3x7-W	5.9	5.1
32-W	6.4	6.8
7-W	8.5	6.9
By Pilot	7.2	6.4
By Co-Pilot	5.5	5.5
On Display	7.8	6.7
Scen. A: 1st Run	6.9	6.4
2nd Run	6.6	5.1
Scen. B: 1st Run	7.3	7.0
2nd Run	5.4	5.2
Daylight	6.4	6.4
Night	6.9	5.8
1 Info Unit Message	6.3	5.3
2 Info Units	8.3	5.9

3.1.12 Differences Between GAT-1 and GAT-2 Results

The GAT-1 tests reported in FAA-RD-73-69 used a single pilot and somewhat different results might therefore be anticipated from those obtained in the present experiment. A much smaller number of comparisons of data points was possible with the GAT-1 tests, since each scenario was flown only once and all responses had to be made using the "Wilco" button on the display panel. Responses were appreciably faster on the GAT-1 tests, probably because the single crew member felt no requirement for waiting until he was certain that another crew member had also absorbed the information before acknowledging and thereby running the possibility of losing

the information. With the GAT-1 tests, reaction time was faster for the NIMO (which was positioned directly in front of the pilot and was therefore relatively easy to read), and slowest for the 7-Window display. Of the two displays intermediate in performance on the GAT-1 tests, the 32-Window display was somewhat better than the 3x7-Window display. The differences found on the GAT-2 tests of these displays can probably be explained by (1) the newly installed dimming capability on the 3x7-Window display made it possible to avoid some of the glare present on the GAT-1 tests; (2) the reservation of 12 characters on the right hand side of the 32-Window display for heading, altitude and speed information created a tendancy for the crew to scan the entire length of the display prior to making a response; and (3) the location of the displays in the GAT-2 was better for the rather large characters of the 3x7-Window. The data from the GAT-1 and GAT-2 tests are compared in Table 3-26.

TABLE 3-26. MEAN RESPONSE TIMES FOR GAT-1 AND GAT-2 TESTS

	GAT-1	GAT-2
Response Times (sec)		
MEAN	4.6	6.4
NIMO	3.3	5.7
3x7-Window	4.7	5.5
32-Window	4.4	6.6
7-Window	6.1	7.7
Day	4.7	6.4
Night	4.6	6.4

3.1.13 Data from AOPA Pilots

General aviation forms an extremely important segment of overall aircraft operations in that the number of such general aviation aircraft exceed those in commercial service by a factor of approximately fifty to one. Wide acceptance of Data Link as a concept by at least that segment of the general aviation population who file IFR flight plans would do much to assure its viability,

and the opinions of such pilots during the formative stages of conceptual design must not be overlooked.

The invitation issued to AOPA (Aircraft Owners and Pilots Association) to participate in the NAFEC tests was accepted by two members. The combination of the data from this single crew with that from the much larger number of airline and test pilot crews could have resulted only in (1) a dilution of the impact of any results obtained from this single crew, and (2) an unbalancing of the number of data points obtained in certain cells in a previously and carefully counterbalanced experimental design. For these reasons, the data from this AOPA crew are considered separately. At the same time, results obtained from this crew should not be construed as necessarily representative of those which might be obtained from a larger population of general aviation pilots, or of AOPA members in toto.

The two AOPA pilots (subjects #33 and #34) were respectively 35 and 60 years of age and had flying experiences of 3400 and 7600 hours.

As might be expected from pilots used to flying their own aircraft, and frequently alone, the co-pilot functioned mainly in the role of observer on all four simulated flights made by this crew. No responses were made by the co-pilot. Two responses were made directly on the display panel and the remaining 157 responses by the pilot on his control column.

Mean response time was 6.1 seconds, comparable with that of the airline pilots. Since only a single crew participated, there could be no counterbalancing of the effects of scenarios, first vs. second runs of a scenario, or of day vs. night conditions. Table 3-27 lists the combinations studied, and mean reaction times for each. The rank ordering of the response times to the several displays is comparable with that of the other pilot groups.

TABLE 3-27. MEAN REACTION TIME OF AOPA PILOTS TO THE FOUR DISPLAYS

Display	32-W	7-W	NIMO	3x7-W
Scenario	A	B	B	A
Run	1st	1st	2nd	2nd
D/N	Day	Day	Night	Night
Pilot No.	33	34	33	34
Reaction Time	6.0	8.7	3.8	5.9

3.2 RESULTS FROM QUESTIONNAIRE

Putting numbers on performance when man must cope with a machine must frequently confound the separate issues of possible deficiencies in the machine with man's desire to perform useful work. When only a single dimension of machine variable is explored, any differences in man's performance under different conditions may provide useful information. With the present experiment, the displays varied in type font, character size and color, brightness, contrast and information format. Thus, while useful numbers were obtained, questioning of the pilot subjects could provide supplemental information valuable in planning future studies. Questionnaires were administered to the 16 test pilots, the 16 airline pilots and the two AOPA pilots at the completion of their flights in the simulator. The questionnaire was handed to the pilots prior to their simulator runs in the hope that foreknowledge of the questions would permit them to formulate more concrete opinions as the trials proceeded.

The questions asked and the responses are listed in Appendices C and D. The results are summarized below.

Both the test pilots and airline pilots were highly favorable to Data Link but not unanimously so. The test pilots appeared to be a little more enthusiastic than the airline pilots. Thirteen out of 16 test pilots and 9 out of 16 airline pilots, for example, thought that Data Link would reduce pilot work load. The airline pilots seemed to be a little more concerned that a visual communication system would interfere with other visual functions. Three of

the airline pilots for example, said they would prefer synthetic speech to visual displays, because they were distracted by the visual displays. Several of the respondents from both groups felt that more development and testing would be required before a final evaluation of Data Link could be made.

A few of the respondents from both groups volunteered the opinion (no question was asked about this subject) that Data Link did not communicate important information that is now communicated by voice. For example one pilot said that Data Link would need to give the pilot a better idea of what other aircraft were doing, and that the pilot should be able to tell ATC when he had made visual contact with an aircraft given in a traffic advisory.

Most of the pilots in both groups ranked the displays in the following order (from best to worst): 32-W, 3x7-W, 7-W, NIMO (See Appendix C for details). The NIMO was unpopular because it was hard to read. 15 airline pilots said that NIMO characters were too small; 6 out of 8 airline pilots and 4 out of 8 test pilots said NIMO was hard to read under daylight conditions. Several of the pilots from both groups said that NIMO characters were poorly formed (especially the numerics) fuzzy, and distorted (especially the last line). 13 out of the 16 airline pilots said they would prefer a line display to an improved NIMO (the remaining 3 gave borderline responses). Many of the test pilots said that improvements might cause them to reevaluate their opinion of the NIMO, but they were not asked their preference as to an improved NIMO vs. line display.

The 7-W was unpopular mainly because it had only 7 windows, which meant that separate portions of many of the messages required sequential presentation.

The 32-W and 3x7-W were popular primarily because they had the scratchpad capability, because they had more windows, and because they were easy to read compared with the NIMO. The test pilots had a stronger preference for the 32-W over the 3x7-W than did the airline pilots. The following table shows how many pilots ranked each display first.

TABLE 3-28. NUMBER OF FIRST RANKINGS GIVEN TO DISPLAYS BY PILOT GROUPS

	32-W	3x7-W	7-W	NIMO
Test Pilots	11	2	3	0
Airline Pilots	10	6	0	0
AOPA Pilots	1	1	0	0

Scratchpad was a highly popular feature. All of the airline pilots and 15 out of 16 of the test pilots liked it in some form. The airline pilots favored the recall feature of the 3x7-W to the continuous scratchpad of the 32-W by 9 to 6. The test pilots on the other hand favored the 32-W scratchpad over the 3x7-W recall feature by 9 to 4.

The test pilots favored the idea of having data link set heading bugs and altitude alert. (9 to 1 with 6 abstentions.) The airline pilots were, on the other hand opposed (9 against, 4 in favor, 3 borderline). Some of them were rather vehement on this point.

Displays with a large number of windows were favored. 12 airline pilots stated that an ideal display would have at least 21 windows (the other four did not reply to this question). 6 suggested that the ideal number might be greater than 32. The test pilots also generally favored displays with 21 or more characters. Three suggested displays of more than 32 characters.

White was the favorite color, preferred by 7 test pilots and 5 airline pilots. Red, through it had some adherents, aroused the most opposition.

The preferred character size seemed to range between the 32-W and the 3x7-W, that is between 0.20" and 0.35" high.

Originally, it had been planned to deliver the longer ATC messages such as clearances and ATIS via synthetic speech; however, the vocabulary limitations of the only speech synthesizer which was available for the experiment forced cancellation of this, and instead, such messages were read off by the experimenter. The

pilots were, however, given a brief opportunity to listen to synthetic speech at the completion of the experiment. All groups indicated a preference for the visual displays over synthetic speech. 14 of the test pilots preferred the visual displays and two gave a borderline response. The airline pilots were more evenly divided. 8 favored the visual displays and 5 favored synthetic speech. The airline pilot questionnaire, however, emphasized "improved" synthetic speech, whereas the test pilot questionnaire did not.

The responses of two AOPA pilots to the questionnaire are recorded separately in Appendix D. Both pilots appeared to be favorable to Data Link with reservations. One thought that Data Link would not be able to transmit enough detailed information. The 32-Window and 3x7-Window displays were favored because of scratchpad capability, easy readability and large number of windows. One pilot rated the 7-Window as least favorable because of the need for scrolling, while the other rejected the NIMO display because of difficulty in reading the characters.

4. DISCUSSION

Since the primary purpose of this experiment was to gain information which could reduce the number of displays requiring further simulator evaluation and eventual flight testing, some discussion as to the results of the experiment covering this aspect is desirable.

The displays tested represented only four out of a much larger number of possible configurations involving the variables (1) font; three types, (2) brightness; four levels, (3) color; red, orange, green, white, (4) character size; four levels and (5) data format; linear versus multiple short lines. Many of the remaining 380 possible combinations of these variables would require special order displays, and others such as white LED cannot be implemented with existing technology. The experimental displays were accordingly selected to be representative of off-the-shelf components.

The deficiencies of the 7-Window display were evident both in excessive response time and poor pilot opinion. Too many of the common short ATC messages cannot be accommodated within the constraints of 7-Windows, and the requirement for the successive presentation of portions of such messages is frustrating and time consuming. The use of a 7-Window display is effectively ruled out from further experiments.

The concept of using a NIMO tube with cathodes in a time-shared manner originally appeared attractive because of the low cost of the tube and the simplicity of the circuitry required for X-Y address of the selected cathodes. The ATC application required a special mask, and the manufacturer produced a batch of tubes containing this special mask within a reasonable time period and at low cost. The intended application of the NIMO was for general aviation where it could be located directly in front of the pilot to compensate for the small size of the tube. It was anticipated that deficiencies in character alignment in this original batch of tubes could be corrected in later batches.

Attempts by the manufacturer to correct the alignment deficiencies during a second tube run made at about the time of the present experiment were unsuccessful. A requirement for complete retooling was established and the high cost of such retooling could not be amortized easily without high volume production. No further work is anticipated with the NIMO, with the possible exception of a second look when and if Data Link becomes operational and widely accepted.

The simulator testing of the 32-Window display yielded generally favorable results and comments. Unfortunately, it was not possible to establish a true sunlight condition in the simulator area. In sunlight, the low brightness and contrast of the plasma display makes it difficult or impossible to read. Additionally, the form factor of the display prevents its installation in a standard instrument case, and installation of the display in some other location such as the cowling would further complicate the daylight readability problem: a problem which cannot be corrected easily by the usual methods for contrast control such as narrow-band filters because of the multiple spectral lines in a neon gas-discharge.

LED (light emitting diode) technology accordingly appears to be the most attractive area for further study, despite the preferences of a majority of pilots for a color other than red. At present, prepackaged LED 5x7 dot matrices are available only in red, but single diodes and small arrays are now available in both yellow and green. It is only a matter of time before demand will create justification for 5x7 green arrays for other purposes, and at that time, green arrays will be studied for the ATC application.

Monitoring of the status of emerging display technologies which might eventually become competitive with LED for the Data Link application will continue. Electrochromics and Liquid Crystals in particular may likely be strong candidates in the near future.

5. PLANS FOR FUTURE EXPERIMENTS

The Data Link experiments thus far have concentrated on the evaluation of Short Message ATC (SMATC) displays, and with a requirement for only a limited category of pilot responses. Implementation of the complete Data Link concept additionally requires evaluation of means for presenting longer messages such as clearances, ATIS and weather reports, plus pilot input means having the flexibility to permit entry of flight plan changes and a variety of other requests. Study is also required of the value of synthetic speech as a supplement to or as a replacement for visual displays for Data Link.

For the next series of tests on the GAT-2, a newly designed display capable of presenting two lines of eight LED characters each, and having storage capability for the recall of the latest heading, altitude and speed commands, and packaged in a 3-ATI case, will be the primary source for visual short message ATC information. This will be supplemented by synthetic speech and by printers for longer ATC messages. Input devices having two different levels of complexity and capability will also be evaluated. A total of seven such hardware combinations will be compared with a control condition where all communication is verbal and follows present ATC procedures.

A second similar experiment is scheduled later using airline simulators.

6. SUMMARY

Eight two-man crews of FAA/NAFEC test pilots each made four runs in a GAT-2 simulator to evaluate four displays presenting short message ATC commands and advisories. The counterbalanced experimental design was later replicated with eight crews of airline and ALPA pilots, and a single crew of AOPA pilots provided further data.

Response time measurements were taken with each display and this information was supplemented by a questionnaire administered to each crew member at the completion of their experimental runs.

The use of a display limited to seven characters, or another employing a NIMO CRT was ruled out from further evaluation. Pilot opinion was generally favorable to the use of a display presenting three lines of seven LED characters each and to a linear display of 32-plasma characters.

APPENDIX A

THE SCENARIOS AS DISPLAYED

These are the scenarios as they were presented on the four displays.

The column labeled 3x7-W RECALL shows how the 3x7-W display appears after the recall button is pushed.

It should be understood that when more than one line of information appears in a message on the 7-W display, these lines required successive presentation.

Some of the messages could not be transmitted with the NIMO display and had to be transmitted by voice. An asterik (*) following the NIMO column indicates that a missing message or part of message was transmitted by voice.

Number in first column refers to flight plan maps, presented as Figures 2-7 and 2-8.

The abbreviations used are explained in Appendix B.

SCENARIO A

This is JFK International Airport. Ceiling measured 1000 overcast, visibility 4, haze. Wind 330 degrees at 8. Temperature 62. Altimeter two niner niner six. ILS Runway 4R approach in use. Landing 4R. Departures on Runway 13R. Inform the controller on initial contact that you have received information Charlie.

No. 32-Window			3x7-W	3x7-W RECALL	7-W	NIMO
1 JFK G 121.90			JFK G 121.90	HDG ALT SPD	JFK G 121.90	CONTCT GROUND
2 CLR TXI RWY 13R			CLR TXI RWY 13R	HDG ALT SPD	CLR TXI RWY 13R	CLEARD TO TAXI
3 JFK T 119.10			JFK T 119.10	HDG ALT SPD	JFK T 119.10	CONTCT TOWER 1191
4 PSN HLD			PSN HLD	HDG ALT SPD	PSN HLD	*
5 CLR TKOF, RWY 13R			CLR TKOF PWY 13R	HDG ALT SPD	CLR TKOF RWY 13R	CLEARD TAKOFF RY13R
6 CLB TO 015	HDG 130	HDG ALT SPD 130 015	↑ 015 HDG 130	HDG 130 ALT 015 SPD	↑ 015 HDG 130	CLIMB ↑↑ 015 MAINTN HEADNG 130
7 JFK D 121.10	IDENT	130 015	JFK D 121.10 IDENT	HDG 130 ALT 015 SPD	JFK D 121.10 IDENT	CONTCT DEPRTR 1211 SQUAWK

*These heading altitude and speed labels were printed on the bezel immediately above the reserved windows.

No. 32-Window			3x7-W	3x7-W RECALL	7-W	NIMO
8 RDR CTC CLB TO 030	130	030	RDR CTC ↑ 030	HDG 130 ALT 030 SPD	RDR CTC ↑ 030	RADAR CONTCT CLIMB ↑ ↑ 030
9 RGT TO 150 VCTR V16	150	030	→ 150 VCTR V16	HDG 150 ALT 030 SPD	→ 150 VCTR V16	TURN* → → 150
10 RGT TO 230	230	030	→ 230	HDG 230 ALT 030 SPD	→ 230	TURN → → 230

This is Atlantic City Airport. Ceiling measures 500 overcast visibility 1/4 mile. Wind calm, temperature 60. Dew point 63, Altimeter two niner niner two. VOR Runway 31 approach in use. Landing Runway 31. Departures on Runway 4. Inform the controller on initial contact that you have information Bravo.

No. 32 Window			3x7-W	3x7-W RECALL	7-W	NIMO
11 RGT TO 260	260	030	→ 260	HDG 260 ALT 030 SPD	→ 260	TURN → → 260
12 PSN 4NM SE V16	260	030	PSN 4NM SE V16	HDG 260 ALT 030 SPD	PSN 4NM SE V16	*
13 CLB TO 050 RESM NAV		050	↑ 050 RESM NAV	HDG ALT 050 SPD	↑ 050 RESM NAV	CLIMB* ↑ ↑ 050
14 WR1 A 124.80		050	WRI A 124.80	HDG ALT 050 SPD	WRI A 124.80	CONTCT APPRCH 1248
15 SQK1120 IDENT		050	SQK1120 IDENT	HDG ALT 050 SPD	SQK1120 IDENT	SQUAWK 1120
16 RDR CTC		050	RDR CTC	HDG ALT 050 SPD	RDR CTC	RADAR CONTCT
17 TFL 01 4NM SLO		050	TFC 01 4NM SLO	HDG ALT 050 SPD	TFC 01 4NM SLO	TRAFIC 01 4ML

No. 32-Window		3x7-W	3x7-W RECALL	7-W	NIMO
18 CLR TFC	050	CLR TFC	HDG ALT 050 SPD	CLR TFC	MAINTN ALTUDE 050
19 SPD 120	050 120	SPD 120	HDG ALT 050 SPD 120	SPD 120	MAINTN SPEED 120
20 TFC 02 5NM NEB FST	050 120	TFC 02 5NM NEB FST	HDG ALT 050 SPD 120	TFC 02 5NM NEB FST	TRAFIC 02 5ML
21 LFT TO 195 - TFC	195 050 120	◄195 TFC	HDG 195 ALT 050 SPD 120	◄195 TFC	TURN* ◄ ◄ 195
22 RGT TO 260 CLR TFC	260 050 120	►260 CLR TFC	HDG 260 ALT 050 SPD 120	►260 CLR TFC	TURN* ► ► 260
23 PSN 3NM SE V16	260 050 120	PSN 3NM SE V16	HDG 260 ALT 050 SPD 120	PSN 3NW SE V16	*
24 RESM NAV SPD NML	050	RESM NAV SPD NML	HDG ALT 050 SPD	RESM NAV SPD NML	*
25 DSND TO 035	035	↓ 035	HDG ALT 035 SPD	↓ 035	DESCND ↓ ↓ 035
26 ACT A 124.60	035	ACY A 124.60	HDG ALT 035 SPD	ACY A 124.60	*
27 SQK1015 IDENT	035	SQK1015 IDENT	HDG ALT 035 SPD	SQK1015 IDENT	SQUAWK 1015
28 RDR CTC ACY ALTM 994	035	RDR CTC	HDG ALT 035 SPD	RDR CTC	RADAR CONTCT
		ACY ALTM 994	HDG ALT 035 SPD	ACY ALTM 994	ALTMTR 2994

No. 32-Window		3x7-W	3x7-W RECALL	7-W	NIMO
29 *CLR GRETNA VIA*	035	*CLR GRETNA VIA*	HDG ALT 035 SPD	*CLR GRETNA VIA*	*
30 ACY R-039	035	ACY R-039	HDG ALT 035 SPD	ACY R-039	*
31 HLD GRETNA LFT TURNS	035	HLD GRETNA ◄ TURNS	HDG ALT 035 SPD	HLD GRETNA ◄ TURNS	*
32 EFC IN 6MIN	035	EFC IN 6MIN	HDG ALT 035 SPD	EFC IN 6MIN	EST DELAY 6MIN
33 SPD 110 ALT 035	035 110	SPD 110 ALT 035	HDG ALT 035 SPD 110	SPD 110 ALT 035	MAINTN SPEED 110 MAINTN ALTUDE 035
DSND TO 120	120 110	↓ 120	HDG ALT 120 SPD 110	↓ 020	DESCND ↓ ↓ 120
34 DSND TO 020	020 110	↓ 020	HDG ALT 020 SPD 110	↓ 120	DESCND ↓ ↓ 020
35 CLR ACY VIA R-039	020 110	CLR ACY VIA R-039	HDG ALT 020 SPD 110	CLR ACY VIA R-039	*
36 VCTR VOR RWY 31	020 110	VCTR VOR RWY 31	HDG ALT 020 SPD 110	VCTR VOR RWY 31	*
37 LFT TO 095	095 020 110	◄ 095	HDG 095 ALT 020 SPD 110	◄ 095	TURN ◄ ◄ 095
38 TFC 11 3NM WB	095 020 110	TFC 11 3NM WB	HDG 095 ALT 020 SPD 110	TFC 11 3NM WB	TRAFIC 11 3ML

No.	32-Window		3x7-W	3x7-W RECALL	7-W	NIMO
39	CLR TFC RGT TO 165	165 020 110	CLR TFC → 165	HDG 165 ALT 020 SPD 110	CLR TFC → 165	TURN* → → 165
40	RGT TO 235	235 020 110	→ 235	HDG 235 ALT 020 SPD 110	→ 235	TURN → → 235
41	RGT TO 280	280 020 110	→ 280	HDG 280 ALT 020 SPD 110	→ 280	TURN → → 280
42	CFAP VOR RWY 31		CFAP VOR RWY 31	HDG ALT SPD	CFAP VOR RWY 31	*
43	ACY T 118.90		ACY T 118.90	HDG ALT SPD	ACY T 118.90	CONTCT TOWER 1189
44	CLR LND WND 290/6		CLR LND WND 290/6	HDG ALT SPD	CLR LND WND 290/6	CLEARD* TOLAND RY31

SCENARIO B

This is the Philadelphia International Airport. Ceiling measures two thousand, overcast, visibility six. Smoke, wind 280 degrees at eight. Temperature 61, altimeter two niner niner six. Landing runway 27-left, departures on 27-right. Inform the controller on initial contact that you have received information BRAVO.

No. 32-Window	3x7-W	3x7-W RECALL	7-W	NIMO
1 PHL G 121.90	PHL G 121.90	HDG ALT SPD	PHL G 121.90	CONTCT GROUND 1219
2 CLR TX1 RWY 27R	CLR TXI RWY 27R	HDG ALT SPD	CLR TXI RWY 27R	CLEARD TO TAXI
3 PHL T 118.50	PHL T 118.50	HDG ALT SPD	PHL T 118.50	CONTCT TOWER 1185
4 PSN HLD	PSN HLD	HDG ALT SPD	PSN HLD	*
5 CLR TKOF	CLR TKOF	HDG ALT SPD	CLR TKOF	CLEARD TAKOFF 27R
6 CLB TO 020 HDG 270 270 020	↑ 020 HDG 270	HDG 270 ALT 020 SPD	↑ 020 HDG 270	CLIMB ↑ ↑ 020
7				MAINTN HEADNG 270
8 PHL D 119.00 IDENT 270 020	PHL D 119.00 IDENT	HDG 270 ALT 020 SPD	PHL D 119.00 IDENT	CONTCT DEPRTR 1190
9				SQUAWK

No.	32-Window		3x7-W	3x7-W RECALL	7-W	NIMO
10	RDR CTC VCTR V157	270 020	RDR CTC VCTR V157	HDG 270 ALT 020 SPD	RDR CTC VCTR V157	RADAR* CONTCT
11	LFT TO 200	200 020	◄ 200	HDG 200 ALT 020 SPD	◄ 200	TURN ◄ ◄ 200
12	LFT TO 140 THRU V157	140 020	◄ 140 THRU V157	HDG 140 ALT 020 SPD	◄ 140 THRU V157	TURN ◄ ◄ 140 *
13	CLB TO 040	140 040	↑040	HDG 140 ALT 040 SPD	↑040	CLIMB ↑ ↑ 040
14	LFT TO 040	040 040	◄ 040	HDG 040 ALT 040 SPD	◄ 040	TURN ◄ ◄ 040
15	PSN 2NM SE V157	040 040	PSN 2NM SE V157	HDG 040 ALT 040 SPD	PSN 2NM SE V157	*

This is LaGuardia Airport. Ceiling 900 feet, visibility 3, haze. Wind one two zero at five. Temperature five nine. Altimeter two niner niner zero. Expect ILS approach runway one three. Palisade Park RADIO BEACON for ILS runway one three out of commission until further notice. All ILS approaches will be radar vectored. Inform controller on initial contact you have information FOXTROT.

No.	32-Window		3x7-W	3x7-W RECALL	7-W	NIMO
16	RESM NAV	040	RESM NAV	HDG ALT 040 SPD	RESM NAV	*
17	TFC 02 5NM NWB FST	040	TFC 02 5NM NWB FST	HDG ALT 040 SPD	TFC 02 5NM NWB FST	TRAFIC 02 5ML
18	CLR TFC	040	CLR TFC	HDG ALT 040 SPD	CLR TFC	MAINTN ALTUDE 040

No.	32-Window		3x7-W	3x7-W RECALL		7-W	NIMO
19	TFC 10 4NM SWB SLO	040	TFC 10 4NM SWB SLO	HDG ALT SPD	040	TFC 10 4NM SWB SLO	TRAFIC 10 4ML
20	CLR TFC	040	CLR TFC	HDG ALT SPD	040	CLR TFC	MAINTN ALTUDE 040
21	LGA A 127.30	040	LGA A 127.30	HDG ALT SPD	040	LGA A 127.30	CONTCT APPRCH 1273
22	SQK1092 IDENT	040	SQK1092 IDENT	HDG ALT SPD	040	SQK1092 IDENT	SQUAWK 1092 ←
23	SQK1042 IDENT	040	SQK1042 IDENT	HDG ALT SPD	040	SQK1042 IDENT	SQUAWK 1042
24	RDR CTC CLB TO 050	050	RDR CTC ↑ 050	HDG ALT SPD	050	RDR CTC ↑ 050	RADAR CONTCT
25							CLIMB ↑ ↑ 050
26	LGA A 118.00 IDENT	050	LGA A 118.00 IDENT	HDG ALT SPD	050	LGA A 118.00 IDENT	CONTCT APPRCH 1180
27							SQUAWK
28	RDR CTC	050	RDR CTC	HDG ALT SPD	050	RDR CTC	RADAR CONTCT
29	*HLD W RBV V157*	050	*HLD W RBV V157*	HDG ALT SPD	050	*HLD W RBV V157*	*
30	1MIN LEG LFT TURNS	050	1MIN LEG ← TURNS	HDG ALT SPD	050	1MIN LEG ← TURNS	*

No. 32-Window			3x7-W	3x7-W RECALL	7-W	NIMO
31 EFC 1N 15MIN		050	EFC IN 15MIN	HDG ALT 050 SPD	EFC IN 15MIN	EST DELAY 15MIN
32 TFC 12 5NM WB FST		050	TFC 12 5NM WB FST	HDG ALT 050 SPD	TFC 12 5NM WB FST	TRAFIC 12 5ML
CLR TFC		050	CLR TFC	HDG ALT 050 SPD	CLR TFC	MAINTN ALTUDE 050
33 *CLR LGA VIA RBV		050	*CLR LGA VIA RBV*	HDG ALT 050 SPD	*CLR LGA VIA RBV*	*
34 R-054 AND LGA R-220		050	R-054 AND LGA R220	HDG ALT 050 SPD	R-054 AND LGA R220	*
ALT 050		050	ALT 050	HDG ALT 050 SPD	ALT 050	*
35 DSND TO 040		040	↓ 040	HDG ALT 040 SPD	↓ 040	DESCND ↓ ↓ 040
36 LFT TO 350 - TFC	350	040	← 350 TFC	HDG 350 ALT 040 SPD	← 350 TFC	TURN ← ← 350
37 RGT TO 115	115	040	→ 115	HDG 115 ALT 040 SPD	→ 115	TURN → → 115
38 TFC 03 2NM SB SLO	115	040	TFC 03 2NM SB SLO	HDG 115 ALT 040 SPD	TFC 03 2NM SB SLO	TRAFIC 03 2ML
39 CLR TFC RESM NAV		040	CLR TFC RESM NAV	HDG ALT 040 SPD	CLR TFC RESM NAV	MAINTN* ALTUDE 040
40 DSND TO 030		030	↓ 030	HDG ALT 030 SPD	↓ 030	DESCND ↓ ↓ 030

No.	32-Window				3x7-W	3x7-W RECALL	7-W	NIMO
41	LGA A 127.30 IDENT		030		LGA A 127.30 IDENT	HDG ALT 030 SPD	LGA A 127.30 IDENT	CONTCT APPRCH 1273 SQUAWK
42	RDR CTC LGA ALTM 988		030		RDR CTC	HDG ALT 030 SPD	RDR CTC	RADAR CONTCT ALTMTR*
					LGA ALTM 998	HDG ALT 030 SPD	LGA ALTM 998	2998
43	VCTR ILS RWY 13		030		VCTR ILS RWY 13	HDG ALT 030 SPD	VCTR ILS RWY 13	*
44	LFT TO 350 SPD 130	350	030	130	◄350 SPD 130	HDG 350 ALT 030 SPD 130	◄350 SPD 130	TURN ◄ ◄ 350 MAINTN SPEED 130
45	DSND TO 018	350	018	130	↓018	HDG 350 ALT 018 SPD 130	↓ 018	DESCND ↓ ↓ 018
46	SPD 110	350	018	110	SPD 110	HDG 350 ALT 018 SPD 110	SPD 110	MAINTN SPEED 110
47	LFT TO 260	260	018	110	◄260	HDG 260 ALT 018 spd 110	◄260	TURN ◄ ◄ 260
48	LFT TO 180	180	018	110	◄180	HDG 180 ALT 018 SPD 110	◄180	TURN ◄ ◄ 180
49	LOM 2NM	180	018	110	LOM 2NM	HDG 180 ALT 018 SPD 110	LOM 2NM	*
50	CFAP ILS RWY 13				CFAP ILS RWY 13	HDG ALT SPD	CFAP ILS RWY 13	*

No. 32 Window	3x7-W	3x7-W RECALL	7-W	NIMO
51 LGA T 118.70	LGA T 118.70	HDG ALT SPD	LGA T 118.70	CONTCT TOWER 1187
52 CLR LND WND 125/8	CLR LND WND 125/8	HDG ALT SPD	CLR LND WND 125/8	CLEARD* TOLAND RY13
53 LGA G 121.70	LGA G 121.70	HDG ALT SPD	LGA G 121.70	CONTCT GROUND 1217

APPENDIX B

DATA LINK PILOT BRIEFING SHEET

You are about to participate in a series of simulated flights to evaluate four prototype in-cockpit data link displays. The displays differ as to the number of characters which may be displayed at one time, the size and color of the characters and the ways in which the characters are formed. The prime objective of this experiment is to determine how much verbal communications between the pilot and ATC can be eliminated by use of data link, and how rapidly you comprehend the messages.

You will be flying two different scenarios or flight plans, and each flight will start "at the ramp" at the beginning of a typical IFR flight. You will fly four sessions (flights), one for each display, and will be instructed in the use of each display prior to the simulated flights.

During the course of each flight, you will receive a variety of messages. You will be required to interpret the message and acknowledge by pushing the "WILCO" button on the display panel or the button on the pilot's or co-pilot's control column - each serves the same purpose.

Each message will be preceeded by an audio alert signal. As each message is displayed, it will flash momentarily and if the message is to be acknowledged, the WILCO button will also flash momentarily. If the message does not require acknowledgement, the WILCO button will not flash. Occasionally, we will present an impossible message such as "climb to 90,000 feet" or "turn right to 540 degrees. Your response, of course, will be to press the "UNABLE" button. Such messages are introduced to force you to interpret the message correctly and not to press the "WILCO" button routinely without thinking. The controller, in such cases, will then give you a proper command.

On messages that require you to make an adjustment such as a radio frequency setting, please press the "WILCO" button first,

then make your setting. The radio frequency settings which will be given to you represent the channel on which you would obtain voice contact if it were required. Even though a message might say "Contact Tower on 119.1," a voice response is not required. Please use voice only if you require clarification of a message, or an emergency situation arises.

To summarize, you should acknowledge all command-type messages such as - turn left, contact tower, change frequency, and all traffic advisories. No acknowledgement is required for informational type messages such as - position 2 miles, radar contact, etc.

A tape recorder will be in the cockpit to record any comments you might have throughout the flight. It is an "open" microphone, so talk as freely as you wish.

Occasionally a message will appear as *(message)*. The asterisks indicate the first portion of a message that is too long for a single line. The other portion of the message will appear immediately after "WILCO" is pushed.

Two displays have "scratchpad" capability; that means that headings, altitude and speed will always be available to you on the display. One display will show these items continuously (32 window) and the other will display the item "on call" (3 x 7).

At the conclusion of the series of flights you will be asked to fill in a questionnaire concerning your evaluation of the displays. Please remember that the displays which you will have flown represent only four out of many possibilities and that within certain limitations, the size, color, shape, and orientation of the characters in the messages could be varied independently to yield a better combination for the next generation prototypes.

The following abbreviations will be used in the messages:

Abbreviation	Message Meaning
ALT 030	Maintain Altitude 3000
ALTM992	Altimeter 2992
CLB(DSND); ↑,↓	Climb (Descend)
CFAP	Cleared for Approach
CLR	Clear(ed)
DSND (CLB) ↓,↑	Descend (Climb)
EFC	Expect Further Clearance
HDG 130	Maintain Heading 130°
HLD	Hold
LFT (RGT) ←,→	Left (Right)
LND	Land
LOM	Outer Marker
NM	Nautical Miles
A	Approach Control - ex. (DCA A 127.3)
G	Ground Control - ex. (LGA G 121.9)
T	Tower - ex. (PHL T 118.5)
D	Departure Control - ex. (ACY D 123.5)
NML	Normal
PSN	Position
R-039	Radial - 39°
RDR CTC	Radar Contact
RESMNAV	Resume Normal Navigation
RGT (LFT) →,←	Right (Left)
SPD	Maintain Speed
SQK	Squawk
TFC 01 4NM	Traffic 1 o'clock 4 miles
NEB FST (SLO)	Northeast Bound Fast (Slow)
TKOF	Takeoff
WND 115/12	Wind 115° @ 12 knots
VCTR	Radar Vectors

APPENDIX C
PILOT'S QUESTIONNAIRE AND RESULTS

Questionnaires were given to the 16 test pilots and the 16 airline pilots. The questionnaires were similar, but slightly different in format and in question wording. The questions and the responses are given below. Generally, the question appears in upper case, followed by a tabulation of the responses, followed by comments that were made by the pilots. Unless otherwise specified, each "reason given" and "comment" represents all the comments made by a single pilot with respect to a given question. The questions are not presented in the same order as on the questionnaires; they have been grouped under the following subject headings:

1. Ranking of the displays
2. General evaluation
3. Abbreviation and symbols
4. Display location
5. Control buttons
6. Long messages
7. Scratchpad
8. Character size
9. Character generation
10. CRT potential
11. Number of lines and characters
12. Lighting and color
13. Ideal Display
14. Synthetic speech
15. Additional comments

C.1 RANKING OF THE DISPLAYS

Both airline pilots and test pilots were asked to rank the displays in order of preference.

Most of the subjects rated the 32-W best, the 3x7-W second, the 7-W third and the NIMO last, as indicated in Table B-1.

TABLE B-1. RANKING OF DISPLAYS

TEST PILOTS					
Rank	1	2	3	4	3 or 4
Display					
32-W	11	2	1	2	0
3-7-W	2	9	5	2	0
7-W	3	3	6	3	1
NIMO	0	2	3	10	1
Total	16	16	15	15	2
AIRLINE PILOTS					
Rank	1	2	3	4	
Display					
32-W	10	6	0	0	
3x7-W	6	7	3	0	
7-W	0	3	11	2	
NIMO	0	0	2	14	
Total	16	16	16	16	

In addition, the test pilots were asked to give reasons for their ranking. The reasons are listed below. (Often pilots gave more than one reason for their choices and frequently gave no reason for a choice.)

32-W - reasons for giving a high ranking:

Nine pilots cited the scratchpad feature and 6 of these said they preferred it to the recall feature of the 3x7-W

32-W "-"high" (Continued)

Three pilots - easy to read

Three pilots - adequare information with least effort

Seven pilots - no scrolling necessary

One pilot - color

One pilot - character shape

One pilot - only one line

One pilot - 32-W concise

32-W - reasons for giving a low ranking:

One pilot - impossible to recall different segments of longer messages

One pilot - would prefer white color

3x7-W - reasons for giving a high ranking:

Five pilots cited recall feature (32-W scratchpad was preferred, however, in all five cases)

Three pilots - easy to read

One pilot - concise

One pilot - no scrolling

Two pilots - adequate information

One pilot - good size

One pilot - good display

3x7-W - reasons for giving a low ranking:

Two pilots - red color

One pilot - more than one line

7-W - reasons for giving a high ranking:

Three pilots - scrolling allows desired part of message to be displayed

One pilot - has both auto and manual scrolling

One pilot - good light and brightness

7-W-"high" (Continued)

One pilot - amber color

One pilot - ability to dim lights

Two pilots - character size

One pilot - easy to read

7-W - reasons for giving a low ranking:

Two pilots - increases work load

One pilot - no way to recall information once lost

One pilot - 7 character limit requires maximum use of abbreviations

One pilot - auto scrolling gives ambiguous information

One pilot - poor readability

One pilot - poor intensity control

One pilot - not enough information

One pilot - message broken up

NIMO - reasons for giving a high ranking:

Three pilots - compactness

Two pilots - green color

One pilot - readability good

One pilot - good potential

NIMO - reasons for giving a low ranking:

Four pilots - not enough information - one of these said display must be supplemented with voice contact

Two pilots - hard to read

One pilot - green light hard to read at night

One pilot - hard to read in bright light

One pilot - green color

One pilot - numbers hard to read

NIMO - "low" (Continued)

One pilot - inadequate display

One pilot - increases work load

One pilot - too small

C.2 GENERAL EVALUATION

Test pilots only

DO YOU FEEL THAT ADDITIONAL EXPERIENCE WORKING AS A TWO OR THREE MAN CREW MIGHT CHANGE YOUR OPINION OF DATA LINK?

Eight said that already they were favorable to Data Link. Comments:

a) More experience may alter opinion

b) Good for any crew size, especially one man crew; superior to voice

c) Too much conversation fatiguing

d) For either one or two man crew, Data Link reduces voice requirements necessary today

Four said no (more experience will not change opinion of Data Link).

Three said yes. Comments:

a) We have just started to evaluate Data Link

b) More experience necessary for one or two man crew; not pertinent to three man crew; active function on other side of Data Link essential

d) Yes, for the better

One said perhaps, but unlikely.

Test pilots and airline pilots

WHAT ARE YOU FEELINGS CONCERNING THE IMPACT ON PILOT WORK LOAD IF DATA LINK BECOMES AVAILABLE?

Test pilot responses

Thirteen said Data Link will reduce workload. Comments:

a) Three said work load would be reduced if Data Link properly designed

b) If display is 32-W and ATC does not mix voice with Data Link

c) Voice communication more of a load

d) Great help where message is displayed for other pilot to respond to

e) Only problem could be relaxing

One said that it depends on aircraft; GAT-11 instability makes co-pilot support mandatory.

One said Data Link too much work, large memory display essential.

One said good en route but has problems in terminal area.

Airline pilot responses

Nine said Data Link will reduce workload. Comments:

a) Especially in terminal area where much time is consumed with routine messages

b) Will take time to learn usage and abbreviations. Major reduction for controller with pilot receiving same messages as today

c) If properly handled-method of presentation key

d) In terminal area

e) Workload benefit and safety factor

f) Only messages relevent to aircraft will be received; makes cockpit quieter and more orderly

One said slight increase.

Two said not significant. Comment:

Only saving - elimination of lag in establishing voice contact

One said Data Link O.K. if kept strictly practical.

One said could be useful tool if properly organized.

One said difficult to evaluate, probably no reduction; may save time by not having to monitor radio frequencies.

One gave no answer.

Airline pilots only

DID THE 3x7-W DISPLAY HAVE ANY TENDENCY TO INCREASE COCKPIT WORKLOAD?

Twelve said no. Comment:

Reduced workload

Three said yes. Comments:

a) Requires attention shift from instruments to display

b) Pushing of "WILCO" button time consuming, distracts visual attention

c) Vertical separation between lines too great

One gave no answer.

Airline pilots only

DID THE NIMO DISPLAY HAVE ANY TENDENCY TO INCREASE COCKPIT WORKLOAD?

Eleven said yes. Comments:

a) Three said very hard to read

b) Two said numerals hard to read

c) Smallness of characters forces pilots to lean toward display and prevents him from seeing outside

d) Need verification of letters

e) All displays deny use of auditory sense

f) Radio transmission messages difficult

g) Unable to recall HDG-ALT-SPD

Five said no.

Airline pilots only

DID THE 7-W DISPLAY HAVE ANY TENDENCY TO INCREASE PILOT WORKLOAD?

Ten said yes. Comments:

a) At times it made us concerned whether we were complying properly with ATC instructions

b) Requirement for scrolling after "WILCO" pressed time consuming

c) Requires attention shift to display from instruments

d) Requires monitoring to get entire message

e) HDG-ALT-SPD not saved; takes longer to interpret

f) Extra buttons to push and requires more attention

g) Necessary to monitor longer which slows instrument cross check

Six said no. Comment:

Not having to pick out message from irrelevent chatter helpful

Test pilots only

DID YOU FEEL THAT ANY OF THE DISPLAYS PROVIDED TOO MUCH INFORMATION?

Airline pilots only

SAME QUESTION BUT ONLY WITH RESPECT TO 7-W and 3x7-W DISPLAYS

Results

Test Pilots	Airline Pilots
No - 15 pilots	No - 16 pilots
Yes - 0 pilots	
Don't know - 1 pilot	

Comments:

a) Two said too little information was given; one said that less useful information was given than by voice

b) Future Testing might show that displays do give too much information

c) No, provided all the information can be retained until understood before erased

C.3 ABBREVIATIONS

Test pilots only were asked:

WHERE ANY OF THE DISPLAYS CONFUSING BECAUSE OF THE NEED FOR ABBREVIATIONS? IF SO, DO YOU REMEMBER ANY PARTICULARLY CONFUSING MESSAGES?

Four said no. Comment:

Abbreviations were O.K. after one hour practice per system

Twelve said yes, giving the following examples:

a) Two pilots - on 7-W TFC←350 confused with traffic advisory at first

b) Two pilots cited NIMO

1) NIMO had poor characters

2) Digits 8 - 9 - 6 hard to read

3) CONTCT TOWER etc. and CONTCT APPROACH CNTL, etc.

c) One pilot said 32-W no problem. On other displays mistook A (Approach) for R (Radar) and Altitude for Heading

Other comments did not refer to specific displays:

a) Vector vs. Victor - crew pondered for interpretation often

b) Some unusual abbreviations; not enough time to record everything; CFAP-PSN

c) VCTR a problem

d) Reading altitude difficult

e) ↓120 might be read as 1200'

f) Radar vector should be emphasized

g) Using U for V took time to get used to

h) Unfamiliar with abbreviations

i) Two said that abbreviations should be standardized

Airline Pilots

WERE THE ABBREVIATIONS USED IN THE 32-W DISPLAY UNDERSTANDABLE?

All 16 pilots said yes, offering the following comments:

a) Prefer abbreviations to use of arrows; presentation of entire message made abbreviation understandable in context

b) Use of 3-letter NAVAID or station identifiers can cause confusion

c) THRV V-157 difficult

d) Wind velocity/direction not standard

e) Abbreviation of place names in unfamiliar area difficult

f) One pilot said the abbreviations should be standardized and three said they could be understood with practice

WHERE ANY OF THE MESSAGES ON THE NIMO DISPLAY CONFUSING DUE TO NEED FOR ABBREVIATIONS?

Thirteen pilots said no. Comments:

a) Liked use of arrows

b) Could be confusing with long messages and lack of recall

Three pilots said yes. Comments:

a) Clearance confusing when already in state specified by clearance - caused us to doubt accuracy of instruments

b) Difficulty may disappear with experience

c) C appeared as V

The question was not asked of the 3x7-W display.

One pilot said 3x7-W required fewer abbreviations than the others.

Test pilots only

WAS THE LACK OF A DECIMAL POINT IN CERTAIN DISPLAY TROUBLESOME?

Fourteen said no. Comments:

a) Once you were used to it

b) Familiarity with characters helps, however

Two said yes. Comment:

In NIMO - very poor display

C.4 LOCATION OF DISPLAY

Test pilots and airline pilots:

IF YOU WERE FACED WITH A TRADEOFF BETWEEN A SMALL DISPLAY IN A PRIME LOCATION AND A LARGER DISPLAY IN A LESS DESIRABLE LOCATION, WHICH WOULD YOU PREFER?

Test Pilots

Three said small/prime

Seven said larger/less desirable area. Comments:

a) Large display visible to all crew, adequate alerting

b) In a two pilot craft

Six did not give direct answers. Comments:

a) 32-W display in front of pilots

b) Depends - small prime better for solo-pilot

c) Unanswerable until specific system evaluated

d) NIMO O.K. for light sircraft

e) Heading, altitude, speed, in prime area; other messages in less desirable area

f) Medium size display in prime area

Airline pilots

Twelve said small/prime. Comments:

a) Depending on meaning of 'less desirable' area

b) Important to attract pilots attention

c) Especially for terminal approach flying

d) Must be large enough to read in turbulence

e) If each pilot had one

One said large/less desirable location.

One said both.

One said needs specific proposal before evaluation.

One gave no answer.

Test pilots and airline pilots were asked:

WOULD YOU LIKE SEPARATE DISPLAYS IN PRIME LOCATIONS FOR PILOT AND CO-PILOT?

Test Pilots

Four said no.

Six said not necessary if display was placed in area where both pilots could see.

Two said possibly. Comments:

a) Would provide reliability of redundancy

b) Might be necessary in large cockpit

Three said yes. Comment:

Would provide backup in case of failure

One did not answer.

Airline Pilots

Eight said no. Comments:

a) Three said unnecessary if display convenient to both pilots

b) Not enough cockpit space available for two displays

Eight said yes. Comments:

a) Desirable but not essential unless redundancy needed

b) Preferable in DCG

c) Two suggested displays be inserted in center of control yoke - normal reading position - would not use up prime panel space

d) Pilot actuated function should be interconnected so when non-flying pilot pushes "WILCO", it acknowledges and puts out lights on both pilot and co-pilot panels

C.5 CONTROL BUTTONS

C.5.1 Location of "WILCO" BUTTON

Test pilots and airline pilots were asked:

WHAT IS YOU PREFERENCE FOR LOCATION OF THE "WILCO" BUTTON; ON THE DISPLAY OR ON THE CONTROL COLUMN?

Test Pilots

Three said control column. Comment:

Display may be too far away

Five said display. Comments:

a) Display best in this test. Might be a problem in larger cockpit. Center of wheel good. Horn position caused several accidental responses

b) Made me aware of message - especially when scrolling was necessary

c) Lets both pilots read before one pushes "WILCO" button. With button on control column one pilot may push "WILCO" before the other can read the message.

Five said both locations. Comment:

Relocate control column button on wheel

Two said depends on location of displays, GAT-11 set up O.K.

a) Coordination between pilot and co-pilot would be a problem

b) One said control column location more convenient but display location forces pilot to read message.

Airline Pilots

Ten said both locations. Comments:

a) Used display button more at first - as procedures between pilot and co-pilot developed used control column button more

b) "WILCO" light display often malfunctioned

Five said on display only. Comment:

Too easy to push button on control column before sure of message

One said on control column only.

C.5.2 Relabelling of Pushbuttons

Airline Pilots Only:

WOULD YOU PREFER RELABELLING ANY OF THE PUSHBUTTONS AND/OR ESTABLISHING A DIFFERENT PILOT RESPONSE FUNCTION ON THE 32-W DISPLAY?

Nine said no. Comment:

Further study may reveal need for change

Seven said yes. Comments:

a) Unable button unnecessary since unable message must be resolved with ATC by voice anyway. Does "WILCO" for traffic advisory mean "I'll watch for traffic" or "I have traffic in sight"

b) Remove clear button; allow scrolling of long message by pushing "WILCO" button; hard copy printout

c) Add button to call up HDG-ALT-SPD on demand; have message and avoid flash continuously until "WILCO" or unable pressed

d) Make clear into recall and use to get HDG-ALT-SPD on demand

e) Relabel clear to recall so first message can be returned

f) Need for "Start action" as well as "acknowledge" button and "unwilling, give me another option," as well as "unable" button

g) Two said that both pilots should have to push a "WILCO" button to acknowledge message. For example, first pilot would push his own button thus acknowledging message to ATC and changing flashing "WILCO" light to steady. The second pilot would press his button, extinguishing "WILCO" light. Then both pilots would know that the other had received the message without verbal communication

C.5.3 Location of Other Controls

Test Pilots Only:

WHAT ABOUT LOCATION OF OTHER CONTROLS?

a) Eleven said should be on display.

b) Two said should be accessable to both pilots.

c) Three did not answer.

C.5.4 Clear Button

Test Pilots Only:

DID YOU EVEN CLEAR THE DISPLAY? IF SO, REGULARLY, OR INFREQUENTLY? WHICH DISPLAYS:

Four said yes, frequently. Comments:

a) For practice and to get familiar

b) Traffic - ALT ↓ ALT CHGS, HDG CHGS and when on speeds

c) Half the time on all displays

Seven said yes, infrequently. Comments:

a) Two said did not seem very necessary

b) All displays

c) Only twice

d) During night operations

e) NIMO - too bright at night

One said yes - especially the NIMO.

Four said no. Comments:

a) This function could be eliminated

b) Liked to retain last message, especially if heading, altitude, or speed

Airline Pilots Only:

DID YOU USE THE CLEAR BUTTON AT ANY TIME WITH THE 32-W DISPLAY?

Three said occasionally.

Three said no.

Airline Pilots Only:

DID YOU FEEL THAT THE CLEAR BUTTON SERVES ANY USEFUL PURPOSE WITH 32-W DISPLAY?

Ten said yes. Comments:

a) Good to have clear display; recall feature also good

b) Under right conditions would reduce glare

c) Continuous display tolerable, but some advisory messages distracting when not cleared

d) Three said that it helps to remove information that is no longer needed

e) Prefers to have all advisory and warning lights out under normal conditions

Five said no. Comments:

Change of message and flashing "WILCO" good attention getters. Helpful to retain residual message

Airline Pilots Only:

DID YOU USE THE CLEAR BUTTON AT ANY TIME WITH THE NIMO DISPLAY?

a) Two said frequently.

b) Five said occasionally.

c) Seven said rarely.

d) Two said not at all.

Airline Pilots Only:

DO YOU FEEL THAT THE CLEAR BUTTON SERVES ANY USEFUL PURPOSE ON THE NIMO DISPLAY?

Twelve said yes. Comments:

a) Three said useful to erase stale information

b) At night it reduces light in cockpit

c) How about clearing display with recall

d) Does not like lights continually on - gives feeling of "uncompleteness"

Four said no. Comments:

a) NIMO not distracting because of small size

b) Old message not objectionable

Airline Pilots Only:

HOW DID YOU USE CLEAR BUTTON WITH 7-W DISPLAY?

a) One said considerably.

b) Nine said occasionally.

c) Five said rarely.

d) One said not at all.

Airline Pilots Only:

DO YOU FEEL THAT THE CLEAR BUTTON SERVES ANY USEFUL PURPOSE ON THE 7-W DISPLAY?

Twelve said yes. Comments:

a) Partial message remaining on display distracting

b) Display gave too much glare at night even if dimmed

c) Continual change of message after message comprehended distracting

d) No need to stare at used data

e) Useful under some conditions

f) Useful to turn out unnecessary lights so a light means something

Four said no.

C.5.5 Alerting

Test Pilots and Airline Pilots:

DID YOU FIND THE AUDIO ALERT SIGNAL PRECEDING EACH MESSAGE TO BE HELPFUL?

Test Pilot Responses

Fifteen said yes. Comment:

a) Especially in the afternoon part of test

b) One said alert audible only occasionally in GAT-11; very noticible and helpful in GAT-1.

Airline Pilot Responses

Fifteen said yes. Comments:

a) Five said a definite necessity

b) Necessary to alert pilots in airborne environment

c) Volume good - frequency too close to that used for altitude alert in carrier aircraft

d) Especially if display not cleared before new message

e) Sounds similar to altitude alert

f) Must be effective but not annoying

g) Good sound and duration

One said helpful in daylight, annoying at night.

Test Pilots Only:

DID THE FLASHING OF THE DISPLAY PROVIDE SUFFICIENT ALERTING?

Thirteen said yes. Comments:

a) Under night conditions, audio desirable for day

b) Much too bright, co-pilot dozed for a while and was not alerted by either audio or flashing "WILCO" button

c) But audio was real key

d) But depended on co-pilot reading out loud

e) Four said along with audio alert

f) Audio alert should follow up "WILCO" if message not "Wilco'd" for

Three said no. Comments:

a) "WILCO" too bright - needs dimming control

b) Not if both pilots were looking away

c) Depends on location and lighting of display; audio is necessary

Airline Pilots Only:

DID THE MOMENTARY FLASHING OF THE MESSAGE PROVIDE ANY MEANINGFUL ALERT FUNCTION?

Ten said yes. Comments:

a) Visual cue valuable during heavy workload

b) May obliterate need for audio alert-depending on location

c) Should be continuous until acknowledgement

d) Two said of limited value

Six said no. Comments:

a) Audio alert and lighted "WILCO" enough

b) Two said not useful with audio alert

c) Made message hard to read

Test Pilots and Airline Pilots:

WOULD YOU PREFER A LONGER OR SHORTER FLASHING OF THE MESSAGE?

Test Pilot Responses

Fourteen said O.K. as is. Comments:

a) Color and dimming feature should be incorporated

b) Flashing should not start until message complete

One said longer.

One said might prefer shorter flash.

Airline Pilot Responses

Ten said as is.

Three said longer. Comment:

Should be continuous

Two said shorter.

One said no flash; can not read message while flashing.

C.5.6 Lighting of Pushbuttons

Airline Pilots Only:

RATE THE BRIGHTNESS OF PUSHBUTTONS ON 32-W DISPLAY.

Pilots who had 32-W during simulated day

Six said satisfactory.

Two said too bright. Comments:

a) Especially at night. Dim continuous light at night would help identify pushbuttons

b) Needs dimming feature for night

Pilots who had 32-W during simulated night

Five said satisfactory.

Three said too bright. Comment:

Two said dimming feature needed at night

Airline Pilots Only:

RATE THE BRIGHTNESS OF PUSHBUTTONS WHEN LIT ON THE 3x7 DISPLAY.

Pilots who had 3x7-W during simulated day

Seven said satisfactory.

One said too bright.

Pilots who had 3x7-W during simulated night

Six said satisfactory.

Two said too bright.

Airline Pilots Only:

RATE THE BRIGHTNESS OF PUSHBUTTONS WHEN LIT ON THE NIMO DISPLAY?

Pilots who had NIMO during simulated day

Six said satisfactory.

One said too bright.

One did not answer.

Pilots who had NIMO during simulated night

Six said satisfactory.
Two said too bright.

C.5.7 Message Without WILCO

Test Pilots Only:

DO YOU FEEL THAT SOME MESSAGES SHOULD NOT REQUIRE A WILCO? DID YOU AGREE WITH THE CHOICES MADE FOR THIS TYPE OF MESSAGE IN THE EXPERIMENTS?

Twelve said yes, not all messages should require WILCO.
Comments:

a) Seven agreed with choice of messages in experiment

b) Two said they did not agree entirely with the choices

c) Messages not WILCOed should be the same as in voice communication

Three said no.

One did not answer.

C.6 LONG MESSAGES

Test Pilots Only:

WERE THERE CASES IN WHICH TOO MUCH NEW INFORMATION WAS PRESENTED AT ONE TIME?

Twelve said no. Comments:

a) But retainer display for critical parameters necessary

b) Not anymore than given verbally

Four said yes. Comments:

a) On autoscroll in 7-W some abbreviations excessive or unclear like NED; NIMO ran some words together like TOLAND

b) Memory displays become inadequate and operator has to maintain scratchpad information

c) Two said two-part message excessive if you could not refer back to first part

Test Pilots Only:

WOULD IT BE BETTER TO PRESENT ONLY ONE PIECE OF INFORMATION AT A TIME, EVEN THOUGH THIS INCREASED THE REQUIREMENTS FOR "WILCO" BUTTON PUSHING?

Thirteen said no. Comments:

a) Three said not a factor in 32-W which is best display

b) Present message all at once if possible, but allow pilot to digest on own schedule

c) If adequately identified and spaced

d) Two said would break up message too much

e) Not necessary if message can be retained longer

f) Not necessary if pilot can rescroll first part of message

Two said yes. Comment:

Necessary unless memory display can be increased or automatic tape can be produced

One said either way O.K.

C.6.1 Long Messages on 32-W

Airline Pilots Only:

WHEN PRESENTING A LONG MESSAGE, THE 32-W DISPLAY LOSES THE FIRST PORTION OF THE MESSAGE WHEN "WILCO" IS PUSHED. IS THIS A TOLERABLE FEATURE?

Ten said yes. Comments:

a) Better than 7-W scrolling - these messages should be kept to a minimum

b) Three said not desirable but tolerable

c) O.K. if a cockpit printer is used

Six said no. Comments:

a) Three said must be able to recall entire message

b) Prefer recall capability of entire message or cockpit printout

c) Double character capability would solve this problem

C.6.2 Long Messages on NIMO

Airline Pilots Only:

WHEN PRESENTING A LONG MESSAGE, THE NIMO DISPLAY LOSES THE FIRST PART OF THE MESSAGE WHEN "WILCO" IS PUSHED. IS THIS A TOLERABLE FEATURE?

Ten said no. Comments:

a) Reluctant to push "WILCO" until first part of message understood, but light keeps flashing urging action

b) Should have complete message retrieval

c) Note taking could be required on complex clearances

d) Will lead to error

Six said yes. Comments:

a) Not desirable but tolerable

b) Forces pilot to record data

c) O.K. if a cockpit printer is used

C.6.3 SCROLLING ON 7-W

Test Pilots Only:

DID YOU LIKE THE SCROLLING FEATURE ON THE 7-WINDOW DISPLAY, OR WOULD YOU PREFER MANUAL SCROLLING?

Eleven preferred auto. Comments:

a) Would like both - prefers auto if only one available

b) Auto good when manual available

c) Likes auto combined with manual playback

d) Auto allows message to be received while occupied elsewhere

e) Manual time consuming and distracting

f) Like ability to select desired speed

Two preferred manual.

Auto requires memorizing and preoccupies pilot; incompatible with instrument flying

One rejected auto, or any type of scrolling for new message acquisition.

One said auto O.K. but unimportant.

Airline Pilots Only:

DID YOU THINK THE AUTOMATIC SCROLLING FEATURE OF THIS DISPLAY IS A DESIRABLE FEATURE?

Eight said yes. Comments:

a) But manual is adequate

b) Two said auto feature is absolutely necessary for scrolling

c) Scrolling should be endless for long messages instead of being broken after 3 lines

Seven said no. Comments:

a) Two said auto scrolling stops when "WILCO" pushed even if message is not complete. "WILCO" should not flash until message is complete, or part of message may be lost

b) Prefers manual

c) Took too much time to read

Airline Pilots Only:

WOULD YOU PREFER MANUAL SCROLLING FOR ONE MESSAGE AT A TIME?

Six said yes.

Ten said no. Comments:

a) Continuing change of message after message comprehended was distracting

b) Two were lukewarm on this question

c) Auto O.K. as long as manual available

d) Auto scroll leaves hands free

Airline Pilots Only:

IS THE SCROLL RATE ADJUST CAPABILITY A DESIRABLE FEATURE?

Eleven said no. Comments:

a) Two said did not like auto scroll to begin with

b) A fixed rate slightly faster than midpoint O.K.

c) Medium rate adequate

Five said yes. Comment:

A must

C.7 SCRATCH PAD

Test Pilots Only:

DID YOU LIKE THE AUTOMATIC SCRATCH PAD CAPABILITY OF THE 32-W DISPLAY OR WOULD YOU PREFER TO HAVE ALL WINDOWS AVAILABLE FOR MESSAGES?

Twelve liked scratchpad. Comment:

Needs scrolling or additional windows for memory

Four preferred all windows for messages. Comments:

a) Two wanted manual recall of scratchpad

b) The more you can see of a message the better

Test Pilots Only:

DID YOU LIKE THE SCRATCHPAD RECALL CAPABILITY OF THE 3x7 DISPLAY?

Nine said yes.

Four said no. Comment:

Too distracting, adds to workload

Four said yes and no. Comments:

a) Two wanted manual recall of scratchpad

b) The more you can see of a message the better

Test Pilots Only:

DID YOU LIKE THE SCRATCHPAD RECALL CAPABILITY OF THE 3x7 DISPLAY?

Nine said yes.

Four said no. Comment:

Too distracting, adds to workload

Four said yes and no. Comments:

a) Retention good but need to recall bad; pilot should be allowed to retain as long as he likes

b) O.K. but prefers 32-W

c) No, but adequate; I would like this feature on a 32-W

Test Pilots Only:

HOW OFTEN DID YOU USE RECALL FEATURE OF 3x7-W?

Four used it frequently

Two used it infrequently

One did not use it

Nine did not answer question

Test Pilots Only:

DID YOU PREFER 3x7-W RECALL FEATURE TO 32-W SCRATCHPAD?

Four said yes

Three said no

Six said they preferred 32-W

One would like to see 32-W and 3x7-W features combined

Two did not answer

Airline Pilots Only:

THE 32-W DISPLAYS PRESENTS HDG-ALT-SPD CONTINUOUSLY (SCRATCHPAD). IS THIS A DESIRABLE FEATURE?

Fifteen said yes. Comments:

a) Pilot should be able to clear display if he wants

b) Especially in G/A aircraft that has no bugs; less so in aircraft that has bugs

c) Eliminates hand recording of data or pushing recall

d) Good if always available but not on display

e) Eliminates note taking

f) In cockpit with bug might be good to be able to erase them

g) Good in absence of heading bug and altitude alert

h) At night HDG-ALT-SPD letters not visible; need background lighting

One said no; recall of HDG-ALT-SPD good but broken messages bad, sometimes good to have clear display.

Airline Pilots Only:

GIVEN THE OPTION WOULD YOU RATHER UTILIZE THE ENTIRE WINDOW FOR MESSAGE DISPLAY AND HAVE HDG-ALT-SPD AVAILABLE ON CALL?

Nine said yes. Comments:

a) Seeing entire message important (using all 32-Windows) but recall also important

b) Would allow for longer messages

c) If possible only long message should erase scratchpad

d) Desirable but not mandatory

e) If this would reduce broken messages where first part can't be recalled

Six said no. Comments:

a) Double message capacity and keep this feature

b) Especially in terminal area; with 3x7-W had to use recall continuously

One had no preference.

Airline Pilots Only:

THIS DISPLAY PRESENTS HDG-ALT-SPD (SCRATCHPAD) WHEN DESIRED BY PUSHING RECALL BUTTON. IS THIS INFORMATION DESIRABLE?

Sixteen said yes. Comments:

a) Useful to blank out entire display with recall

b) But redundant if bugs must be set

c) Both 32-W and 3x7-W good

d) Prefers 32-W

e) Two said they prefer 3x7-W

f) Scratchpad should not be erased by new message, but by pilot

g) Scratchpad most impressive part of display

TEST PILOTS AND AIRLINE PILOTS

WHAT IS YOUR OPINION OF HAVING DATA LINK SET THE HEADING BUGS AND ALTITUDE ALERT AUTOMATICALLY AFTER PUSHING WILCO?

Test Pilot Responses

Nine said yes. Comments:

a) Two said Data Link should also set speed alert when applicable

b) Would reduce work load but not sure cost and maintenance could be justified

One said no, pilot must control bugs.

Two said good idea but needs testing.

Four gave no answer.

Airline Pilot Replies

Nine said no. (Many of the pilots were rather vehement on this point.) Comments:

a) Automatic system cannot take general situation of aircraft into account

b) Setting bugs pilot responsibility. Most jets have heading bug mode on auto pilot. If engaged Data Link could turn aircraft. Not an acceptable arrangement

c) May be unable to comply or wish to delay in many situations to new HDG or ALT

d) Mechanical setting can go wrong and must be set anyway

e) Pilot setting of bugs provides double check on pilot's comprehension. Opposes any automatic manipulation of FLT-NAV components in cockpit

Four said yes. Comments:

a) Two said would decrease workload

b) Desirable but not mandatory

One said sounds useful but needs evaluation; must determine when ground control and when pilot will set bugs.

One said auto-setting of bugs should be optional.

One proposed that pilot should acknowledge new HDG or ALT with push and insert automatically with a second push.

C.8 CHARACTER SIZE

Test Pilots Only:

NEGLECTING OTHER CONSIDERATIONS, DID YOU HAVE A PREFERENCE FOR THE CHARACTER SIZE USED ON SOME PARTICULAR DISPLAY?

Four said 3x7-W.

Three said 32-W.

One said 7-W.

One said 32-W or 3x7-W.

One said 32-W or 7-W.

One said all O.K. except NIMO.

Two said the bigger the better.

One said depends on location.

Two had no preference

Airline Pilots Only:

HOW WOULD YOU RATE THE CHARACTER SIZE OF THE FOLLOWING DISPLAYS?

32-W

Fifteen said satisfactory.

One said too small; O.K. if located directly in front of each pilot.

3x7-W

Nine said satisfactory. Comments:

a) This display too large for most cockpits

b) Could be smaller

c) Made a little larger

Six said too large.

One said too small; either size and shape made difficult to read.

NIMO

Fifteen said too small. Comments:

a) Either size or shape made difficult to read

b) NIMO unclear, characters not well formed

One said satisfactory.

7-W

Nine said satisfactory.

Seven said too large.

C.9 CHARACTER GENERATION

Test Pilots Only:

DID YOU HAVE ANY PREFERENCE FOR THE METHOD IN WHICH CHARACTERS WERE GENERATED: DOT MATRIX VERSUS STENCIL (THE NIMO CRT) VERSUS SEGMENTS (THE 7-WINDOW)?

Four said dot matrix.

Four said segments. Comments:

'V' in 32-W marginal, otherwise 32-W is also O.K.

One said stencil, then dot matrix; least segments.

Three said dot matrix or segments O.K.; NIMO poor.

One had no preference.

Three did not answer.

C.10 CRT POTENTIAL

Airline Pilots Only:

WOULD YOU PREFER AN IMPROVED CRT DISPLAY OR THE USE OF LINES FOR MESSAGE DISPLAY?

Thirteen said lines. Comments:

a) Larger CRT displaying lines O.K.

b) Hard to answer because NIMO is so small and hard to read

c) Improved CRT may change mind

One said further development and testing needed.

One said lines O.K.; CRT needs further development.

One said no preference; a good CRT such as used on RNAV displays.

Test Pilots Only:

A NEW NIMO MASK IS ON ORDER WHICH WILL HAVE BETTER CHARACTER ALIGNMENT AND CAN DISPLAY A LARGER PERCENTAGE OF THE REQUIRED MESSAGES. MIGHT THIS CHANGE YOUR OPINION OF NIMO?

Two said already like NIMO. Comment:

Assume alignment will be fixed and message problem solved

Two said no (do not like NIMO). Comment:

NIMO too small for large cockpit

Six said yes. Comment:

But NIMO is limited by its capability

Two said possibly. Comment:

Needs larger tube

Two said to a small degree.

One said don't know; NIMO looks sloppy.

One did not answer.

Airline Pilots Only:

ADDITIONAL COMMENTS ON NIMO

a) Sound level of alerting O.K.

b) Lack of decimal points O.K.

c) Too much time to decipher traffic advisory partly because of size of digits

d) Bad alignment last line; poor contrast; broken segments; fuzzy; small size recessed

e) Uses too much prime space

f) Distortion; bottom line

g) 8 looked like E3 - confused with 11

h) Bottom line occasionally totally unreadable would not have accepted aircraft for flight

C.11 BEST NUMBER OF LINES AND CHARACTERS

Airline Pilots Only:

IF YOU WERE DESIGNING A DISPLAY FOR DATA LINK USING A LINES DISPLAY, HOW MANY LINES OF HOW MANY CHARACTERS WOULD YOU PREFER?

The responses are tabulated below.

Number of Characters Per Line	Number of Lines					
	1	1 or 2	2	2 or 3	3	3 or more
7					3	1
10					1	
25-30	1					
32	1		1	1*		
32 or more	1	1				
As many as possible in available space	2					

*2 or 3 lines - depending on length of longest message

Three did not answer.

C.12 LIGHTING AND COLOR

Test Pilots Only:

WERE ANY OF THE DISPLAYS DIFFICULT TO READ UNDER SIMULATED DAYLIGHT?

Responses of Test Pilots who had NIMO under simulated daylight:

Four said no.

Four said yes, with NIMO. Comments:

a) Because of very poor display

b) Required effort under bright light

c) Difficult under all conditions

Responses of Test Pilots who had NIMO under simulated night conditions:

Seven said no (no problem).

One did not answer.

Test Pilots Only:

WAS SUFFICIENT DIMMING CAPABILITY PROVIDED FOR SIMULATED NIGHT CONDITIONS ON THE 3x7-W AND 7-W DISPLAYS?

Responses of Test Pilots who had 3x7 under simulated night conditions:

Seven said yes. Comment:

Control button light too bright

One did not answer.

Responses - 7-W under simulated night conditions:

Five said yes. Comments:

a) Two said control light too bright

b) More dimming was provided than necessary

One said did not use dimming feature.

Two did not answer.

Airline Pilots Only:

WAS THE BRIGHTNESS CONTROL FEATURE OF THE 7-W DISPLAY OF ANY BENEFIT DURING SIMULATED DAY AND/OR NIGHT CONDITIONS?

Responses of Airline Pilots who had 7-W under simulated day conditions:

Six said yes.

Two said no.

Pilots under simulated night conditions:

Four said yes. Comment:
Push buttons also need brightness control

Two said no.

Two did not answer.

Airline Pilots Only:

WAS THE RED-ORANGE COLOR OF THE CHARACTERS OF THE 32-W DISPLAY EASILY READABLE?

Sixteen said yes. Comments:

a) Two said would prefer white

b) Two said 32-W best display

c) 32-W most satisfactory color and format

d) O.K. under night conditions

e) Could be hard to read under direct sunlight

f) Better than red and green; not as good as white

Airline Pilots Only:

WAS THE RED COLOR OF THE CHARACTERS OF THE 3x7-W DISPLAY EASILY READABLE DURING SIMULATED DAY/NIGHT CONDITIONS?

Responses of Airline Pilots who had 3x7-W display under simulated day conditions:

Six said yes. Comments:

a) Prefer white

b) Dislike red

c) Did not test in bright sunlight

Two said no. Comments:

a) Prefer white

b) Dislike red

Airline Pilots Only:

WAS THE GREEN COLOR OF THE CHARACTERS OF THE NIMO DISPLAY EASILY READABLY UNDER SIMULATED DAY/NIGHT CONDITIONS?

Responses of Airline Pilots who had NIMO under simulated day conditions:

Six said no.

One said yes. Comment:

But is not standard color; not tested under direct sunlight

One did not answer.

Responses - simulated night:

Five said yes.

Three said no.

Airline Pilots Only:

WAS THE COLOR (WHITE) OF THE 7-W DISPLAY EASILY READABLE?

Fourteen said yes. Comments:

a) Better than red, easier on eyes

b) The best color

Two said no.

Test Pilots and Airline Pilots:

Seven said white. Comments:

a) Or some pale cool color

b) Then green; red is worst; intensity control is essential

One said same color as in 3x7-W or 32-W.

One said green as in NIMO.

One said amber as in 32-W.

One said amber or green.

One said any color but red.

Four had no preference.

Airline Pilot Responses:

Five said white. Comments:

a) To standardize with other lights

b) Needs brightness control

One said white-day; red-night.

Two said red.

One said amber/orange.

Three said red/orange. Comment:

White O.K.; green may not be O.K. under all conditions

One said green, not red.

One said light red, blue, or green.

One said any color that will contrast with white cockpit.

One said no preference.

C.13 IDEAL DISPLAY

Airline Pilots Only:

IF YOU WERE DESIGNING A DISPLAY FOR DATA LINK, HOW MANY LINES OF HOW MANY CHARACTERS WOULD YOU LIKE, WHAT TYPE CHARACTER STYLE, COLOR AND CHARACTER SIZE?

Six described displays similar to 32-W. Comments:

a) Two said 32-W ideal

b) 32-W with segment characters

c) 32-W, maybe two lines or vertical presentation, increase memory display

d) Character style and size of 32-W, as many characters as possible on one line, white color

e) One line; 32-W style characters; character size between 32-W and 7-W

Two described displays similar to 3x7-W. Comments:

a) 3x7-W in white

b) 3x7-W with continual readout of HDG-ALT-SPD; 1/2-inch characters; amber color

One described display similar to 7-W with character size of 3x7-W, amber or green color; scrolling and dimming control of 7-W.

Two specified CRT displays. Comments:

a) 2-3 lines; 15-20 characters per line; stencil style; white color with intensity control, NIMO size

b) Slightly enlarged NIMO; 3 lines; CRT can potentially display characters not presently used

Other (4 responses). Comments:

a) Twenty-four active message units with scrolling if necessary

b) Two lines; 7-W style, white, size of 3x7-W display

c) Two lines; 7-32 characters; 32-W characters and color; keep recall features of 7-W; 7-W size characters

d) Two lines only

One did not answer.

C.14 SYNTHETIC SPEECH

Test Pilots Only:

WAS THE SYNTHETIC SPEECH ON THE TEST TAPE SUFFICIENTLY INTELLIGIBLE?

Eleven said no. Comments:

a) Interpretation required intense concentration

b) Pilots often use high frequency sensitivity; try increasing treble instead of base

One said borderline.

Two said yes. Comment:

But not good

One said would require practice.

One did not observe.

Test Pilots Only:

DO YOU THINK YOUR UNDERSTANDING OF SYNTHETIC SPEECH WOULD IMPROVE WITH PRACTICE?

Four said yes. Comment:

Opinion based on similar project with VOLSCAN

One said probably.

Two said quality must be improved.

Five said no.

One said tape with increased base unintelligible to everyone I observed.

One said heard better synthetic speech elsewhere.

One did not observe.

Test Pilots Only:

DO YOU THINK THAT SYNTHETIC SPEECH MIGHT BE PREFERABLE TO THE USE OF VISUAL DISPLAYS?

Fourteen said no. Comments:

a) Should be evaluated, might be helpful

b) Certain messages must be retained longer than verbally, preferable to keep a written record

c) Voice will conflict with other conversation

Two said possibly. Comments:

a) Synthetic speech not yet sufficiently developed

b) Might be helpful in conjunction with visual displays

Airline Pilots Only:

DO YOU THINK THAT IMPROVED SYNTHETIC SPEECH MIGHT BE PREFERABLE TO THE USE OF VISUAL CHARACTER DISPLAYS?

Eight said no. Comments:

a) Would have no scratchpad or recall; also length of time for receiving voice greater

b) Should be evaluated; would probably prefer visual displays

c) More confusion with synthetic speech in interpretation and retention

Five said yes. Comments:

a) Never heard synthetic speech, but visual display distracting

b) Visual display distracting

c) Pilots vision already overloaded

One said perhaps, would like to try it.

Two did not observe.

C.15 ADDITIONAL COMMENTS

Test Pilot Comments:

a) Seven were in favor of Data Link

b) Two said Data Link would reduce chance of error

c) Main problem for Data Link is in terminal area; oral communication here useful (i.e., command and advisory information between controllers and other pilots)

d) Don't know how lack of oral communication will effect situation in terminal area

e) No way of positively determining "clearance limit"

f) Change NM to MI

g) Display buttons should all have nominal lighting

h) Three suggested a cockpit printout

i) Tie Data Link to auto pilot

j) Turn should come after angle (0.90°→instead of →90°)

k) Symbols better than words

l) Should be able to recall all of two-part message rather than only last part

m) Pilot should not be able to cut off message prematurely by pushing "WILCO" button

n) All lighting should have dimming control

o) "WILCO" flash should be delayed until message is complete

p) Control wheel-mounted "WILCO's"

q) Pilot needs means of recalling (at his option) previous instructions (including superseded instructions)

r) Number should have their dimensions specified (°, ft, etc.) on display

s) Pilot needs means of indicating whether he has made visual contact with traffic called out by radar advisory such as special form of Wilco function

Airline Pilot Comments:

a) Two said Data Link has potential but more research needed

b) Data Link leads to loss of awareness of position in air traffic situation

c) Response lights need dimming control for night operation - need to shield pilots eye made us push button at night before doing instruction

d) Background lighting needed for response buttons

e) On 3x7 when told to descend and slow down, no indication of which to do first

f) Data Link must make pilots aware of what other aircraft are doing (did one miss its approach, etc.)

g) Ideal display-windows 32-W or more with scroll, scratchpad on request, character size of 3x7-W, complete message retrievability, better alerting system

h) Data Link must enable pilot to:

1) Get clarifications of instructions or traffic advisories

2) Get an immediate avoidance vector for traffic

3) Get approval for airways short cuts

4) Indicate inability to climb or descend to resolve traffic conflicts

i) A single light intensity with day/night filter might be workable

j) Clearances should contain trip identification for confirmation.

APPENDIX D
RESPONSES OF TWO AOPA PILOTS TO QUESTIONNAIRE

RESPONSES OF THE TWO PILOTS ARE LABELED "A" AND "B"

1. Evaluation of 32-Window Display.

   1.1 Character Size?

   A and B - satisfactory.

   1.2 Red-Orange color easily readable?

   A and B - Yes.

   1.3 When presenting a long message, this display loses the first portion of message when WILCO is pushed. Is this a tolerable feature?

   A - Yes, pilot education should solve any problems with this.

   B - Yes, but I would prefer the ability to call back the first part of the message in some way.

   1.4 Did you use the clear button at any time?

   A - No.

   B - Yes.

   1.5 Clear button - serves useful purpose?

   A - No.

   B - Yes - Particularly that recall portion.

   1.6 Abbreviations easily readable?

   A - Yes; pilot education will be required.

   B - No. I get the impression that with all of these abbreviations, the FAA is treating all pilots like they were airline captains. I realize there are limitations on how much you can abbreviate but I suspect that FAA spends enough money on human factors engineering to be able to cope with that problem.

1.7 Is continuous scratchpad (HLT-ALT-SPD) desirable?

A and B - Yes.

1.8 Would you rather utilize entire window for message display and have HDG-ALT-SPD available on recall?

A - No; continuous presentation is desirable but not essential.

B - I guess so.

1.9 Rate the brightness of push buttons when lit.

A - Satisfactory.

B - Depending on the circumstances they are too bright. I'd suggest you use a system like is currently available on just about all King radios that has an electric eye that automatically controls the brightness of the buttons and other lighted signals based on the direct brightness of the cockpit itself.

1.10 Would you prefer relabeling of push buttons and/or establishing a different pilot response function on the display?

A and B - No.

2. Evaluation of 3x7-Window Display.

2.1 Character Size?

A - Too large.

B - Probably too large. In my opinion you could get a lot more information in smaller characters. Remember: pilots have to be able to readily read all the small numbers on radio facilities charts. The characters in this display are both lighted and at least 10 times as large as that.

2.2 Red color easily readable under simulated night conditions?

A and B - Yes.

2.3 Rate the brightness of push buttons when lit.

A - Satisfactory.

B - Probably too bright.

2.4 Did you feel that this display provided too much information?

A and B - No.

2.5 This display presents HDG-ALT-SPD (scratchpad) when desired by pushing RECALL button. Is this a desirable feature?

A - Yes.

B - Yes. It could be either in this fashion or in a modified smaller scale to get more information into the display.

2.6 Did this display have a tendency to increase cockpit workload?

A - No.

B - I don't think so although I think that you should pay a little attention with all of these units to the fact that under normal conditions the pilot would have to push the WILCO button rather than punching that button on the control wheel (which is unusual and not standard).

2.7 Did this display provide too much information?

A and B - No.

3. Evaluation of NIMO display.

3.1 Character size?

A and B - Satisfactory.

3.2 Green color easily readable under simulated night conditions?

A - No.

B - Yes.

3.3 Did you use clear button at any time?

A - Not at all.

B - Occasionally.

3.4 Does clear button serve any useful purpose?

A - No.

B - I guess so, but needs RECALL feature.

3.5 When presenting a long message, this display loses the first part of message when WILCO is pushed? Is this a tolerable feature?

A - Yes, needs pilot education.

B - Yes, if recall available.

3.6 Did this display have any tendency to increase pilot workload?

A - Yes; small characters and distortion required more concentration on display.

B - No.

3.7 Abbreviations confusing?

A - No.

B - Yes, and I suspect it was because the abbreviations had to be abbreviated themselves because of the tiny little window that was used.

3.8 Rate the brightness of push buttons when lit.

A - Satisfactory.

B - See 1.9.

3.9 General comment.

B - NIMO so poor as to almost eliminate itself. At one time I wired a 5-inch Sony TV set to my airplane and found it satisfactory.

4. Evaluation of 7-Window Display.

4.1 Character size?

A - Satisfactory.

B - Probably much too large. I would suspect that with the same amount of space available you could double or triple the usable messages you could put into this thing. (See 2.1.)

4.2 Is the automatic scrolling feature of this display a desirable feature?

A - No. Tendency to stop scrolling after first part of compound message.

B - Yes, everything else being equal.

4.3 Would you prefer manual scrolling for one message at a time?

A - Yes, this would increase workload but would avoid missing part of message.

B - Yes.

4.4 Did this display have tendency to increase cockpit workload?

A - Yes, increased attention to display necessary during scrolling.

B - A little more than the others; primary in trying to decode the super-abbreviations.

4.5 White color easily readable?

A and B - Yes.

4.6 How often did you use clear button?

A and B - Occasionally.

4.7 Does clear button serve any useful purpose?

A and B - Yes.

4.8 Is the scroll rate adjust feature a desirable feature?

A - No.

B - Neutral.

4.9 Was brightness control feature useful?

A - Not during day.

B - Yes, especially at night. (See 1.9.)

4.10 Do you feel this display provided too much information?

A - No.

B - No, it was too little.

4.11 Abbreviations confusing?

A - No.

B - Yes.

5. General questions applying to all four displays.

5.1 Is audio alert signal preceding each message helpful?

A and B - Yes.

5.2 Did momentary flashing of message provide any meaningful alert function?

A and B - Yes.

5.3 Would you prefer a longer or shorter flashing duration of the message?

A and B - As is.

5.4 What is your preference for location of WILCO button?

A - Control column.

B - Display; control column bad because many planes have emergency cut-off buttons for auto pilot there.

5.5 Do you think improved synthetic speech might be preferable to the use of visual character displays?

A - No; might be as good, but certainly not better.

B - Possibly, although I think the scratchpad capability of seeing characters displayed continuously or repeated are of considerable value to a pilot who is flying a complex procedure all alone.

5.6 What are your feelings concerning the impact on pilot workload if Data Link becomes available?

A - Would ease workload slightly.

B - Data Link should help; will cut down on verbiage, but almost total silence may have unfavorable psychological effect on pilots used to friendly conversation with controllers. Also pilots generally need a wealth of detailed information: such as a warning on wing tip vortices or taxiing instructions in a strange airport. It is unlikely that all this information could ever be standardized for Data Link.

5.7 Would you like separate displays in prime locations for pilot and co-pilot?

A - No.

B - Most aircraft have only one pilot.

5.8 If you were faced with a trade-off between a small display in a prime location or a larger display in a less desirable location, which would you prefer?

A - Small prime; characters could be smaller without loss of readibility.

B - NIMO was only example of small display and that was unacceptable. I could only make such a judgement on the basis of some logical modern display.

5.9 Do you have a color preference for display?

A - Red.

B - No.

5.10 Would you prefer an improved CRT display or the use of lines for message display?

A - Lines.

B - See 3.9.

5.11 How many lines and how many characters per line should display have?

A - Three or fewer lines; as many characters per line as possible.

B - Does not matter once you get characters down to a usable size.

5.12 What is your opinion of having Data Link set the heading bug and altitude alert automatically after pushing WILCO.

A - No, malfunction would be chaotic.

B - Too exotic.

5.13 Please rate the four displays from highest preference to lowest.

A - 32-W, 3x7-W, NIMO, 7-W.

B - 3x7-W, 32-W, 7-W, NIMO.