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HUMAN FACTORS EXPERIMENTS FOR DATA LINK
Interim Report No. 3

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16. Abstract

The results of three experiments involving eight FAA NAFEC test pilots are reported. Section I describes the evaluation of four prototype Data Link displays in a GAT-1 simulator. While there was lack of agreement among the pilots as to the relative merits of the four displays, their opinions concerning Data Link as a concept were generally favorable.

Section 2 describes reaction time and error rate measurements made as 144 slides were presented containing a variety of short ATC messages. It was determined that differences in type font were not significant, that arrows were generally better than words for altitude and heading commands, and the "L" or "R" as heading commands in messages such as HDGL230 were extremely difficult to comprehend.

Section 3 describes a second laboratory experiment which studied the differences between long and short abbreviations with and without spaces. The need for the use of spaces was demonstrated.

The results of the experiments described in Sections 2 and 3 closely parallel those previously obtained using TSC engineers as experimental subjects.

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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.

Previous reports in this series have acknowledged the contributions of the numerous TSC personnel whose efforts have made these tests possible. Special acknowledgement must be made in the present report to the efforts of the eight FAA NAFEC test pilots, J. Bailey, A. Bazer, I. Budoff, R. Grace, R. Lamprecht, J. Ryan, J. Terry and W. Tranter during their participation in this series of simulated flights, and to A. Madge and to W. Stevens, Chief NAFEC Test Pilot for their assistance in the design and testing of the flight scenarios.

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1. SIMULATOR TESTS OF PROTOTYPE DISPLAYS

1.1 INTRODUCTION

Planning for flight tests of Data Link equipment has included an intensive survey of display devices having varying capabilities for presenting the information required for the successful operation of a digital Data Link System for Air Traffic Control (ATC). Section 1 of Report No. FAA-RD-72-150, "Human Factors Experiments for Data Link," documented preliminary tests on a GAT-1 simulator using synthetic speech and a prototype visual display which presented heading, altitude and speed commands in a fixed format using an array of nine digits. The present experiment reports on the evaluation of four additional displays, all having the capability for the presentation of a considerably wider variety of ATC commands. All four displays were evaluated in the Transportation Systems Center's GAT-1 simulator using eight Federal Aviation Administration-National Aviation Facility Experiment Center (FAA NAFEC) test pilots as experimental subjects. The objective of the experiment was to accumulate data which, supplemented by additional experiments now in the planning stage, will eventually permit a reduction in the number of display devices requiring flight test evaluation.

1.2 EXPERIMENTAL CONDITIONS

1.2.1 The Prototype Displays

In selecting devices suitable for the presentation of short-length ATC messages, consideration must be given to a number of possible variables if the most efficient use of simulator and test pilot time is to be made. Characters may be generated using a variety of type fonts; the most common methods involve selectively energizing segments of a 16-segment array, the use of characters based upon a 5 x 7 dot matrix, or stencil-type characters such as are produced by a Charactron Cathode Ray Tube (CCRT). Possible device technologies include gas discharge (plasma), light-emitting diodes (LED), incandescent filaments, liquid crystals, thin film electroluminescence as well as cathode ray tubes. Consideration must be given to the selection of color as it may influence pilot preference for a particular display. Variation in character size also may affect the acceptability of the display. Selection furthermore must be within the constraints of available off-the-shelf hardware. Thus, gas discharge displays are limited to neon reddish-orange, since this is the only efficient emitter. Green LED displays are gradually becoming available, but are presently much less efficient and lower in brightness than are red displays. Displays requiring the use of multiple electrodes are easier to make in larger character sizes and hence are more available in such sizes. Within these constraints, four devices were selected as examples which would permit useful comparisons. All were packaged along with their required drive circuitry in the same sized chassis to permit them to be installed and interchanged in a common location on the panel of the GAT-1 simulator. Since the displays were fabricated for experimental expedience, miniaturization and high density packaging were not attempted.

The plasma display, depicted in Figure 1-1, utilized a Burroughs Self-Scan Panel 8.50 inches wide by 2.25 inches high. On this panel, it was possible to present a linear array of 32 characters each in a 5 x 7 dot matrix format with characters 0.20 inches high and 0.14 inches wide. Light output per dot was 25 foot-Lamberts nominal.

The second prototype display, depicted in Figure 1-2, presented three lines of seven characters, using Monsanto red light-emitting diodes. Characters again were based on a 5 x 7 dot matrix. Character height was 0.35 inches, and the brightness typically 300 foot-Lamberts.

Sixteen-segment alphanumeric readouts from Master Specialties Company provided the devices for the third display, which was limited to the presentation of a maximum of seven characters at any one time. The display, depicted in Figure 1-3, used fiber optics to conduct the emission from incandescent lamps onto the viewing area where it was displayed on a black background.

Figure 1-1. The 32-Window Display

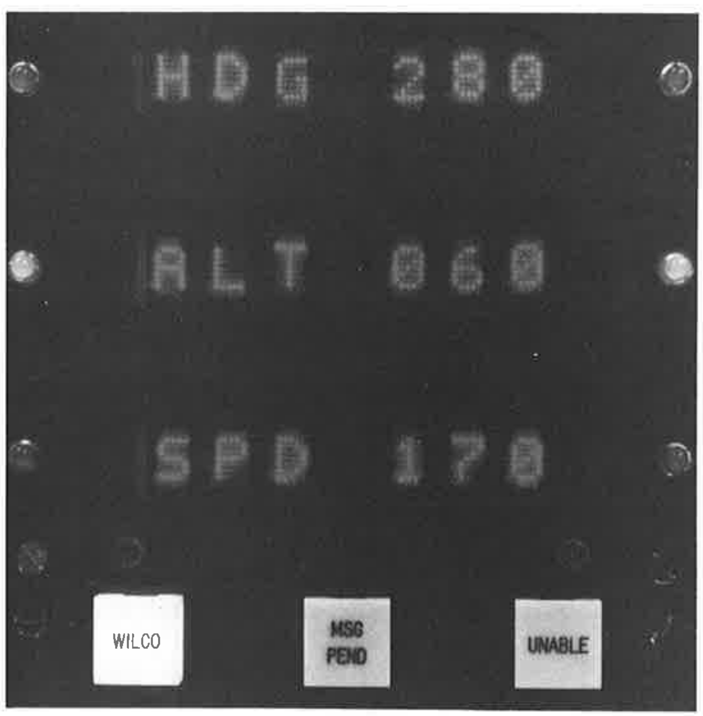

Figure 1-2. The 3x7 Display

Figure 1-3. The 7-Window Display

Character height was 0.42 inches and typical brightness 400 foot-Lamberts. Storage registers for three 7-character messages were provided, and these could be accessed sequentially by depression of the "Message Pending" pushbutton located below the readout.

The final display utilized a special miniature NIMO tube, a variety of shadow mask cathode ray tube produced by Industrial Electronic Engineers, Inc. The tube contains an array of 64 cathodes and 64 discrete mask areas, so arranged that any cathode and its associated mask section can produce a character or a message on a 3/4 inch square active area at the end of the tube. No deflection circuitry is employed. The position at which information appears on the tube face is entirely a function of the geometry of the cathodes and their associated mask areas.

In normal usage, an array of such tubes can be arranged to spell out messages in characters 3/4 inch high, or a single tube can be used to provide up to 64 separate messages in smaller characters. For the TSC application, a special mask was employed which produced messages to a maximum of six characters on each of three lines. Additionally, certain mask positions were reserved for individual digits at specific locations, so that by time-sharing cathodes and mask positions at a flicker-free rate, it was possible to display messages along with any required numerical values. Figure 1-4 depicts the NIMO display, and Figure 1-5 the shadow mask used.

In addition to the display proper, each of the above units provided pushbuttons to permit "Wilco" or "Unable" responses, and a "Clear" pushbutton which cleared the display and returned it to view on alternate depressions. A "Message Pending" indicator was also provided on the panel to inform the pilot that a new message was waiting to be sent to the display, and would immediately replace the message currently displayed as soon as a "Wilco" or "Unable" was received.

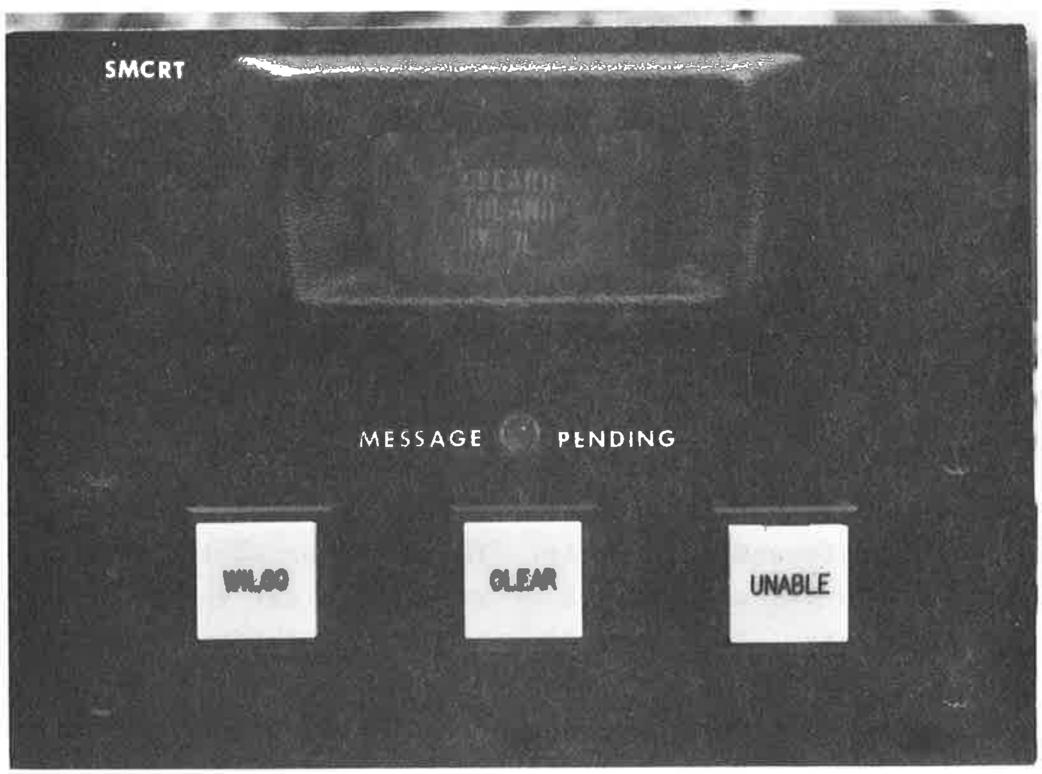

Figure 1-4. The NIMO Display

SEE PRINTR	EST DELAY MIN	DEPART STACK MIN*	NO RADAR CONTCT	NEG ON REQST	REQST OK'D	RADAR CONTCT	TRAFIC ML
CONTCT TOWER	CONTCT GROUND	CONTCT DEPRTR	CONTCT CENTER	CONTCT APPRCH	DATA LINK	CLEARD TO TAXI	SQUAWK
TURN → →	TURN ← ←	MAINTN HEADNG	CLIMB ↑ ↑	DESCND ↓ ↓	MAINTN ALTUDE	MAINTN SPEED	CLEARD TAKOFF RY
ALTMTR	CLEARD TOLAND RY	0	1	2	3	0	1
2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7
8	9	0	1	2	3	4	5
6	7	8	9	5	R	L	*

Figure 1-5. The Special NIMO Shadow Mask

For the tests, the displays were connected to a standard teletype through a TSC-constructed interface box which provided the required decoding, storage and control functions. The interface box further provided control of the duration of flashing of new messages when they appeared on the display and of flashing of the "Wilco" button to alert pilots when they did not respond to a new message within a predetermined time from its appearance. New messages were typically flashed three times at a rate of twice per second and with a 50 percent duty cycle. If there was no response within three seconds, the "Wilco" button was flashed at the same rate and duty cycle. The flashing of the display of a new message was accompanied by an audio alert which "beeped" at the same rate. Indicator lights on the interface box informed the experimenter of "Wilco" and "Unable" responses by the pilots and of "Message Pending" when a pilot had not yet responded to an earlier message. An interval timer connected to an outlet on the interface box measured response times. The interface box is depicted in Figure 1-6.

A tape punch and reader connected to the teletype made it possible to make and play back tapes for the experiment, so that commands and advisories could be called up rapidly and displayed in an error-free manner.

Figure 1-7 presents an interior view of the GAT-1 cockpit with the NIMO display in position, and Figure 1-8 an overview of the experimental setup with the GAT-1 in the background and the experimenter's control console in the foreground. A block diagram of the setup is presented in Figure 1-9.

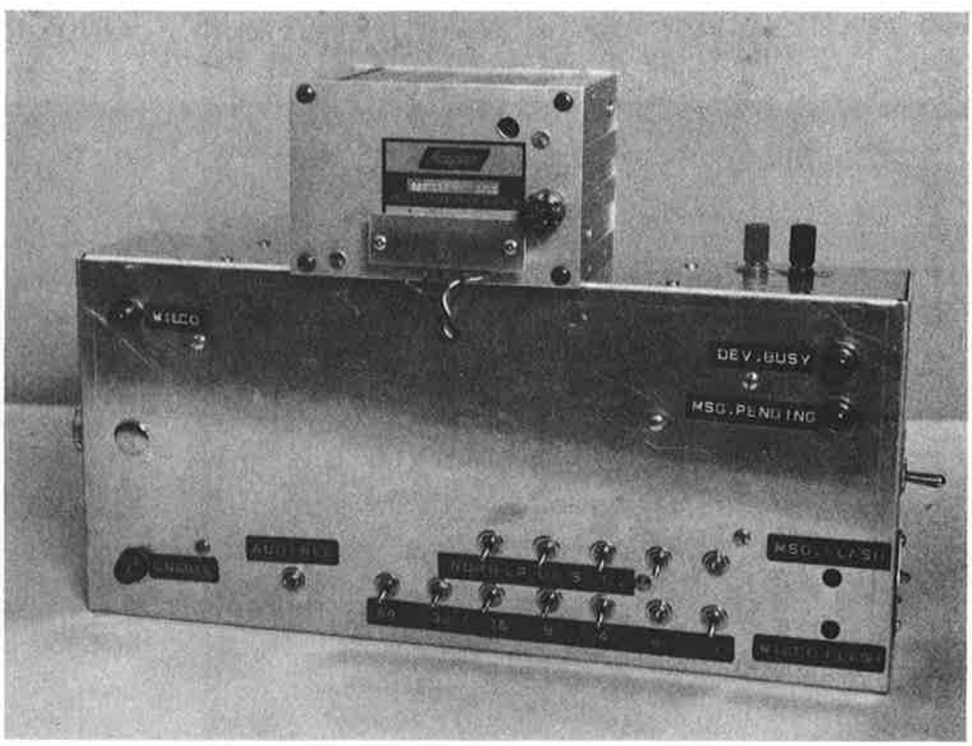

Figure 1-6. The Interface Box

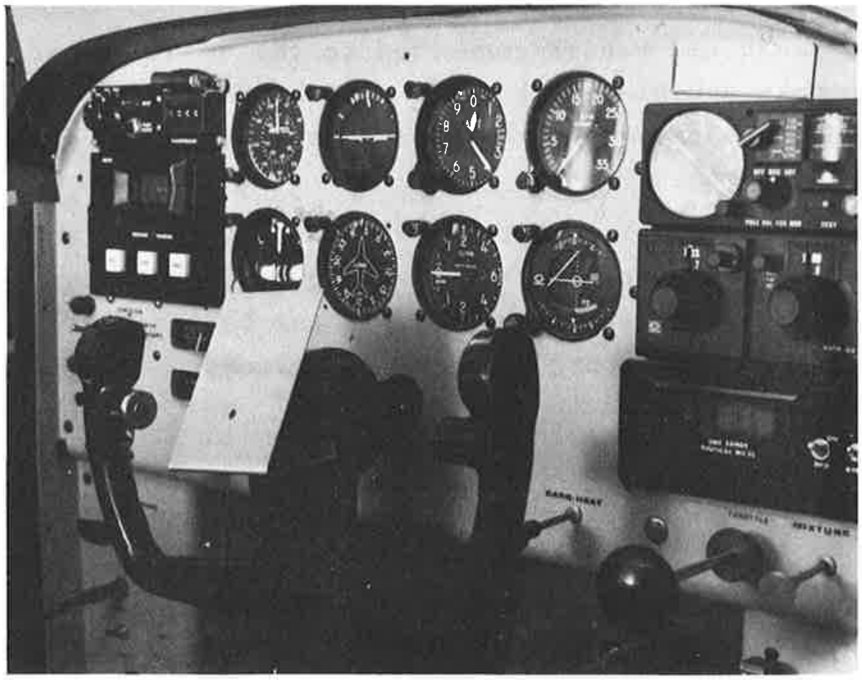

Figure 1-7. Interior View of GAT-1 Cockpit with NIMO Display Installed on Left Side of Front Panel.

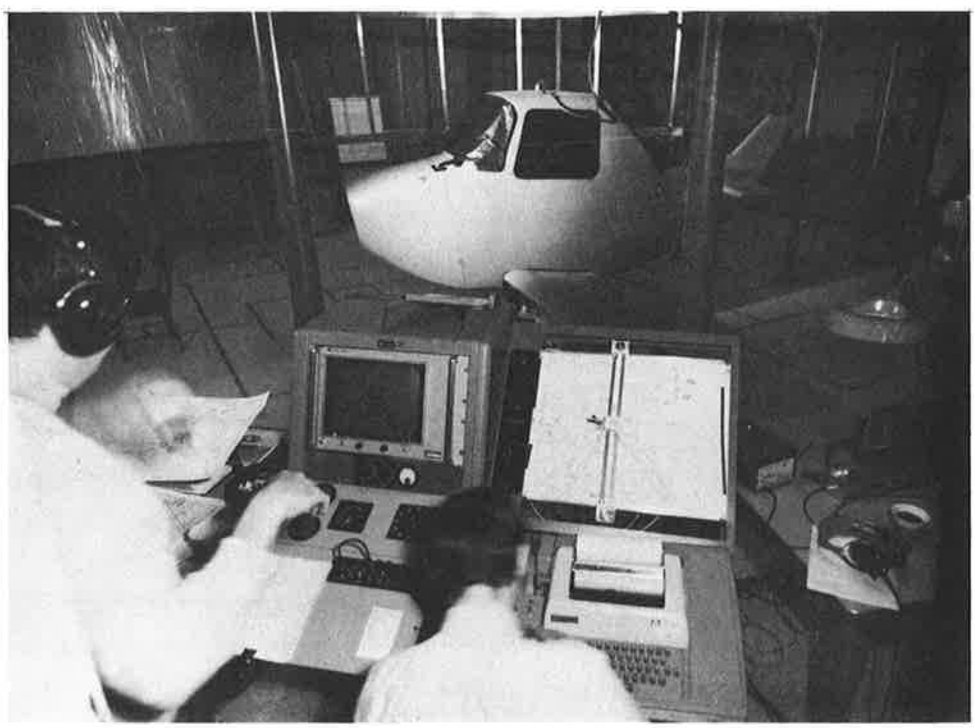

Figure 1-8. Overview of Experimental Setup

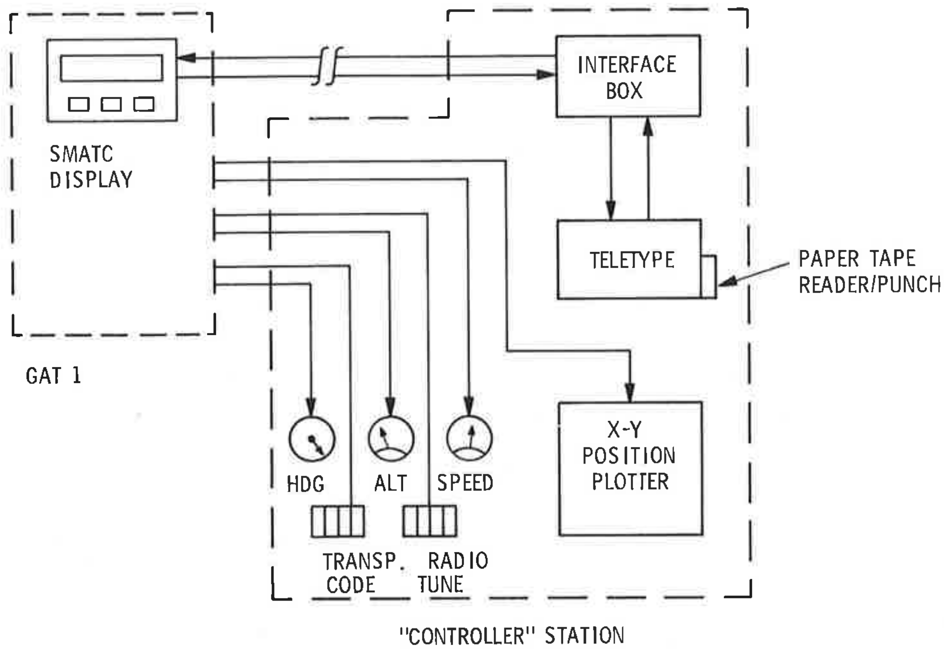

Figure 1-9. GAT-1 Simulation Block Diagram

1.2.2 Experimental Design

Using eight pilots, each making a total of eight runs, two on each of four scenarios and under simulated night (blackout curtains on the cockpit windows) and day operations (the cockpit enclosed in translucent plastic and illuminated by a 1,000 watt floodlight from a distance of 15 feet), it was possible to counterbalance for all practice effects using the Greco-Latin Square Design:

TABLE 1-1. EXPERIMENTAL DESIGN

		PILOT #			
		1,5	2,6	3,7	4,8
SEQUENCE OF TESTS	Simulated Day Ops	AE	BF	CG	DH
		BG	AH	DE	CF
		CH	DG	AF	BE
		DF	CE	BH	AG
	Simulated Night Ops	BH	AE	DF	CG
		DG	CF	BE	AH
		CE	DH	AG	BF
		AF	BG	CH	DE

where "A," "B," "C," and "D" represent the four scenarios (to be described later), and "E," "F," "G," and "H" represent the 7-window, 3 x 7, 32-window and NIMO displays respectively. In the above design, Pilots 1 through 4 ran first under simulated daylight conditions and Pilots 5 through 8 first under simulated night conditions.

1.2.3 The Scenarios

The GAT-1 simulator in its standard version contains navigational aids for flight training over completely fictitious territory. Recalibration of the navigational aids made it possible in the present experiment to simulate flights around the Boston area, and to record flight paths on an X-Y recorder using charts of the area at three different scales.

For the experiment, four different scenarios were generated. Scenario "A" involved takeoff from Runway 34 at Providence, vectoring to V139 airway and further vectoring from the vicinity of Whitman VOR for an eventual landing on Runway 33L at Boston's Logan Airport. Scenario "B" was a somewhat similar cross-country flight starting on V106 Airway southwest of Gardner, Massachusetts, with a hold at Gardner, navigation of V431 to Manjo, with vectoring for a landing on Runway 22L at Logan. Scenario "C" involved takeoff from Logan's Runway 9 with clearance to Hanscom Field, but a simulated change in weather closed Hanscom, forced a return to Boston with a landing on Runway 4R. In Scenario "D," after a clearance for landing on Logan's Runway 33L, two missed approaches were created, with landing finally taking place on Runway 4R. Figures 1-10 through 1-13 depict the flight paths generated by the four scenarios.

The complete scenarios, with messages in the form in which they appeared on each of the displays, are presented in Appendix A. Here, it should be noted that occasional impossible messages were presented, such as "Turn right to a heading of 550 degrees" to force the use of the "Unable" button, so that pilots would not routinely press the "Wilco" button before examining the meaning of messages. The use of asterisks should also be noted to delineate

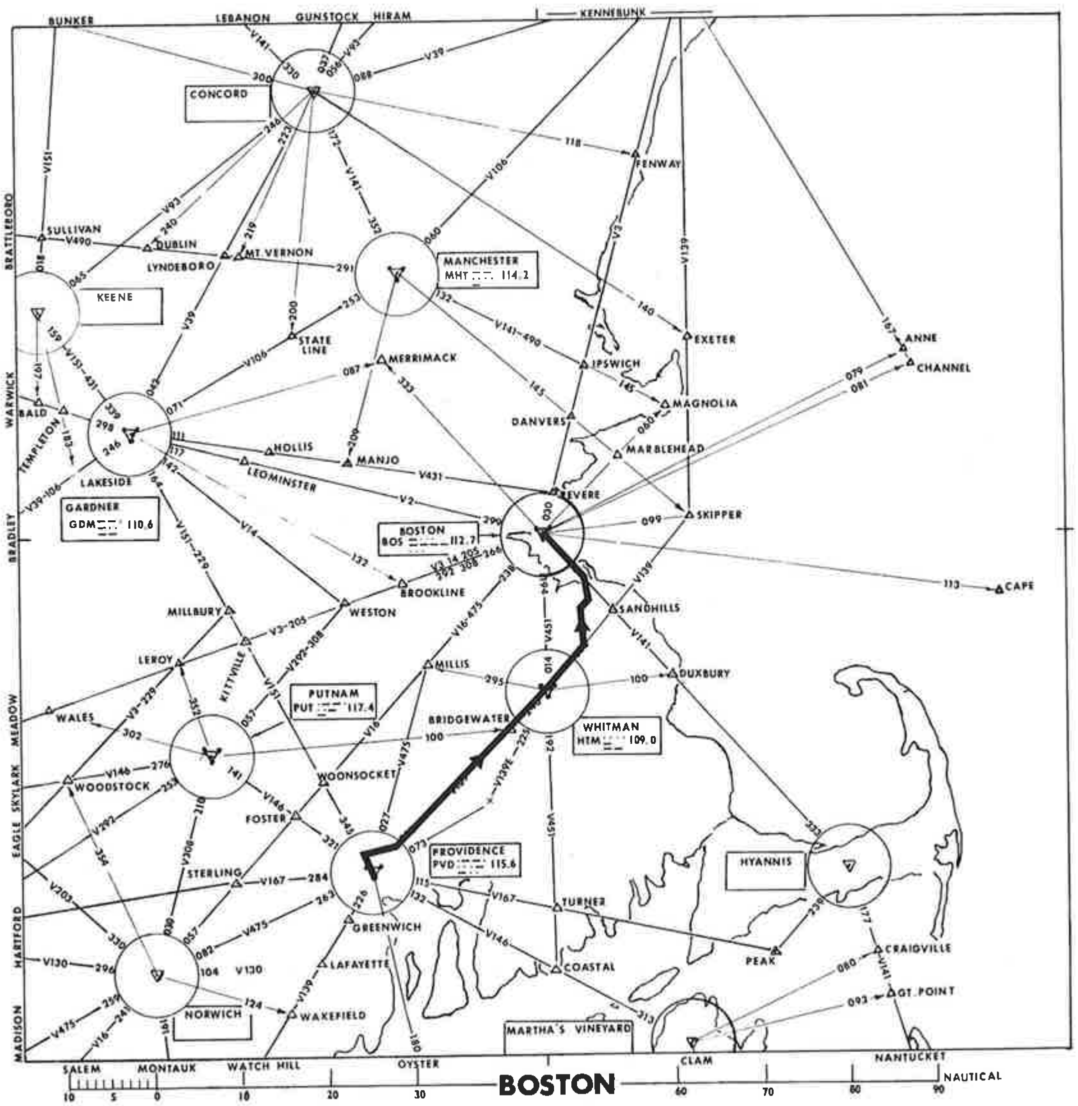

Figure 1-10. Flight Path Generated by Scenario "A"

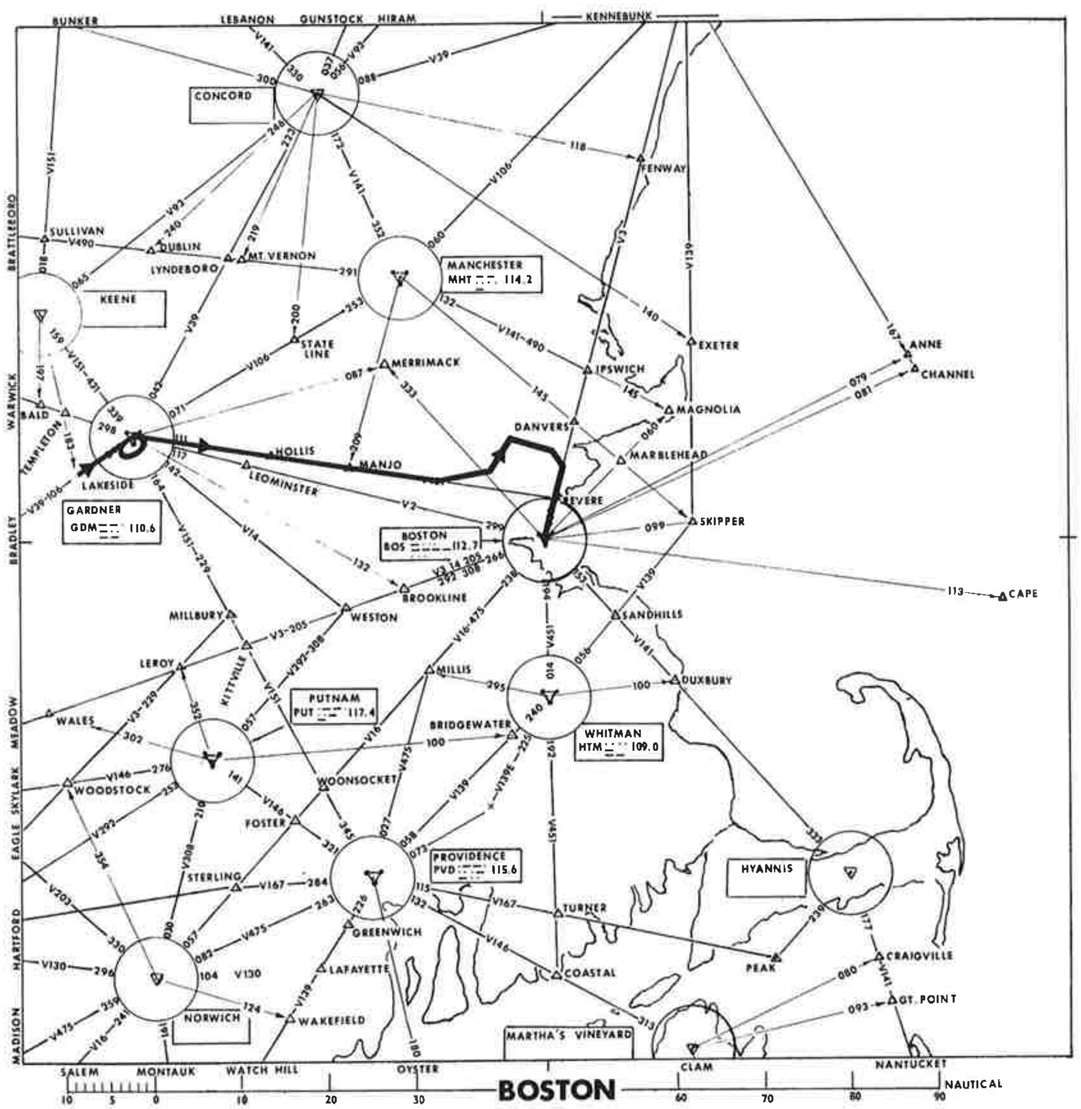

Figure 1-11. Flight Path Generated by Scenario "B"

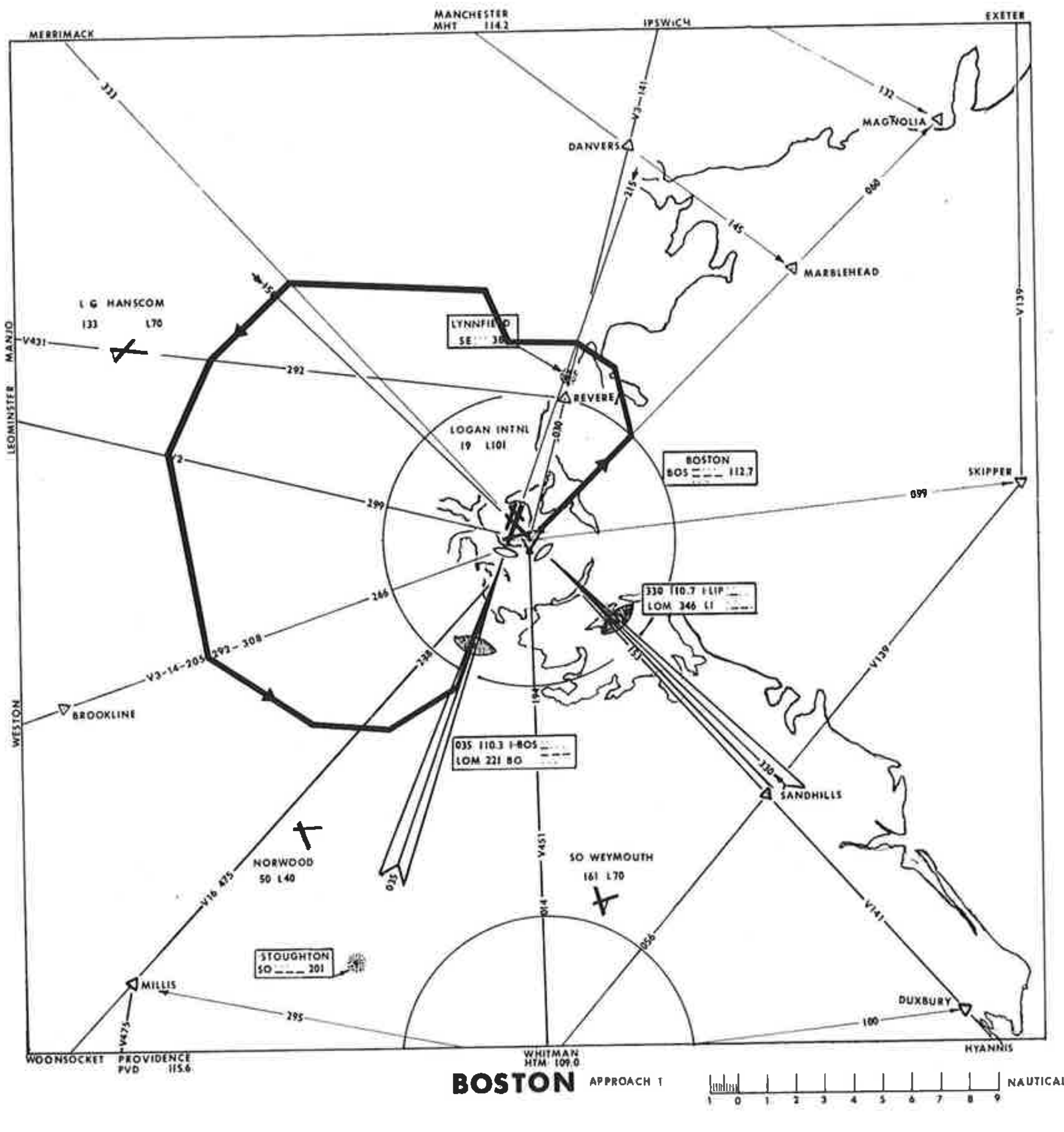

Figure 1-12. Flight Path Generated by Scenario "C"

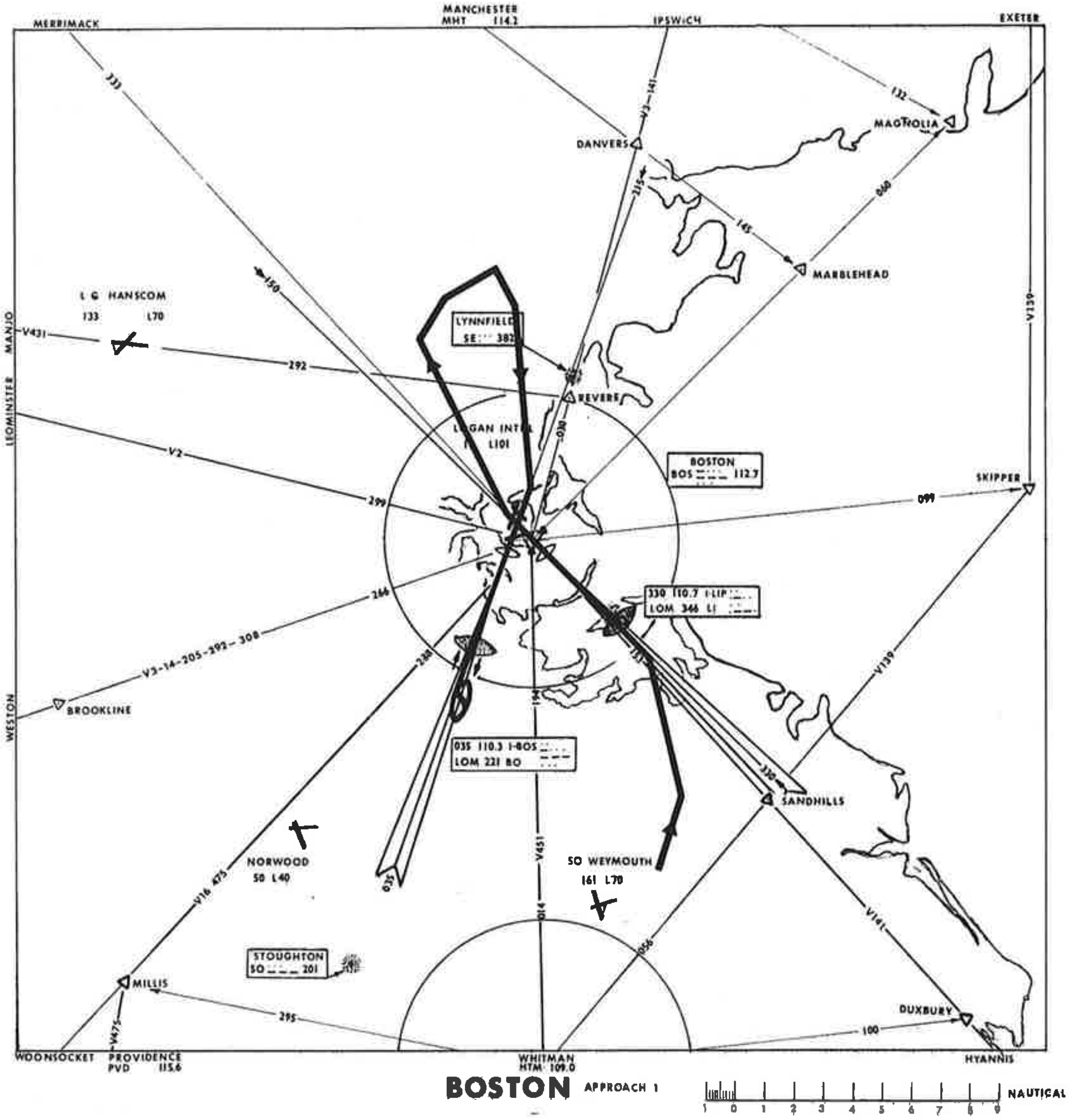

Figure 1-13. Flight Path Generated by Scenario "D"

new information in complex messages on the 32-window display. On the 3 x 7 7-window display, a similar function was provided by illuminating small red lights at each end of each line, and these are delineated by dots in the scenarios as they are reproduced in Appendix "A."

1.2.4 Experimental Subjects

Questioning of the NAFEC test pilots concerning their experience was limited to determination of their age, total flying hours in all types of aircraft and hours flown in a light single-engine aircraft during the previous year. These data are tabulated below:

TABLE 1-2. QUALIFICATIONS OF PILOTS USED IN EXPERIMENT

PILOT #	AGE	TOTAL FLYING HOURS	LT. AIRCRAFT HRS LAST YEAR
1	50	15,000	0
2	53	10,000	10
3	53	12,000	10
4	51	18,000	30
5	44	8,000	0
6	46	8,200	2
7	48	9,500	0
8	48	12,000	80

1.2.5 Experimental Procedures

The eight test pilots were run on consecutive days over a period of two weeks. Upon reporting in the morning, each participated in the laboratory tests described in Sections 2 and 3 of this report. Each was then taken to the simulator area and given the instructions found in Appendix A-1.

As soon as the simulated flights of the previous pilot were completed, the new experimental subject was then given about 30 minutes to familiarize himself with the control and display layout and the flying qualities of the simulator. The Data Link prototype displays were also demonstrated to him on a table by running through a brief series of typical messages.

Each subject then made four experimental runs in the afternoon and completed his remaining four simulated flights the following morning. Each simulated flight occupied approximately 45 minutes with a rest period between flights while a new prototype display was installed.

1.3 EXPERIMENTAL RESULTS

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 in the next section of this report, any apparent priority given to these data should be considered only as a means for the orderly presentation of information.

1.3.1 Response Time Data

Response times to the nearest hundredth of a second were recorded for each message on each experimental run. The experimental design used cancelled out the effects of practice for the variables (1) display type, (2) scenario, and (3) day versus night operations when data from the eight subjects were combined. Table 1-3 gives the mean response time for each subject for the experimental conditions under which he served. Here, it should be noted that no subject served under all possible conditions. If a complete block design had been used, the number of experimental hours would have been increased by a factor of four, and the validity of certain of the data would be questionable because on a pilot's eighth flight on a given scenario, he would be expected to be able to anticipate many of the commands.

Where appropriate, analysis of variance* provides a powerful tool for determining the confidence level with which one may assume that differences found between or among measures are truly different and are not the result of chance. Complete block designs

*Appendix G provides a brief overview of statistical terminology.

TABLE 1-3. MEAN RESPONSE TIME IN SECONDS FOR COMBINATION OF SCENARIOS, DAY VS. NIGHT CONDITIONS FOR EACH DISPLAY FOR EACH EXPERIMENTAL SUBJECT

SCEN.	DAY/NITE	DISPLAY	#1	#2	#3	#4	#5	#6	#7	#8
A	D	NIMO		3.11				4.31		
"	N	"				2.88				2.74
"	D	7W	5.37				7.87			
"	N	"		8.56				5.69		
"	D	3x7			3.93				5.38	
"	N	"	5.02				3.44			
"	D	32W				4.03				4.37
"	N	"			3.74				4.86	
B	D	NIMO			3.03				3.84	
"	N	"	3.61				2.65			
"	B	7W				4.59				6.63
"	N	"			7.44				5.49	
B	D	3x7		4.34				7.62		
"	N	"				4.40				4.70
"	D	32W	4.57				4.46			
"	N	"		4.97				5.78		
C	D	NIMO	3.05				2.55			
"	N	"			3.07				3.63	
"	D	7W		5.36				6.44		
"	N	"	5.45				4.09			
"	D	3x7				3.28				5.69
"	N	"		5.50				5.48		
"	D	32W			3.41				4.96	
"	N	"				3.28				3.74
D	D	NIMO				2.36				4.20
"	N	"		3.51				4.79		
"	D	7W			5.19				6.86	
"	N	"				6.22				5.84
"	D	3x7	3.84				3.60			
"	N	"			3.97				4.77	
"	D	32W		5.19				6.36		
"	N	"	3.63				2.92			
MEAN			4.32	5.07	4.22	3.88	3.95	5.81	4.97	4.74

which have no obvious shortcomings such as the above mentioned practice effects are amenable to such treatment. With the Greco-Latin Square design of the present experiment, the application of analysis of variance could lead to false assumptions since we have no certainty of the absence of interactions among variables.* The preference of certain pilots for certain displays could introduce such interactions, as could the variation among pilots in their ability to adapt to the different light levels of different displays under both simulated day and night conditions. For this reason, analysis of variance has not been applied to the data. Instead, means for the various combinations of conditions are discussed separately.

As might be anticipated, there was great variability in mean reaction time for the several pilots. These data are presented in Table 1-4.

TABLE 1-4. MEAN REACTION TIME FOR PILOTS

PILOT #	MEAN REACTION TIME IN SECONDS
1	4.32
2	5.07
3	4.22
4	3.88
5	3.95
6	5.81
7	4.97
8	4.74

In general, reaction time increases with age. There was, however, no apparent correlation between age and reaction time for the pilots used in this experiment, as is indicated in Figure 1-14.

There does, however, appear to be some slight correlation between reaction time and flying experience, as indicated in Figure 1-15. The mean reaction time for the four more experienced pilots was 4.29 seconds as opposed to 4.95 seconds for the less experienced pilots in the group. Care should again be exercised in attaching

*Dixon and Massey, "Introduction to Statistical Analysis," 1st Ed. p. 141.

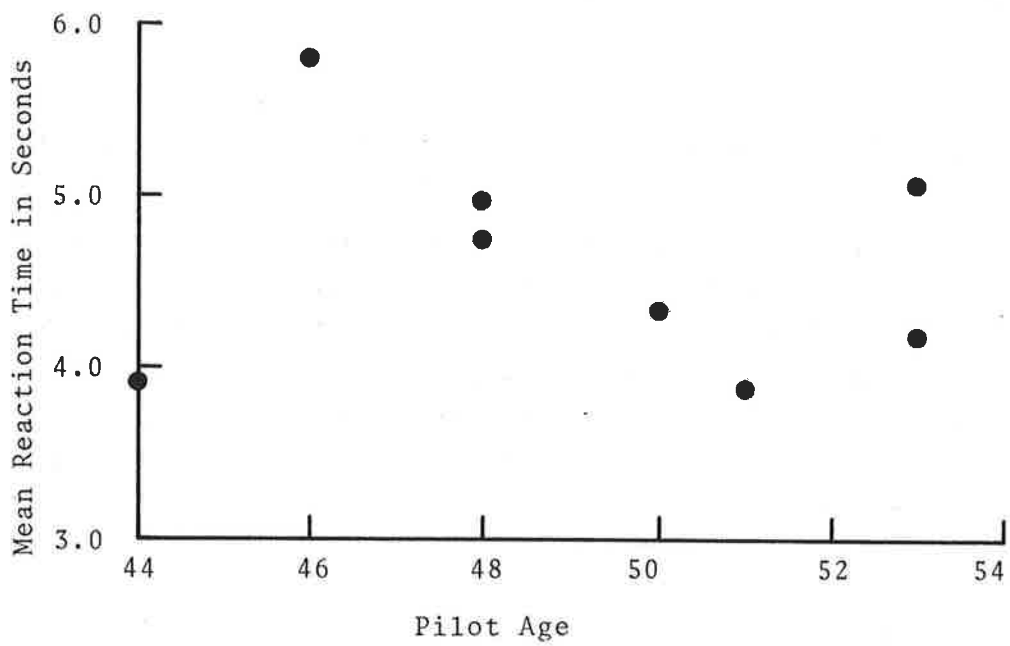

Figure 1-14. Pilot Reaction Time as a Function of Age

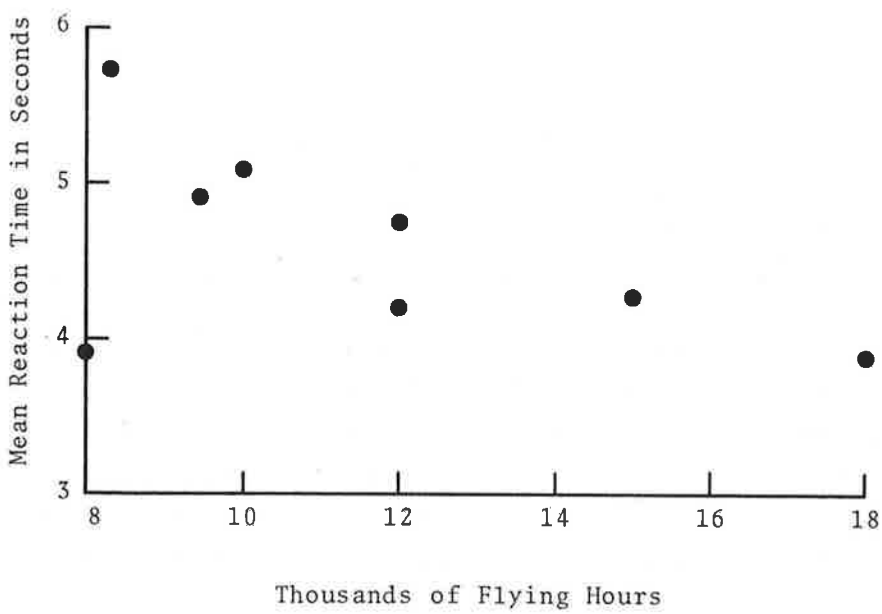

Figure 1-15. Mean Reaction Time as a Function of Flying Experience

too much significance to this at this time. The data points presently available are too few to permit a meaningful statistical test.

Success was achieved in equating the four scenarios for difficulty. Mean reaction time for Scenarios "A," "B," "C," and "D" was 4.71, 4.88, 4.32 and 4.58 seconds respectively.

Three of the displays showed no apparent differences in response time as a function of the differences between simulated day and night illumination levels. Reaction time was appreciably greater for the 32-window display under simulated daylight. This may reflect the noticeable washout of this display under high ambient illumination levels and should be examined closely when the displays are used under natural daylight conditions. Data for the four displays are presented in Table 1-5.

TABLE 1-5. MEAN REACTION TIMES IN SECONDS FOR THE FOUR PROTOTYPE DISPLAYS AS A FUNCTION OF LIGHT LEVELS

	DAY	NIGHT	MEAN
NIMO	3.31	3.36	3.33
7-W.	6.04	6.10	6.07
3 x 7	4.71	4.66	4.69
32-W.	4.67	4.12	4.39
MEAN	4.68	4.56	4.62

The differences in response time for different displays was remarkably consistent. Table 1-6 lists the mean response time for each display for each of the experimental subjects. In all cases, response time to the NIMO was fastest and to the 7-window display slowest. In six out of the eight pilot subjects, response time to the 32-window display was faster than to the 3 x 7-window display.

TABLE 1-6. MEAN REACTION TIMES OF INDIVIDUAL SUBJECTS TO EACH OF THE FOUR DISPLAYS

SUBJECT	S1	S2	S3	S4	S5	S6	S7	S8	MEAN
DISPLAY									
NIMO	3.33	3.31	3.05	2.62	2.60	4.55	3.74	3.47	3.33
7-W	5.41	6.96	6.32	5.41	5.98	6.07	6.18	6.24	6.07
3 x 7	4.43	4.92	3.95	3.84	3.52	6.55	5.08	5.20	4.69
32-W	4.10	5.08	3.58	3.66	3.69	6.07	4.91	4.06	4.39
MEAN	4.32	5.07	4.22	3.88	3.95	5.81	4.97	4.74	4.62

Similar consistency is found when ratios are computed for each subject's reaction time to a particular display to his mean reaction time for all displays, as indicated in Table 1-7. Here, the low ratio for Subject 6 to the 7-window display should be noted. This subject apparently used a scrolling technique for the individual lines of the message somewhat different from the other pilots.

TABLE 1-7. RATIO OF REACTION TIME TO INDIVIDUAL DISPLAYS TO MEAN REACTION TIME TO ALL DISPLAYS FOR INDIVIDUAL PILOT SUBJECTS

SUBJECT	S1	S2	S3	S4	S5	S6	S7	S8	MEAN
DISPLAY									
NIMO	0.77	0.65	0.72	0.68	0.66	0.78	0.75	0.73	0.72
7-W	1.25	1.37	1.50	1.39	1.51	1.04	1.24	1.30	1.31
3 x 7	1.03	0.97	0.94	1.00	0.89	1.13	1.02	1.10	1.02
32-W	0.95	1.00	0.85	0.94	0.94	1.04	0.99	0.86	0.95

Differences in reaction time are, of course, to some extent influenced by differences in message length. With the NIMO, it was possible to present only a single unit of information at a time, a unit of information in this case being defined as a single command or advisory. With other displays, it was possible to present a new command, while maintaining a "scratch pad" of previous values of other parameters, or to provide a new radio frequency setting and transponder code setting in a single message.

Figure 1-16 presents mean reaction times for the several displays as a function of message units in the display.

The decrease in reaction time as the number of message units increases from two to three in Figure 1-16 resulted from the extremely long reaction times for two-unit messages providing radio frequency and transponder settings. It should be noted here that pilots failed to follow instructions when this message appeared, and delayed their "Wilco" until they had made appropriate settings so as not to lose the message. When these messages are omitted from the calculations, as indicated in Figure 1-17, there is a regular and only modest increase in reaction time as the number of message units is increased for both the 3 x 7-window and 32-window displays. However, with the 7-window display, the reaction time for these multiple unit messages increases to a level which would probably not be tolerable for air traffic control.

For purposes of clarification, it should be pointed out that the messages containing radio frequency and transponder settings required the use of all three registers of the 7-window display. They are considered as three-unit messages even though they contain only two units of information.

Pilots were informed before starting the experimental runs that occasional impossible commands would be issued. This was so that they would not routinely press the "Wilco" button without first interpreting the meaning of the message. Typical impossible messages asked for a speed of 900 knots or a heading of 558 degrees, or cleared for a landing on Runway 3LL. A total of 44 such messages were introduced into the 64 experimental runs. Thirty of these produced an immediate "Unable" response, five produced a "Wilco" followed immediately by an "Unable", and nine of the impossible messages were "Wilco'd" and the error was not corrected. Only two of the eight pilots failed to make any errors. Mean response time for the messages correctly detected as erroneous was 5.71 seconds as compared with a mean value of 4.62 seconds for all messages.

It should be emphasized that in a real-world situation, we should not imply that such errors would not be detected by

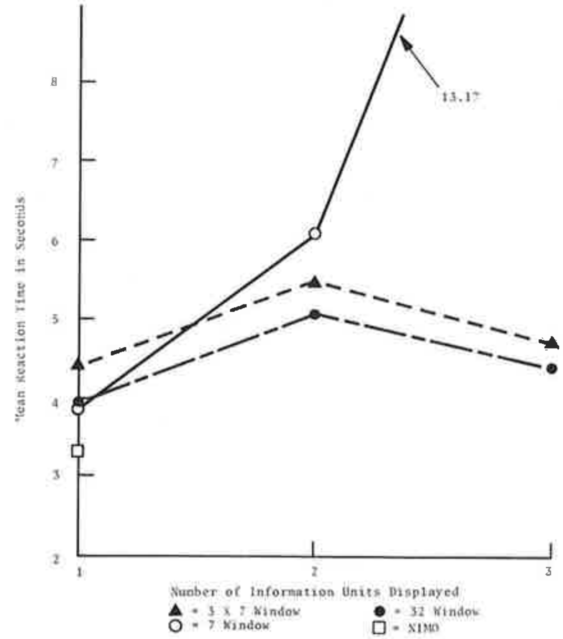

Figure 1-16. Reaction Times as a Function of Information Units in Message

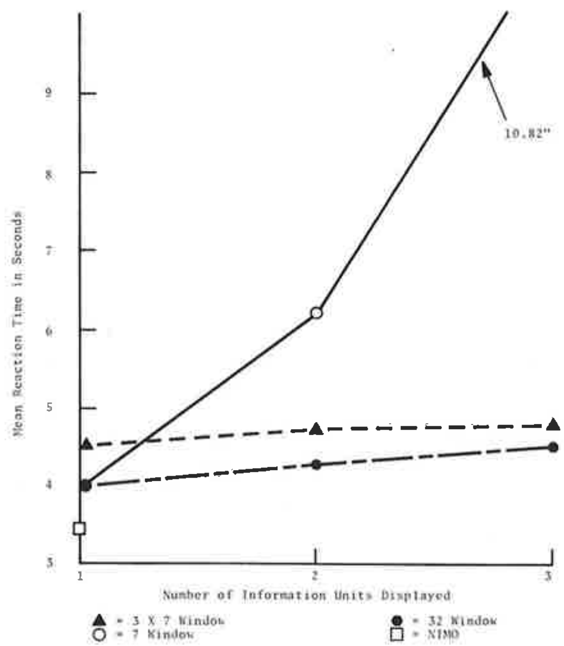

Figure 1-17. Mean Reaction Time as a Function of Message Length with Radio Frequency/Transponder Code Messages Omitted

controller or the pilot. The reason for introducing "errors" into the experiment was that stated above.

1.3.2 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. Such a questionnaire, containing 28 questions, was administered to the experimental subjects at the completion of their flights in the simulator. At the suggestion of the second pilot participant, the questionnaire was handed to subsequent 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 are listed in Appendix B with a transcript of the answers received.

1.3.3 Debriefing Session

A debriefing session was held with seven of the eight pilot subjects approximately two weeks after the completion of the simulation experiments. (Actually, two sessions were held on consecutive days, the first with six pilots and the second with one pilot. One pilot was not available on either day.) The purposes of the session were (1) to discuss some of the specific results of the tests in the hope of learning the reasons for them, (2) to obtain opinions from the pilot subjects concerning the design of the next set of experiments using the two-man cockpit simulator, GAT-2, and (3) to determine the pilots' feelings toward proposed changes in the displays in preparation for the GAT-2 experiments.

A series of twenty questions was discussed at the session. Appendix C presents each question in the order discussed, along with a summary of the pilot responses.

All the pilots expressed interest in the Data Link program and were optimistic about the potential of Data Link in Air Traffic Control. They pointed out that the experiments conducted so far, using a one-man crew simulator, were of limited usefulness in assessing the impact of Data Link on the two-man crew and in evaluating the relative merits of the various displays in this environment. For these reasons, they felt that the planned experiments utilizing the FAA NAFEC GAT-2 simulator will be extremely important and may alter some of the present conclusions.

1.4 DISCUSSION

While there was universal agreement among the pilots that Data Link offered a positive and pleasant relief from the incessant chatter which presently constitutes ATC, there was a wide diversity of opinions concerning the various means of Data Link implementation which were explored in the present study. In addition to the differences in the amount of information which could be presented on the four displays evaluated in the present experiment, there were differences in character font, color, brightness, size and message format. The prototype displays represented off-the-shelf components assembled to evaluate only four of the 384 possible combinations of font (3 types), brightness (4 levels), color (red, orange, green, white), character size (4 levels) and data format (linear versus multiple short lines). Many of the remaining 380 combinations would require special order displays, and others, such as white LED, cannot be implemented with existing technology. For the four displays evaluated, the lack of agreement among the pilots as to the rank order in which they would place the displays for excellence most certainly indicates that different pilots attached different importance to the several variables.

Even without a more extensive study of the variables involved in the displays, certain merits and deficiencies of each can be listed. The 32-window display in general was received most favorably. It permitted the display of information in normal English text or of multiple messages using abbreviations which were completely meaningful. The self-scan method of character generation permits a major reduction in the drive electronics which would otherwise be required. The display is efficient in terms of the number of characters which may be displayed per panel area. The display, on the other hand, is too wide to permit its use on the front of any standard cockpit instrument package. It is shallow, such that it might be installed on the glare shield and separated from the drive electronics, but in this position it would be difficult to read in direct sunlight, and the output, consisting of multiple spectral lines, is not amenable to the use of narrow-band filters to preserve contrast so that high brightness is not required. Thus, while the simulator evaluation indicated this to be the preferred display, reservations must be made concerning the eventual use of the Self-Scan Panel as a flightworthy instrument.

Pilot opinion of the 3 x 7-window display was much less favorable. The majority of the pilots also expressed opinions against the use of a red display. Whether or not the reaction against the 3 x 7-window display was a result of its being too red or too bright remains to be determined. The substrate for LED is presently expensive, so that the displays are made using minute dots that are very bright. To ease the fabrication of the prototypes for this experiment, no dimming controls were provided. This deficiency is presently being rectified for future tests. Mere capability for altering brightness levels to avoid the glaring red may produce a marked change of pilot opinion in the future.

On the positive side, the 3 x 7-window display has a form factor which would permit it to be packaged in standard instrument cases, and the narrow-band emission permits the use of narrow bandpass filters for contrast control.

The NIMO display used in the experiment represented the first application of this device in a time-shared mode. As such, there was a certain lack of character alignment when multiple digits were presented. Additionally, when the special mask for the ATC application was ordered, information as to the relative frequency of ATC messages was sketchy, and the messages selected accordingly did not represent those having the highest potential usage. A new NIMO mask is presently on order containing a more carefully selected set of messages; character alignment requirements have been specified. While it will not be possible to present all possible ATC messages with such a tube, the small size and low cost of the display and the simplicity of the required driving circuitry makes the NIMO an attractive candidate display system for the owner of a light aircraft who might not be able to afford the more complex and more versatile displays. For this reason, additional evaluation of the NIMO is scheduled to continue.

A major reason for the low ratings which the 7-window display received is probably the requirement for the extensive use of pushbuttons when multiple unit messages are received. According to the ARINC concept, there should be automatic alternation of the lines of messages requiring more than seven characters, and this feature is being installed in the existing prototype for future evaluations.

1.5 PLANS FOR ADDITIONAL EXPERIMENTS

Work is under way to incorporate into the displays many of the changes recommended on the basis of the experiments completed to date. The reconfigured displays will be evaluated in a series of experiments similar to those recently conducted, with a major change being the use of the FAA NAFEC GAT-2 cockpit simulator. This cockpit simulates a light twin-engine aircraft and will allow evaluation of the displays in a two-man crew environment. It is hoped that these experiments will result in not only a thorough study of display tradeoffs with the modifications incorporated, but also in the first important data concerning the implications, effects and handling of Data Link in a multi-crew cockpit.

The following is an outline of the planned experiments, including the changes in each display.

A. Displays (4):

1. The original 7-window display will be modified to provide automatic scrolling of up to three lines of messages. Dimming control will be added as well as a control to vary the rate of the scrolling.

2. Original 32-window Self-Scan display will be modified so that the right 12 windows are dedicated totally to heading, altitude and speed "scratch pad" functions, while the left 20 windows are used for the display of all messages.

3. The original 3 x 7 display will be used with the addition of an internal register which automatically stores heading, altitude and speed messages. By depressing an added "Recall" button, the message currently being displayed will temporarily be replaced with the last heading, altitude and speed commands. A second push will remove the heading, altitude and speed data and will bring the last message back to the face of the display. A dimming control will be added.

4. The NIMO display will retain its original functional configuration, but a new NIMO tube with better mask alignment and a more appropriate choice of messages will be used.

5. In addition to the "Wilco" button on the displays, a "Wilco" button will be installed on each control column.

B. Scenarios:

Two one-hour scenarios, each a typical cross-country flight in a congested area, similar to GAT-1 flights will be used. The New York City area will be used in one or both scenarios if possible. Strong emphasis will be placed on heavily exercising the functional interactions of the two-man crew, but this empahsis will be realistic.

This will include considerable vectoring, altitude, speed, and frequency changes, and transponder code settings. ATIS will be incorporated into each sceanrio, and will be supplied to the crew via prerecorded synthetic speech over the normal VHF ATIS frequency channel. Predeparture clearance will be given via prerecorded synthetic speech over the normal departure clearance frequency. There will be audio back-up of messages during the final approach phase of one or more display/scenario combinations via prerecorded synthetic speech.

C. Data Requirements

1. Response Time will be a recorded from an automatic timer.
2. Source of "Wilco" will be recorded from lights on the interface box.
3. Recalled Messages (3 x 7 display) will be recorded each time heading, altitude and speed are recalled.
4. When messages receive an "Unable" response, they and the reason for the "Unable" will be recorded. Recording will be done for both planned and unplanned "Unable" responses.
5. Dimming Control (3 x 7-window and 7-window). Setting of the dimming control will be recorded at the end of each flight phase (day and night portion).
6. Pilot Comments. Continuous recording capability will be provided in the cockpit for both crew members to use for making verbal comments during the experiments. Pilot commentary will be separated from normal radio equipment.

Following the above described experiments, plans are being formulated to evaluate extended length message (ELM) displays, including printers capable of displaying departure clearances, ATIS reports, weather forecasts etc. Downlink keyboards will be evaluated whereby the pilot may request ATIS, flight plan changes etc., or may generate pilot reports via the Data Link. Various methods of message storage and recall will be studied, as well as displays dedicated solely to the presentation of the last value of heading, altitude and speed sent from the ground (i.e., automatic "scratch pad"). Together with the displays currently being studied, it is hoped that this broad complement of I/O devices will allow the simulation and study of flights from block to block within a total Data Link Environment.

1.6 SUMMARY AND CONCLUSIONS

Eight FAA NAFEC test pilots flew a total of sixty-four simulated flights in a GAT-1 trainer to evaluate four prototype Data Link displays under simulated day and night conditions in a counterbalanced experimental design. While the overall ratings as to the relative merits of the four displays differed, none of the displays appeared to have deficiencies sufficiently great as to rule it out from future consideration. Pilot opinion of Data Link was most favorable.

2. FURTHER COMPARISON OF MESSAGE FORMATS

2.1 INTRODUCTION

Section III of FAA-RD-72-150 described an experiment wherein subjects were required to select an appropriate response from among multiple possibilities as slides were presented containing ATC commands and advisories coded in several ways and having several formats. Disjunctive reaction times* were measured as a means for determining the relative intelligibility of messages. In a procedural variation reported in Section II of FAA-RD-73-55, using the same stimulus material, a response by the subject removed the slide from the screen and he was then required to verbalize the meaning of the message. TSC engineers familiar with ATC terminology were used as subjects for these earlier experiments. The availability of NAFEC test pilots at TSC for the GAT-1 simulator studies described in Section I of the present report made it possible to repeat the slide presentation so that a comparison between the performance of engineers and test pilots could be made. The same procedure was followed; when the pilot subject responded, the screen went blank and he was then required to verbalize the content of the slide.

2.2 OBJECTIVES

In addition to determining performance differences resulting from the change of subject population, the experiment had these objectives:

(1) Determining any response time differences or error rates resulting from the use of three different type fonts: dot matrix, stencil, and 16-segment,

(2) Determining any differences resulting from the use of an extended linear display as opposed to the presentation of the same information on three short lines,

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*Disjunctive reaction time involves the selection of a correct choice from among multiple possibilities.

(3) Measuring differences resulting from the use of arrows versus words for simple altitude and heading commands,

(4) Comparing reaction time and error rate for purely qualitative information versus information providing quantitative values of parameters,

(5) Comparing differences between the presentation of a new command by itself versus the presentation of the new material while maintaining a "scratch pad" of the previous values of other flight parameters, and

(6) Determining requirements for presenting new information at the left or top of the display versus maintaining a fixed sequence for heading, altitude and speed commands.

These and other parameters were explored in the following experiment.

2.3 EXPERIMENTAL CONDITIONS

The slides used in this and the earlier experiments contained eight formats for commands in each of the six broad categories "climb," "descend," "turn left," "tune your transceiver" and "this is a message requiring simple acknowledgement." Artwork for each of the forty-eight such messages was generated in three different type fonts: a 5 x 7 dot matrix, characters simulating those from a 16-segment array and characters simulating stencil such as might appear on the face of a Charactron CRT. The artwork was photographed to provide a total of 144 double-frame 35 mm. high contrast negative slides (white characters on a black background).*

The slides were mounted in two-inch by two-inch slide carriers, randomized and distributed evenly among three slide trays. The slides were alternated with pieces of blank cardboard in the slide trays to permit blanking of the screen as soon as a subject responded to the presentation of each slide.

*The precise formats for each of the 144 slides are reproduced in Appendix E along with the raw data.

Each slide additionally contained a clear spot in the upper right corner to permit the activation of a photocell which started a timer when the slide was presented on the screen.

As further training, the subjects were then handed the response panel layout depicted in Figure 2-1, demonstrating the possible coding for each of the six numbered control buttons, and were urged to check out possible finger placement on the actual control box to facilitate their responses.

Subjects were run individually, and the average total time per subject was approximately 25 minutes. The sequence in which the slide trays were presented to subjects was randomized to counterbalance for practice effects.

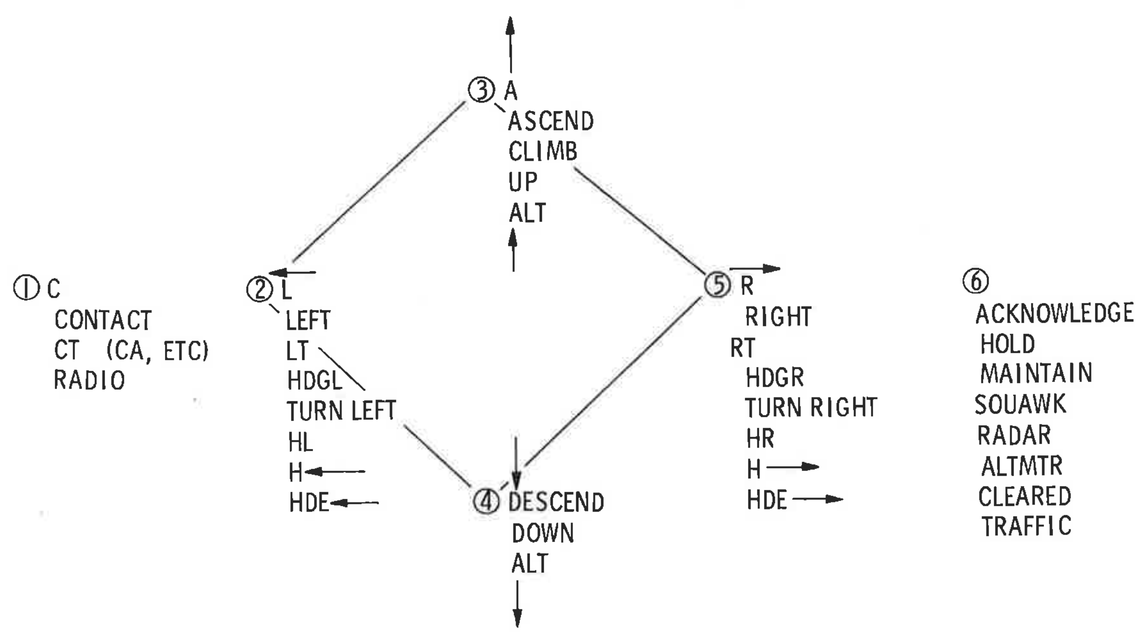

Figure 2-1. Response Layout Panel

Since this was a test of the recognizability of the information and not of visual acuity, the characters of the messages were projected at a height of approximately 1/2 inch on the screen, and the subjects viewed them from a distance of approximately 30 inches.

Equipment for the experiment, other than the slides, consisted of a 35 mm. slide projector, a projection screen with affixed photocell, a response panel for subjects, with six pushbuttons to permit the subjects to indicate their interpretation of the message in terms of the appropriate response, a series of numbered lights to permit the experimenter to ascertain the correctness of the subjects' response, and an interval timer calibrated in hundredths of a second which automatically measured the time from the appearance of the slide to the subjects' responses. All subjects were handed a typewritten sheet containing the instructions in Appendix A-2.

During the experiments, the subjects usually volunteered information they were aware of when they had made an error in their response. When this information was not volunteered, the experimenter pointed out the error to facilitate performance on the remaining slides.

The raw data from the experiment, organized by subject and slide categories are presented in Appendix E. A blank in these data indicates the failure of a slide to drop into the projector properly or a failure of the timer to reset. "E" represents an error in response, and reaction times for these errors were not recorded. Additionally, in producing the tables for the next subsection of this report, data points were eliminated in those few cases where a single subject recorded a response time for a particular slide which was more than twice the response time for any other subject. Such data points probably indicate momentary inattention by that subject.

Also, in the tables of the following subsection, means for subjects for any particular slide were deleted when there were fewer than five measurable responses for the eight subjects. The numbers in the tables of the following subsection accordingly represent means for at least five subjects for the selected slides and conditions to be compared, with times recorded in seconds and hundredths of a second. In the majority of these cases, three such numbers appear for a given message, these representing the response times for the same message when presented respectively with dot matrix (DM), stencil (STEN) and 16-segment (SEG) fonts.

2.4 RESULTS OF EXPERIMENT

As explained in the report on the earlier experiments (FAA-RD-72-150 and FAA-RD-73-55), the experimental design would not have permitted data reduction by an analysis of variance without a major increase in the number of slides requiring presentation. For this repeat experiment, the techniques of the previous reports have again been used; namely, that of analyzing variance of complete data blocks to generate an error term suitable for use with multiple t-tests.

From the tabulated raw data which are reproduced in Appendix E, the means of non-overlapping variables have been selected and are presented in Table 2-1.

TABLE 2-1. MEANS FOR NON-OVERLAPPING VARIABLES DISJUNCTIVE REACTION TIME IN SECONDS

MESSAGE TYPE	CHARACTER FONT		
	DOT MATRIX	STENCIL	SEGMENTED
SINGLE WORD	1.74	1.07	1.36
ARROWS ONLY	1.11	1.14	1.06
WORDS + NUMBERS	2.11	1.61	2.11
ARROWS + NUMBERS	1.80	1.78	1.87
THREE-LINE WORDS	2.43	2.20	2.13
THREE-LINE ARROWS	2.60	2.62	2.55
ONE-LINE ARROWS	2.06	2.41	2.35
ONE-LINE WORDS	2.65	2.01	2.83

Analysis of variance for these data was calculated, and is summarized in Table 2-2.

TABLE 2-2. ANALYSIS OF VARIANCE FOR DATA OF TABLE 2-1

SOURCE	SUM OF SQUARES	DEGREES OF FREE-DOM	MEAN SQUARE	F-RATIO
Message types	583.31	7	83.3	16.83
Font (Rows)	20.12	2	10.16	2.26
Interaction	69.24	14	4.95	
TOTAL	672.67	23		

Using the error terms thus calculated and the values of the t-distribution of 14 degrees of freedom, the required differences between means for various levels of significance may be calculated using the formula:

$$M_D = \left(\sqrt{\frac{2s^2}{N}}\right)(t)$$

where M_D is the mean difference between measures being compared, s^2 is the variance, N is the number of data points being compared and t is the value obtained from tables of the t-distribution. The results of such calculations for various levels of statistical significance are presented in Table 2-3.

TABLE 2-3. MEAN DIFFERENCES REQUIRED FOR MESSAGE TYPE/FONTS FOR VARIOUS SIGNIFICANCE LEVELS

Required differences in seconds

SIGNIFICANCE LEVEL		0.1	0.05	0.02	0.01	0.001
t-distribution of df = 14		1.761	2.145	2.624	2.977	4.140
MEAN DIFFERENCE M_D	MESSAGE TYPE	.196	.239	.292	.331	.460
	FONTS	.581	.708	.866	.982	1.366

A primary consideration in the earlier experiments using the same stimulus material was determining any differences in reaction time or error rate attributable to the use of the different type fonts, since lack of significance of this variable would greatly simplify the preparation of art work for future experiments. No significant differences among type fonts were found in the two earlier experiments, and the Data of Tables 2-4 further substantiate this conclusion.

TABLE 2-4. COMPARISON OF TYPE FONTS FOR DIFFERENT MESSAGE CATEGORIES

Disjunctive reaction time in seconds

MESSAGE TYPE	TYPE FONT		
	DOT Matrix	Stencil	16-Seg.
Radio Frequency	2.45	2.74	2.82
Left Turns	1.96	1.62	2.10
Climb Commands	1.90	1.73	2.17
Descend Commands	1.85	1.96	1.89
Right Turns	2.05	1.69	1.75
Acknowledgements	2.35	1.59	1.85
MEAN	2.09	1.89	2.10

In the first experiment using these stimulus materials, a difference among type fonts was found for messages containing "buried" arrows. With 16-segment characters, the only possible method for forming arrows results in their being only half the size of other characters. Consequently they are more difficult to locate. With the present experiment, a similar result was obtained; "buried" arrows in the 16-segment font produced longer reaction times, although this did not quite reach a level of statistical significance, as indicated in Table 2-5.

Similarly, the use of arrows alone produces slightly faster reaction times than does the use of single words, as indicated in Table 2-6. In the earlier experiments, this finding was at a low level of statistical significance, and here, it is non-significant.

Confirming the finding of the earlier experiments, the difference between the use of arrows and words when numerical values are added is non-significant, as indicated in Table 2-7. Similarly, the difference between the use of directional words versus

TABLE 2-5. COMPARISON OF TYPE FONTS FOR MESSAGES CONTAINING "BURIED" ARROWS

Disjunctive reaction time in seconds

DOT MATRIX		STENCIL		16-SEGMENT	
Slide No.	Time	Slide No.	Time	Slide No.	Time
10	1.70	58	1.64	106	2.20
13	2.37	61	2.95	109	2.39
19	2.99	67	2.68	115	3.40
21	2.01	69	2.63	117	3.28
27	2.38	75	2.98	123	3.11
29	3.40	77	3.05	125	2.19
34	1.66	82	1.51	130	1.61
37	2.63	85	1.85	133	2.36
MEAN	2.39		2.41		2.57

TABLE 2-6. COMPARISON OF SINGLE WORDS VERSUS ARROWS

Disjunctive reaction time in seconds. DM = dot matrix; Sten. = stencil; Seg. = 16-segment characters

SINGLE WORD COMMANDS			ARROWS ONLY		
Left	DM	1.27	←←	DM	1.32
	Sten.	1.02		Sten.	0.88
	Seg.	-		Seg.	1.03
Climb	DM	0.94	↑↑	DM	1.05
	Sten.	1.03		Sten.	1.10
	Seg.	1.14		Seg.	1.12
Descend	DM	1.07	↓↓	DM	1.06
	Sten.	1.04		Sten.	1.37
	Seg.	1.28		Seg.	1.06
Right	DM	2.02	→→	DM	1.04
	Sten.	0.97		Sten.	1.24
	Seg.	1.03		Seg.	1.03
MEAN		1.16			1.11

arrows in three-line messages is non-significant, as indicated in Table 2-8.

When rapid reaction is required, the earlier experiments indicated that arrows alone should be used, followed later by the addition of numerical values if required. The present experiment confirms this, and differences are again significant at the .001 level, as indicated in Table 2-9.

It was also found previously that the addition of numbers increases reaction time when such numerical values are added to textual commands such as "climb" or "descend." The differences found in the present experiment are even more striking, being significant at the .001 level, as indicated in Table 2-10.

A comparison between messages using an extended single-line format and the same information presented on three short lines indicates a shorter reaction time for the three-line format as indicated in Table 2-11. In the earlier experiment, this difference was significant at the .01 level. Due to the higher value of variance in the data of the present experiment, statistical significance of differences is not reached, even though the values differ by 0.14 seconds.

With multiple-unit messages containing both old and new information, it had previously been found that putting the new information at the top or left-hand side reduced reaction times even though the new information was delineated in all cases by setting it between asterisks. In previous experiments, this approached but did not reach a level of statistical significance. In both of the present cases, presented in Tables 2-12 and 2-13, these differences are significant at the .001 level. Even though extra computer programming may be required to place new information in favorable positions in the messages of a working Data Link System, this extra programming requirement can be justified.

The most striking difference between experimental conditions found previously was in the use of arrows instead of "L" or "R" in messages such as "HDGL210." Here, the use of arrows reduced reaction time greatly, and the differences were significant at the

TABLE 2-7. COMPARISON OF WORDS VERSUS ARROWS WITH NUMERICAL VALUES ADDED

Disjunctive reaction time in seconds. DM = dot matrix; Sten. = stencil; Seg. = 16-segment characters

MESSAGE	TIME		MESSAGE	TIME	
CLIMB210	DM	2.23	A↑120	DM	2.71
	Sten.	1.69		Sten.	1.71
	Seg.	2.71		Seg.	2.35
DOWN120	DM	2.15	A↓120	DM	1.52
	Sten.	1.33		Sten.	2.90
	Seg.	2.19		Seg.	1.92
MEAN		2.05			2.19

TABLE 2-8. COMPARISON OF WORDS VERSUS ARROWS IN THREE-LINE MESSAGES

Disjunctive reaction time in seconds. DM = dot matrix; Sten. = Stencil; Seg. = 16-segment characters

MESSAGE	TIME		MESSAGE	TIME	
TURN LEFT 180	DM	1.39	TURN	DM	1.95
	Sten.	1.46	←←	Sten.	1.68
	Seg.	1.67	290	Seg.	1.65
TURN RIGHT 090	DM	1.65	TURN	DM	1.31
	Sten.	1.50	→→	Sten.	1.44
	Seg.	1.71	110	Seg.	1.44
MEAN		1.56			1.58

TABLE 2-9. COMPARISON OF ARROWS ALONE VERSUS ARROWS WITH NUMERICAL VALUES ADDED

Disjunctive reaction time in seconds

ARROWS ALONE		ARROWS + NUMBERS	
Slide No.	Time	Slide No.	Time
15	1.32	16	1.95
63	0.88	64	1.68
111	1.03	112	1.65
23	1.05	20	1.59
71	1.10	68	1.39
119	1.12	116	1.46
31	1.06	28	1.23
79	1.37	76	1.80
127	1.06	124	1.92
39	1.04	40	1.31
87	1.24	88	1.44
135	1.03	136	1.44
MEAN	1.11		1.57

TABLE 2-10. COMPARISON OF MESSAGES HAVING TEXT WITH AND WITHOUT NUMERICAL VALUES

Disjunctive reaction time in seconds

TEXT WITHOUT NUMBERS		TEXT WITH NUMBERS	
Slide No.	Time	Slide No.	Time
14	1.27	12	1.39
62	1.02	60	1.46
110	-	108	1.67
22	0.94	18	2.25
70	1.03	66	1.69
118	1.14	114	2.71
30	1.07	26	2.15
78	1.04	74	1.33
126	1.28	122	2.19
38	2.02	36	1.65
86	0.97	84	1.50
134	1.03	132	1.71
MEAN	1.16		1.81

TABLE 2-11. COMPARISON OF LINEAR VERSUS THREE-LINE PRESENTATION OF THREE PARAMETERS (SUCH AS HEADING, SPEED AND ALTITUDE COMMANDS)

Disjunctive reaction time in seconds

LINEAR MESSAGE		THREE-LINE MESSAGE	
Slide No.	Time	Slide No.	Time
11	2.20	13	2.37
59	-	61	2.95
107	2.36	109	2.39
19	2.99	21	2.01
67	2.68	69	2.63
115	3.40	117	3.28
27	2.38	29	3.40
75	2.98	77	3.05
123	3.11	125	2.19
35	3.03	37	2.63
83	2.40	85	1.85
131	2.48	133	2.36
MEAN	2.73		2.59

TABLE 2-12. COMPARISON OF POSITION OF NEW INFORMATION WITH SINGLE-LINE FORMAT

Disjunctive reaction time in seconds

NEW INFO "BURIED"		NEW INFO ON FRONT	
Slide No.	Time	Slide No.	Time
4	2.27	7	2.46
52	3.26	55	2.45
100	2.85	103	2.73
19	2.99	11	2.20
67	2.68	59	-
115	3.40	101	3.55
27	2.38	35	2.02
75	2.98	83	2.40
123	3.11	131	2.48
MEAN	2.88		2.54

.001 level. Figure 2-14 presents the differences found in the present experiment, again significant at the .001 level.

TABLE 2-13. COMPARISON OF POSITION OF NEW INFORMATION WITH THREE-LINE FORMAT

Disjunctive reaction time in seconds

NEW INFO "BURIED"		NEW INFO ON TOP	
Slide No.	Time	Slide No.	Time
21	2.01	13	2.37
69	2.63	61	2.95
117	3.28	109	2.39
29	3.40	37	2.63
77	3.05	85	1.85
125	2.19	133	2.36
MEAN	2.76		2.42

TABLE 2-14. ARROWS VERSUS "BURIED" "L" OR "R"

Disjunctive reaction time in seconds. DM = dot matrix; Sten. = stencil, Seg. = 16-segment characters

MESSAGE	TIME		MESSAGE	TIME	
HDGL210	DM	3.49	HDG←230	DM	1.70
	Sten.	1.72		Sten.	1.64
	Seg.	3.39		Seg.	2.20
HDGE110	DM	3.07	HDG→120	DM	1.66
	Sten.	2.59		Sten.	1.51
	Seg.	2.35		Seg.	1.61
MEAN		2.77			1.72

The three experiments have produced remarkable consistency in results. Even though the levels of statistical significance have varied, the conclusions drawn previously remain valid. This, in turn, validates the use of TSC engineers as experimental subjects in studies of message format for Data Link messages. Table 2-15 summarizes the results for the three experiments using the same set of slides.

Error rate during the experiment was less than 2 percent, making it difficult to form any positive conclusions concerning errors. Only a single slide produced two errors. Errors per subject varied from zero to seven, but the subject with no errors had the shortest reaction time of the pilots tested.

Mean reaction time for the pilots of this experiment was 2.02 seconds. Engineers used in the previous experiment, in comparison, had a mean reaction time of 1.33 seconds. Here again, it is impossible to draw firm conclusions since reaction time increases with age and the average age of the pilots was approximately 20 years greater than that of the engineer subjects.

TABLE 2-15. COMPARISON OF STATISTICAL DIFFERENCES FOUND IN ORIGINAL AND PRESENT EXPERIMENTS

n.s = no statistically significant differences

PARAMETER	FAA-RD-72-150 EXPERIMENT	FAA-RD-73-55 EXPERIMENT	PRESENT EXPERIMENT
Type font differences	n.s	n.s	n.s
Buried arrows in type fonts	.001	.02	n.s
Single words versus arrows	.02	.05	n.s
Words versus arrows with numbers	n.s	n.s	n.s
3-line messages: words vs. arrows	n.s	n.s	n.s
Arrows alone versus arrows + numbers	.02	.001	.001
Test with and without numbers	.05	.01	.001
Linear versus 3-line messages	.001	.01	n.s
Position of information in 1-line format	.05	n.s	.001
Position of information in 3-line format	.05	n.s	.001
Arrows versus "buried" "L" or "R"	.001	.001	.001

2.5 SUMMARY AND CONCLUSIONS

A series of one hundred and forty-four slides was prepared representing ATC messages in six general categories, with variations in message format, coding and type fonts. The slides were presented individually to eight FAA NAFEC test pilots. Disjunctive reaction time was measured; additionally, when the subjects reacted to the information, it was automatically removed from the screen. They then were required to verbalize the content of the message. The results of the experiment indicated that:

(a) No differences in reaction time resulted from the use of different type fonts except when arrows as symbology were "buried" in the text. Here, the half-size arrows which are a limitation of 16-segment format resulted in longer reaction times.

(b) Arrows were better than words for simple IPC commands. The statistically non-significant trend in the data found here is reinforced by the statistical significance found in previous experiments.

(c) In an emergency situation, only arrows should be presented, followed later by numerical values, if necessary

(d) Multiple commands are better presented on three short lines rather than one extended line. Here again, the present experiment indicated only trends which are made significant by the results of earlier experiments.

(e) "New" information should be presented at the top or left of a display which maintains a "scratch pad" of the previous values of other parameters.

(f) The commands HDGLXXX or HDGRXXX, where "X" represents a digit, should be avoided and arrows substituted for the "L" and "R."

(g) The consistency of trends and of statistically significant differences found in this and earlier experiments validates the use of TSC engineers for studies of means for coding and formatting Data Link Messages.

3. FURTHER TESTS OF CODING SCHEMES

3.1 INTRODUCTION

The availability of FAA NAFEC test pilots at TSC for the simulator studies described in Section I of this report also permitted a second laboratory experiment to replicate tests previously run using TSC engineers as experimental subjects and described in Section I of Report FAA-RD-73-55. The present experiment studied the effects of length of abbreviations and the presence or absence of spaces in messages as variables influencing the speed and accuracy of message comprehension.

3.2 EXPERIMENTAL CONDITIONS

Twenty-five typical ATC messages were selected, and each was typed on individual file cards in four different forms:

(a) Using the shortest possible abbreviation without spaces.

(b) Using the same short abbreviations with spaces.

(c) Using longer abbreviations without spaces.

(d) Using the same longer abbreviations with spaces.

High contrast negative slides (clear characters on a black background) were prepared using a 2-inch by 2-inch format. The slides had a clear spot at one corner to permit the activation of a photocell which started a timer when the slide was projected on a screen. The slides were placed at random in alternate positions in the slide trays, separated by blank slides so that a response by subjects would remove the stimulus material from the screen. In order to vary the projection sequence further, the slides were divided equally between two slide trays, and the order in which the trays were presented to experimental subjects was alternated.

All eight of the FAA NAFEC test pilots participated individually in the experiment. Subjects were seated approximately 30 inches from a projection screen. Since this was a test of message meaning and not of visual acuity, characters were projected at a height of approximately one-half inch on the screen. At the start of the experimental session, each subject was given a typewritten sheet of instructions presented in Appendix A3.

3.3 EXPERIMENTAL RESULTS

The raw data from the experiment, organized by subject and slide categories, are presented in Appendix F. Mean response times for each of the slides and the number of errors, along with the precise formats displayed on the slide are presented in Table 3-1. Errors were recorded either when the subject failed to verbalize the message correctly or when his response time was greater than eight seconds. Even prior to any further processing of the data, it should be noted that the use of spaces reduced errors by more than 50 percent and reduced response times by approximately one-half second.

In the shortest form presented (slides 1 through 25), message lengths varied from four to eleven characters. Figure 3-1 presents mean response times as a function of message length for these twenty-five slides, along with the equivalent messages in longer versions (using spaces and/or longer abbreviations). As might be anticipated, the messages having larger numbers of characters produced longer response times.

It should also be noted that this increase is only modest when spaces are used in the messages and is much more pronounced in the absence of spaces.

Table 3-2 presents an analysis of variance of the variables (A) spaces versus no spaces, (B) short versus long messages, and (C) short versus long abbreviations. Variables (A) and (B) were significant at the .05 level; variable (C) was non-significant.

Both Figure 3-1 and Table 3-2 indicate the importance of the use of spaces, particularly as long abbreviations are used in the longer messages. Here, it becomes increasingly difficult to determine how many characters constitute a given abbreviation and where the next abbreviation begins.

TABLE 3-1. MESSAGE FORMATS, MEAN REACTION TIMES AND ERRORS

A	MESSAGE	B	C	A	MESSAGE	B	C	A	MESSAGE	B	C	A	MESSAGE	B	C
1.	HLDOFFRY33R	1.89	0	26.	HLD OFF RY 33R	3.16	1	51.	HLDOFFRNY33R	2.64	0	76.	HLD OFF RNY 33R	1.61	0
2.	HLDONTXB	2.60	0	27.	HLD ON TX B	1.94	0	52.	HLDONTXYB	3.49	1	77.	HLD ON TXY B	1.30	0
3.	RESS	1.98	0	28.	RES S	1.26	0	53.	RESSPD	1.49	0	78.	RES SPD	1.12	0
4.	BOST1234	2.30	1	29.	BOS T 1234	1.98	0	54.	BOSTWR1234	2.10	0	79.	BOS TWR 1234	1.72	0
5.	RQPOS	1.36	0	30.	RQ POS	2.61	1	55.	REQPOS	1.19	0	80.	REQ POS	1.02	0
6.	REPPOS	1.97	1	31.	REP POS	0.90	0	56.	REPTPOS	1.42	0	81.	REPT POS	1.83	0
7.	FPCNO	4.15	3	32.	FPC NO	3.37	0	57.	FPCNEG	3.51	1	82.	FPC NEG	3.97	0
8.	TXOFFRY	3.93	1	33.	TX OFF RY	1.20	0	58.	TXIOFFRNY	1.48	0	83.	TXI OFF RNY	2.40	0
9.	CLTKOFRY33L	3.48	0	34.	CL TKOF RY 33L	1.78	0	59.	CLRTKOFRNY33L	3.32	0	84.	CLR TKOF RNY 33L	1.76	0
10.	PHLA1234	1.90	0	35.	PHL A 1234	1.74	0	60.	PHLAPP1234	2.12	0	85.	PHL APP 1234	2.41	0
11.	SQLO	1.77	0	36.	SQ LO	1.08	0	61.	SQKLOW	0.93	0	86.	SQK LOW	0.94	0
12.	PHLD1196	2.79	0	37.	PHL D 1196	1.73	0	62.	PHLDEP1196	3.03	0	87.	PHL DEP 1196	1.77	0
13.	CLLDGRY33R	4.43	2	38.	CL LDG RY 33R	2.65	0	63.	CLRLDGRNY33R	2.94	0	88.	CLR LDG RNY 33R	2.15	0
14.	REPA	1.59	0	39.	REP A	1.63	0	64.	REPTALT	1.79	0	89.	REPT ALT	0.91	0
15.	REPS	1.55	0	40.	REP S	1.84	1	65.	REDTSPD	1.94	1	90.	REPT SPD	1.34	0
16.	CLHIAPP	3.27	0	41.	CL HI APP	2.78	1	66.	CLRHIAPP	1.27	0	91.	CLR HI APP	3.09	1
17.	V2MLS	2.37	1	42.	V 2 MLS	1.41	0	67.	VIS2MLS	2.59	0	92.	VIS 2 MLS	1.01	0
18.	W220@05	1.98	0	43.	W 220 @ 05	3.16	1	68.	WND220@05	1.97	0	93.	WND 220 @ 05	2.06	0
19.	RESS	1.01	1	44.	RES S	1.97	0	69.	RESSPD	2.33	0	94.	RES SPD	1.23	0
20.	CLRY	2.06	0	45.	CL RY	1.58	0	70.	CLRRNY	1.75	0	95.	CLR RNY	0.99	0
21.	CT@OM	2.85	2	46.	CT @ OM	2.16	0	71.	CTCTWR@OUM	4.80	0	96.	CTC TWR @ OUM	2.93	0
22.	XBOSA120	3.00	1	47.	X BOS A 120	3.05	0	72.	XBOSALT120	3.21	0	97.	X BOS ALT 120	2.24	0
23.	SLOS130	3.43	0	48.	SLO S 130	1.49	0	73.	SLOSPD130	2.34	0	98.	SLO SPD 130	2.15	0
24.	CBOSD1320	5.33	3	49.	C BOS D 1320	1.96	1	74.	CTCBOSDEP1320	2.33	0	99.	CTC BOS DEP 132	2.69	1
25.	CLINT	4.07	0	50.	CL INT	1.18	0	75.	CLRINT	2.50	2	100.	CLR INT	1.06	0
Mean Times & Total Errors		2.68	16			1.98	6			2.33	5			1.82	2

"A" columns indicate slide numbers, "B" colums the reaction time in seconds, and "C" columns the errors. The raw data from which this table was derived are reproduced in Appendix F

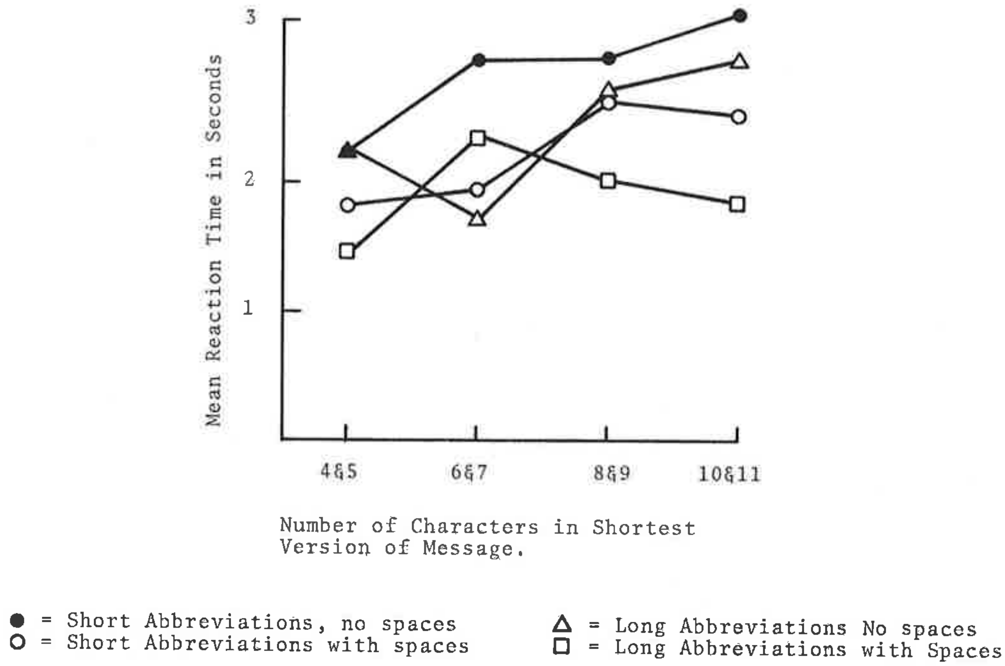

Figure 3-1 Mean Response Time in Seconds as Function of Message Length

TABLE 3-2. ANALYSIS OF VARIANCE OF THE THREE VARIABLES

SOURCE	df	SS	ms	F RATIO
A (Spaces)	1	.075	.075	11.5
B (Message Length)	1	.073	.073	11.2
C (Abbrev. length)	1	.014	.014	2.15
Error	4	.026	.0065	
TOTAL	7	.188		

TABLE 3-3. COMPARISON OF PERFORMANCE OF TSC ENGINEERS AND TEST PILOTS

		Short Abbrev. No Spaces	Short Abbrev. With Spaces	Long Abbrev. No Spaces	Long Abbrev. With Spaces
MEAN REACTION TIMES	TSC ENGINEERS	2.08	1.61	2.20	1.58
	TEST PILOTS	2.68	1.98	2.33	1.82
TOTAL ERRORS	TSC ENGINEERS	19	9	22	13
	TEST PILOTS	16	6	5	2

Since all abbreviations were not of equal length, it seems desirable to plot the data as a function of the number of information units in the message. "Information Units" in this context is defined simply as a word or a group of digits. Figure 3-2 indicates the mean reaction time in seconds as a function of the number of such information units in the messages. Here is should be noted that reaction times are consistently greatest when long abbreviations are used without spaces.

Figure 3-3 presents mean error rate as a function of the number of units of information in the message. Here is should be noted that error rate increases sharply as the amount of information increases. To be sure that information is transmitted to the pilot and interpreted correctly, messages should be as short as possible.

The results of the experiment again validate the previous use of TSC engineers as test subjects. Table 3-3 summarizes the results of the present and previous experiments using the same stimulus material. Mean reaction time for the test pilots was somewhat greater than for the engineers but much of this can be attributed to age differential. The relative reaction times to the four experimental conditions show identical trends. Similarly,

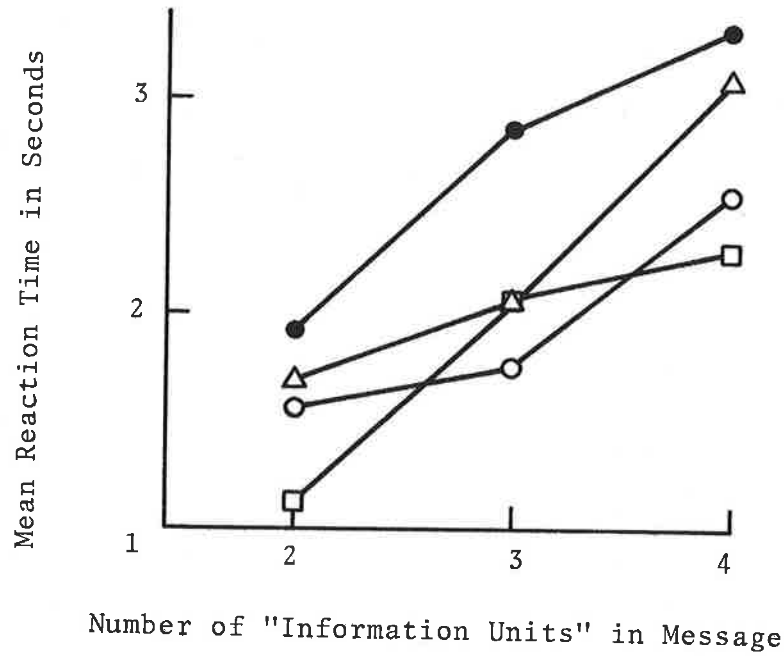

Figure 3-2. Mean Reaction Time as a Function of the Number of "Information Units" in Message

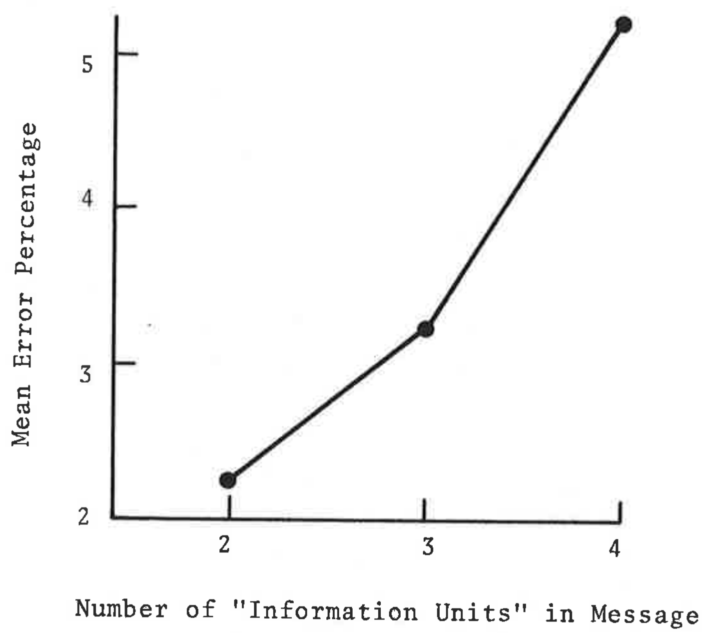

Figure 3-3. Mean Error Rate as a Function of the Number of "Information Units" in Message

the total errors for the two experiments under the four different conditions indicate that lack of spacing in messages greatly increases the incidence of error.

3.4 SUMMARY AND CONCLUSIONS

Twenty-five typical short Air Traffic Control messages were generated in each of four different forms involving the use of short and long abbreviations with and without spaces. These were presented as slides to eight FAA NAFEC test pilots, and reaction time and error rate in message interpretation were measured. The experiment indicated that the shortest possible abbreviations were meaningful to the pilots after only brief training, but that spaces between abbreviations were necessary if rapid and error-free interpretation was to be achieved.

APPENDIX A
INSTRUCTIONS TO EXPERIMENTAL SUBJECTS

A-1. INSTRUCTIONS GIVEN IN EXPERIMENT I

"You are about to participate in a series of simulated flights to evaluate four prototype displays which will present typical ATC messages. 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. At the conclusion of the series of simulated flights you will be asked to fill in a questionnaire concerning your evaluation of the several 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 prototype.

"Also, please note that while the display packaging is the same for the present four prototypes in order to facilitate their installation in the GAT-1, some of the display packages could physically be made much smaller. Remembering that the smaller the display can be made, the greater is its chance of competing for prime panel space, you will also be asked for your opinion concerning the tradeoffs between a small display in prime panel space and a larger display which might require installation in a less prime location.

"The scenarios which you will be flying must of necessity represent a compromise between the flying characteristics of the GAT-1 simulator (essentially a Cessna 150) and the message types which might be more applicable to a commercial jet. This is an experimental limitation over which we have no control. Please try to imagine that you are a commercial pilot.

Other considerations:

1. We are interested in how rapidly you comprehend the message and will be measuring your response time. On

messages which require you to make an adjustment such as a radio frequency setting, please press the "Wilco" button first, then make your setting.

2. Occasionally, we will give you an impossible message such as "Climb to 90,000 feet," or "Turn right to a heading of 540 degrees." Your response to such messages, of course, is to press the "Unable" button. Such messages are introduced to force you to interpret the messages correctly and not to press the "Wilco" button routinely and without thinking. The controller, in such cases, will then give you a reasonable and proper command.

3. At the start of a run, assume that clearance has been given to you as filed.

4. After setting a transponder code, always press the "ID" even though it is not requested. Pushing the "ID" will permit us to determine the accuracy of your setting.

5. Always "Wilco" a traffic advisory. In the absence of an out-the-window display, we must assume that you can always locate such imaginary traffic. The small CRT (the NIMO) presently does not have a means for indicating that the traffic is no longer a threat. Please assume that when the next message is presented, you should no longer be concerned with the traffic advisory.

6. 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, saving other comments for later. A prime objective of this experiment is to determine how much verbal communication can be eliminated by the use of Data Link.

7. Certain messages will present a new command while maintaining a "scratch pad" of other previous commands. In such

cases, the new material will be identified by being enclosed in asterisks, e.g. "HDG 230 *ALT 050* SPD 090".

8. The scenarios end with a Ground Control frequency assignment.
9. Please do not discuss the details of the scenarios with the other pilot subjects until after they have completed all of their simulated flights."

A-2 INSTRUCTIONS GIVEN IN EXPERIMENT II

"IT IS IMPORTANT THAT YOU READ THESE INSTRUCTIONS CAREFULLY TAKING ALL THE TIME THAT YOU WISH, SINCE YOUR PERFORMANCE ON THIS TEST WILL DEPEND TO A LARGE EXTENT ON HOW WELL YOU HAVE ABSORBED THE INFORMATION ON CODING AND ABBREVIATIONS.

This is a study to determine how best to present some of the commands which will be issued to pilots via Digital Data Link during forthcoming flight tests. In this experiment, slides will be presented on a screen and you will be asked to respond as rapidly and accurately as possible to the various types of command.

Your control box has six buttons. The four central buttons, arranged in a diamond-shaped pattern, represent your aircraft controls for up, down, right and left. The button on the extreme left represents your control of the frequency of your radio transceiver. The button on the extreme right is used to acknowledge all other commands or advisories. You are thus required to interpret the message before making a response. When you do make a response, the screen will go blank and you will then be asked to verbalize the message. You will be scored both for the accuracy and speed of your response, although accuracy is the preferred criterion.

Various types of abbreviations will be used at the start of messages:

A = ALT = ALTITUDE, modified by up, down, climb, descend or appropriate arrows.

C = CONTACT. This indicates a command to change radio frequency.

H = HDG = HEADING, modified by R, Right, L, Left or appropriate arrows.

S = SPD = SPEED

T = TURN, modified by R, Right, L, Left or appropriate arrows

When single-letter abbreviations are used, the ones listed above always appear first, but may be followed in the case of a radio frequency command by a second single-letter abbreviation to indicate a specific controller. Thus:

CT = CONTACT TOWER

CA = CONTACT APPROACH CONTROL (Note that the "A" in second position stands for "Approach", not "Altitude").

CG = CONTACT GROUND CONTROL.

On some slides, you may see multiple categories of information. In this case, the new information to which you should respond is set off by asterisks, e.g., HDG 230 *ALT↑160* SPD 220. In the example listed, the appropriate response is, of course, to press the "climb" button.

Examples of commands which require the use of the right hand "Acknowledge" button are:

MAINTAIN ALTITUDE
HOLD SPEED
SQUAWK (This supplies a setting for your transponder).
RADAR CONTACT
CLEARED FOR TAKEOFF
TRAFFIC 12 O'CLOCK 2 MILES.

You will have only one chance to respond to each slide. Do you have any questions?"

A-3 INSTRUCTIONS GIVEN IN EXPERIMENT III

"This is an experiment to determine how cryptic the coding of Data Link messages may be and still provide meaningful information which can be interpreted accurately and rapidly by the pilot.

With brief coding, we can use a smaller display and have a higher probability that the display can be located in a prime viewing area on the panel, but this must be weighted against the training requirements for the pilot and the possibility of errors in message interpretation. We will accordingly give you a maximum of 15 minutes to memorize the abbreviations below; you may take less time if you feel confident that you have them memorized. We will then test you on your ability to interpret short air traffic control messages accurately and rapidly using these abbreviations in combination.

Heading, altitude and speed commands are always followed by 3-digit numbers and radio frequency settings by 4 or 5-digit numbers; this in the shorter abbreviations serves to differentiate between the use of "A" for "altitude" and for "approach," since the latter represents the radio frequency setting for the approach controller position. Runways are designated by one or two-digit numbers and taxiways by 1 or 2 letters. Airports and fixes are 3-letter combinations. This experiment will limit these to Boston (BOS) and Philadelphia (PHL). The other abbreviations to be used are:

ALTITUDE	A,ALT	HOLD	HLD
APPROACH	A,APP	INTERSECTION	INT
CLEAR (or) CLEARED	CL,CLR	LANDING	LDG
CONTACT	C, CTC	LEFT	L
CROSS	X	LOW	LO,LOW
DEPARTURE	D, DEP	MILES	MLS
FLIGHT PLAN CHANGE	FPC	NEGATIVE	NO, NEG
HIGH	HI	OUTER MARKER	OM,OUM
POSITION	POS	SQUAWK	SQ,SQK
REPORT	REP,REPT	TAKEOFF	TKOF
REQUEST	RQ, REQ	TAXI	TX
RESUME	RES	TAXIWAY	TX, TXY
RIGHT	R	TOWER	T, TWR
RUNWAY	RY,RNY	TRAFFIC	TFC, TRAF
SLOW	SL	VISIBILITY	V,VIS
SPEED	S, SPD	WIND	W,WND

Certain distinctions should be made from the context of a message. Thus, you might be asked to <u>clear</u> a runway, moving off to allow an emergency landing by another aircraft, or you may be <u>cleared</u> for takeoff on a specific runway. Similarly, you may be asked to hold on a <u>taxiway</u> or to <u>taxi</u> to a position.

During the experiment, each time a slide is presented, press the response button as soon as you have interpreted the message. The slide will then blank, and you will be asked to verbalize the message to demonstrate that you know its meaning and that you are not merely repeating the symbols which you have seen on the screen.

Are there any questions?"

APPENDIX B
PILOT QUESTIONNAIRE AND RESULTS

The responses of the individual pilots are identified by the letters "A" thru "H" and do not represent the order in which the individual pilots participated. The questionnaire, after blanks to be filled in concerning age and experience, stated:

YOU HAVE JUST PARTICIPATED IN THE EVALUATION OF FOUR PROTOTYPE DISPLAYS FOR DATA LINK:

1. 7W. A DISPLAY LIMITED TO SEVEN WINDOW (CHARACTERS), USING INCANDESCENT LAMPS AND FIBER OPTICS.
2. 3 x 7 WINDOW. THREE LINES OF SEVEN CHARACTERS USING LIGHT EMITTING DIODES IN A 5 x 7 MATRIX FOR CHARACTER GENERATION.
3. 32W. A DISPLAY PRESENTING 32 CHARACTERS ON ONE LINE, USING PLASMA.
4. NIMO. A MINIATURE CHARACTRON CATHODE RAY TUBE.

1. DID YOU HAVE A PREFERENCE FOR ONE PARTICULAR DISPLAY? IF SO. WHY?

S-A Two equal. 32 Window and 3 x 7.

S-B Yes. 3 x 7W. Because it was clearly visible in both light and dark cockpits. Easy to interpret, and ease of operation.

S-C 32W. Reduces the pilot effort. Affords single line clearances without repeated use of "Wilco" to bring up register, it is felt that longer clearance capability will be necessary in actual conditions.

S-D CRT NIMO. Compact and easy to scan and read, with simplicity of presentation.

S-E Order of preference: Nimo, 32W, 3 x 7W, 7W.

S-F I think all four displays are excellent. To make a choice, however, I would prefer the 7W unit with the ability to scroll through the 3 message lines.

S-G 32W is my preference because the information was more clearly presented (no confused abbreviations) and all of it (for a given message) was continuously displayed without a requirement to push a button and scroll up other info.

S-H 32W. Requires no channeling. Uses same phraseology as present ATC system. Characters easy to read. Only disadvantage: in bright sunlight is hard to read. Could possibly use a visor.

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

S-A No.

S-B No.

S-C No.

S-D Yes. 32W had more than enough, and resulted in a long scan.

S-E With proper symbolization, all displays could present less info.

S-F No.

S-G 3 x 7W was confusing to decipher at times.

S-H No.

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

S-A 3 x 7 HDGR030
7W TXINHLD, RES NAV, ✓ for V

S-B Yes. 7W. TXINHLD, the "X" appeared smaller to me. Operation required too much attention and more operations from pilot.

S-C 3 x 7W. Format was weak and confusing on the first scenario.

S-D Words without spacing are hard to interpret. The letter "L" and "R" for direction is harder to interpret than arrows.

S-E The NIMO and 32W for the message supposed to mean POS 32R HLD.

S-F The clearance for a "HIGH APP" was confusing.

S-G 3 x 7 particularly when alpha-numerics of different words were run together (no spaces). HDGR055. LOM 1 should be LOM 1 MI. Also, characters were much too large for short focal length. Excessive eye movement required.

S-H The 3 x 7W when presenting heading changes with a full lines of info. Suggest the direction be indicated by an arrow. Also, with traffic info, there could be a confusion (see remarks).

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

S-A Difficult to judge. Believe 32W could be displayed anywhere.

S-B Larger in a less desirable location.

S-C Large display. Reason is the clearance change after noticed as secondary to flight.

S-D Small display in prime space.

S-E Small display in good location, Display located out of natural scan area is confusing and dangerous, especially when messages are received while on approach.

S-F The larger display.

S-G Small display. Too great an offset creates a distortion.

S-H Large display is less desirable area. Would depend somewhat on crew size.

5. WERE ANY OF THE DISPLAYS DIFFICULT TO READ UNDER SIMULATED SUNLIGHT?

S-A No.

S-B Yes. 32W.

S-C All displays were similarly affected.

S-D Yes. 32W was a bit dim.

S-E No. All displays were easy to read. It was more difficult to see the instruments when flying into the sun.

S-F No.

S-G No, but the glare in the cockpit was grossly annoying.

S-H Yes. The 32W was difficult to read in direct sunlight.

6. WERE ANY OF THEM TOO BRIGHT UNDER SIMULATED NIGHT CONDITIONS?

S-A No.

S-B No generally. However 7W being white there may be an objection.

S-C Not with white light.

S-D Yes. Both the 7W and the 3 x 7W and the button lights. All the displays should have intensity controls.

S-E 3 x 7W was definitely too bright Red and out of proper light balance with the rest of the cockpit.

S-F No.

S-G Yes. White lighting on 7W and white lights in all push buttons. A dimming pot is required. Did not particularly care for bright red lighting in 3 x 7W. Dimming pot required. In fact, eliminate red lighting. White is preferable.

S-H Yes. The red 3 x 7W.

7. DID YOU FIND THE REQUIREMENT FOR SCROLLING THROUGH PORTIONS OF MESSAGES ON THE 7W DISPLAY TO BE ACCEPTABLE?

S-A Acceptable but not desirable.

S-B No.

S-C Acceptable but not desirable.

S-D Yes, but comparatively undesirable.

S-E Absolutely unacceptable. This creates unnecessarily large cockpit workload and distracts the pilot from more important duties.

S-F Very much so.

S-G Yes.

S-H Yes.

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

S-A 3 x 7 or 32W. NIMO not very good.

S-B All except NIMO seemed adequate.

S-C 32W Plasma size 1/4 seemed most suitable.

S-D No. They are all easy to use.

S-E I liked the size in the NIMO presentation. Disregarding some problem with misalignment, I found it the proper size to read.

S-F No.

S-G Yes. 32W was first choice, NIMO second.

S-H Yes. The 7W.

9. DO YOU HAVE ANY COLOR PREFERENCE?

S-A Red as 3 x 7. However, 32W good.

S-B No.

S-C No.

S-D Yes. White or green - not red.

S-E Green color in NIMO.

S-F Yes. Anything but red.

S-G Yes. 32W orange.

S-H White

10. DID THE FLASHING OF THE DISPLAY PROVIDE SUFFICIENT ALERTING?

S-A Yes.

S-B Not used alone. Used with audio.

S-C No.

S-D Yes, in combination with beeper.

S-E Yes.

S-F Yes.

S-G Usually.

S-H Not unless WILCO light is included.

11. WOULD YOU PREFER LONGER OR SHORTER FLASHING?

S-A No.

S-B Longer.

S-C Rate is acceptable.

S-D No. The current time is OK.

S-E OK as is.

S-F Period used is fine.

S-G OK as is.

S-H OK as is.

12. DID YOU FIND THE AUDIO ALERT HELPFUL?

S-A Yes.

S-B Yes.

S-C Yes, without it in daylight operation, I feel you would not recognize 10 above.

S-D Yes, but it must be distinctive in the particular airplane in question.

S-E Very much so. (Very important!)

S-F Yes.

S-G Definitely!

S-H Yes.

13. DID YOU FIND THE METHOD OF DELINEATING "NEW" INFORMATION BY SETTING IT OFF BY ASTERISKS OR LIGHTS TO BE HELPFUL, AND DID YOU NEED THIS ADDITIONAL CUE?

S-A Asterisks good. Red lights on 3 x 7 poor. Maybe in line better.

S-B Yes.

S-C Not as much as I thought. However, asterisks seemed best.

S-D Yes. It is desirable but not essential.

S-E It was helpful, but for example, on #3 (32W), it was still buried in other information, making it less easy to separate from old info.

S-F Yes and yes.

S-G Definitely prefer asterisks or something similar.

S-H Yes. Prevents indecision.

14. 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)?

S-A Both acceptable but not desirable.

S-B No.

S-C No. However, stencil in test was cleaner.

S-D All are good. 7W is probably best.

S-E The NIMO CRT. I feel this has much better potential and could be made to accept various symbols better.

S-F No.

S-G Prefer dot matrix of 32W.

S-H Dot matrix.

15. WOULD YOU LIKE AUDITORY BACKUP OF THE MESSAGES VIA SYNTHETIC SPEECH?

S-A No.

S-B No.

S-C On command only.

S-D Appears unnecessary but should be tested.

S-E In the final phases of the approach, the messages should be verbal, so as not to break up the pilot's scan and ILS concentration. Put WILCO button on control column. Also, on takeoff, commands should have verbal backup.

S-F I would like very much to try this.

S-G Did not feel it necessary during these tests.

S-H No. Would add to distraction in the aircraft.

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

S-A No.

S-B No.

S-C No.

S-D Possible but should be tested. Visual is hard to beat.

S-E Visual display is OK with synthetic speech backup on final or T/O so that pilot does not have to take his eyes from other instruments.

S-F I have no opinion yet.

S-G No. Far more probability for error with synthetic speech.

S-H No.

17. WOULD YOU PREFER HAVING THE "WILCO" BUTTON ON THE CONTROL COLUMN RATHER THAN ON THE DISPLAY?

S-A No.

S-B Yes, especially in single pilot A/C.

S-C Yes.

S-D Maybe: should be tested.

S-E Yes. See above.

S-F No.

S-G No. Too easy to reflexively actuate prior to actual comprehension of the message.

S-H Yes.

18. WHAT ABOUT LOCATION OF THE OTHER CONTROLS?

S-A Good.

S-B No. They could remain on display.

S-C Should be with the unit.

S-D Displays shoud be arranged to integrate with the rest of the panel for optimum visual scan workload.

S-E All three buttons could easily be accommodated on control wheel. The WILCO should be there definitely.

S-F Just fine.

S-G Should be close enough for easy use, but not in a location to permit careless or accidental "wipeout" of the message, e.g. "clear" button.

S-H OK on control box so long as they were in easy reach.

19. WAS THE "SCRATCH PAD" CAPABILITY OF THE DISPLAY HELPFUL: E.G., PERIODICALLY REPEATING HEADING, ALTITUDE AND SPEED INFORMATION?

S-A Helpful but not adequate.

S-B Yes.

S-C Yes, in as much as no retention of long term clearance.

S-D Yes. Some form of message retention should be made available for pilot reminder use.

S-E Occasionally it was helpful, but several times I found it distracting after I read it and found no new information in it.

S-F Yes.

S-G Yes.

S-H Yes.

20. WERE THERE CASES WHERE TOO MUCH NEW INFORMATION WAS PRESENTED AT ONE TIME?

S-A No.

S-B No, provided it could be referred to as long as necessary.

S-C (no answer)

S-D Yes. Messages should be separated by a short time delay to avoid pilot overload and memory "smear."

S-E Frequency change and transponder code must be separated or the pilot has to have the capability to WILCO this information, but retain it until accomplished.

S-F No.

S-G Qualified yes. Simultaneous requirement to change both comm. radio and transponder induced mild stress. (Which should I do first)?

S-H With the 3 x 7W, when traffic info and aircraft instructions were mixed there was some confusion.

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

S-A No.

S-B No, provided it could be referred to as long as necessary.

S-C No.

S-D Probably yes, to give time for pilot response, unless the retention was developed as a substitute.

S-E Yes in some cases. Climb + turn is one.

S-F I don't think so.

S-G Mild yes.

S-H Yes, for the 7W.

22. DID YOU EVER CLEAR THE DISPLAY? IF SO, REGULARLY, OR INFREQUENTLY? WHICH DISPLAYS?

S-A No.

S-B Yes. 1/2 the time. All.

S-C Yes. Infrequently. NIMO & 32W.

S-D Yes. Occasionally. 7W & 3 x 7 mostly due to over brightness.

S-E Yes. Infrequently. 3 x 7W (too bright and distracting).

S-F Yes. Infrequently. All.

S-G Yes. Infrequently. 7W (white lights) annoying at times under simulated night conditions.

S-H Yes. Regularly. 3 x 7W. Find the red glare distracting particularly at night.

23. DID YOU EVER SCROLL THROUGH THE 7-WINDOW MESSAGES AFTER INITIAL RECEIPT OF THE MESSAGE? IF SO, HOW OFTEN?

S-A Yes. Frequently. The 7-window control system created too much workload and while playing with message pending control, a new message was received at the most improper moment - confusing pilot. Believe previous message was not erased.

S-B No, not that I remember.

S-C Yes, particularly when they included several function changes.

S-D Yes. Fairly often. On the 7W, simultaneous activation of pending button and receipt of new message could hide first part of message. Scrolling causes some preoccupation, especially disconcerting at night.

S-E Yes. Whenever I was not sure that I understood properly. Sometimes, it was already gone.

S-F Yes. Three or four times.

S-G Yes. Would always return display to command info such as heading, altitude or new frequency.

S-H Yes. Frequently.

24. THIS QUESTION REQUESTED COMMENTS CONCERNING IMPROVING THE MESSAGE CONTENT OR CODING OF THE NIMO MASK. THE MAJOR SUGGESTION HERE WAS THAT STANDARD ABBREVIATIONS BE USED. ALSO SUGGESTED; ELIMINATE "RIGHT" AND LEFT" AND USE ARROWS ONLY. CHANGE STENCIL TO PROVIDE BETTER DISTINQUISHABILITY BETWEEN "O" AND "8." INVESTIGATE POSSIBILITY OF FLASHING ARROWS FOR EMERGENCY COMMANDS. ADD "IDENT." QUESTION USEFULNESS OF "CLEARED TO TAXI." "DEPART FIX" RATHER THAN "DEPART STACK."

25. WAS THE LACK OF A DECIMAL POINT IN CERTAIN DISPLAYS TROUBLESOME?

S-A In NIMO

S-B No.

S-C Yes, when format was not satisfactory.

S-D No, but a decimal in CRT would help.

S-E It is a matter of getting used to it and of no consequence.

S-F No.

S-G Mildly.

S-H Yes.

26. DO YOU FEEL THAT CERTAIN LACK OF REALISM IN THE SCENARIOS MAY HAVE BIASED YOUR RESULTS, AND CAN YOU OFFER CONCRETE SUGGESTIONS FOR IMPROVEMENTS?

S-A Too much too fast. Critique after each flight with tape recorder. Extend four periods to an 8-hour day.

S-B Possibly more attention could have been directed to the displays without the complication of flying the scenarios in a super sensitive trainer like the GAT-1. I would like to suggest a more stable platform.

S-C No. I don't believe so.

S-D Probably not much bias. However, some improvement could be made in some items. (See comments at end).

S-E Scenarios were OK for the exercise.

S-F I believe this particular test was handled exceptionally well and the only complaint I would have is the difficulty in flying the simulator.

S-G The only problem was the instability of the simulator itself - although it did not bias my evaluation.

S-H No.

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

S-A Install 32-window center of instrument panel - high - just under upper sun shield or cowling. Red color like 3 x 7. Asterisks instead of red lights for new message. If instrument panel too far from either pilot, install on forward end of console between seats. Need controls on the display.

S-B 3 x 7 seemed comfortable to me.

S-C Two-line block print sharp red or amber. 1/4" size. Data info to handle alt, spd, hdg or course/airway on App info, freq., etc. However, I feel we must look closely at the information and the control we expect to render through Data Link. Observation; that splitting the message requiring scrolling is not too acceptable. Therefore, I favor the 32 character. If feel is necessary two lines would be very satisfactory but 3 lines is complex and since a certain amount of memory is involved, the complexity may be unacceptable.

S-D I would be inclined toward the NIMO display approach, with additional elements to provide message retention and pilot-entry note taking. The green color and display size are apparently quite satisfactory from both visibility and distractive points of view.

S-E Large enough to accommodate simple messages and not more than 3 lines.

S-F As I stated before, the 7W would probably by my preference and I think either white or amber colors are more favorable.

S-G The 32-window presentation is basically satisfactory as it currently exists, to satisfy my senses for comprehending and interpreting transmitted intelligence. My design would resemble 32W, however, I would like to add a feature to remind me or enable me to recall command information such as heading, altitude, etc. It can be accomplished either by adding displays to show the last commanded heading or vector, altitude, comm. freq. etc. Perhaps it would be more desirable to broaden the scope of the system to permit the pilot to request repeats or confirmation of information by pressing a discrete button, such as, "A" - "Request repeat/confirm altitude assignment."

S-H The character size of the 7W was desirable, but that of the 32W was adequate, and the 32W and 7W style is desirable. However, I would prefer white lights.

28. ADDITIONAL COMMENTS?

S-A All displays require continuing information such as a altitude, speed, heading or route. Co-pilot could maintain manual annunciator if necessary. CRT display appears cheapest to produce, and would no doubt be the least reliable. Distortion, narrow field of view. The 7-window control system created too much work load and while playing with message pending control, a new message was received at the most improper moment-confusing pilot - believe previous message was not erased.

S-B Depending on other psychological factors, it may be more advantageous to show this questionnaire to subjects before the test. Some of the questions refer to points that may not have been noted or thought to be of intended value.

> Note: On the basis of this comment, the questionnaire were shown to the remaining subjects prior to their simulator runs.

S-C (1) Identify that the Data Link use as represented is a supplement to an already received full Flight Clearance, and that any change of clearance would come through a printer. (2) Clearance should not be given or response expected until the operation of aircraft is accomplished, for example, at the time of Glide Slope engage. (3) Sun glasses have a serious degradation of ability to see the displays. (4) Sunlight will completely obscure the displays without some additional face engineering. Try Polarized screen. This worked in the EADI Display. (Flt. Director). (5) Never mix abbreviations with fully written controls when abbreviations exist etc.

S-D (1) Change Red to White, and dimmable. (2) Delay the WILCO button lite for five sec. (3) "Scratch pad" retention for critical factors. (4) CRT display is very good; green is easy to read. (5) Use multiple CRT's for "scratch pad" and pilot notes. (6) Five second WILCO light delay is about right. (7) White on 7W is good. (8) 32W is easy to read but a little dim. (9) Relief from audio fatigue is great. (10) On the 7W simultaneous activation of the pending button and receipt of new message could hide first part of message. (11) Buttons need illumination. (12) Scrolling causes some preoccupation, especially disconcerting at night. (13) Some minimum delay between messages would be an advantage. (14) Unusual maneuver commands may require explanatory advisory. (15) "New Message" lights desirable but not essential. (16) System appears to be a "natural" for flight parameter proximity warning.

such as altitude, heading speed, etc. (17) Provide ATIS on Data Link. (18) CRT digits are sometimes hard to distinguish ("8" vs. "0") for example. (19) Emphasis on visual communication makes instrument arrangement more critical re: eye scan workload. (20) Inbound to GDM, the commands "depart in 1 min" and " resume nav" are somewhat redundant and might be combined.

S-E Weather info: BOS 10 2 / -S 220/5 This was always one of the most desirable items on Data Link. (2) Other item: Clearances. A lengthy clearance from clearance delivery could be read and copied in segments. Each WILCO would advance to the next portion of the clearance until all copies and understood instead of a read-back. (3) Green on CRT display is a nice color and easy to read. (4) Departure clearance should be given in position on runway, not on a climb out, (most dangerous part of flight). (5) Traffic advisory given on 3 x 7W is confusing and time consuming; there is positively too much to read. (6) 7W creates dangerously too much pilot workload. Pilots can't be bothered pushing buttons instead of flying, especially on final. The letters are unnecessarily large. (7) NIMO display could be placed under glare shield in pilot's view. (8) Symbols should be spaced better. (9) This flight simulator has the VOR/ILS X-pointer too far right and out of normal scan for precise navigation. (10) 32W is unnecessarily large. Perhaps OK for transport category A/C where it could be located on center console to be in view of both crew members. Full letters are not necessary; abbreviations are just as good, symbols even better. (11) There should be a verification that the Data Link is working OK. On long legs, especially at night when the traffic is light and there is no radio chatter, pilots will call the center from time to time to see if the radios are working. (12) It will be frustrating to get in touch with the computer or an impersonal voice when one gets a wrong clearance!

S-F I think the small NIMO CRT should be installed so that the face of the tube would be perpendicular to the pilot's line of vision.

S-G Suggest using a tape recorder to enable a subject pilot to record his impressions or comments during or immediately after a run. Also "taping" a debrief after completion of all runs will provide a good deal more useful info than this written questionnaire.

S-H With cost as no factor, I rate the different systems as follows:

1.	32W:	Good:	Lettering and presentation. Current Phraseology. Requires no scrolling. Asterisks for new information.
		Bad:	Hard to read in bright sunlight. Would prefer white lights. Might use more symbology as arrows instead of words.
	7W:	Good:	Size of symbols. White lighting. Good warning indication. Retains considerable info.
		Bad:	Requires considerable scrolling. Requires considerable WILCO responses when multiple messages come in.
	3x7W:	Good:	Presents considerable amounts of info. Does not require scrolling. Indicates new info.
		Bad:	Red lights. Some letters and numbers are hard to read. When a line is filled with info, so that no spaces are available, instructions required a second look. Suggest using arrows wherever possible.

When traffic info includes altitude, pilot could interpret as instructions for his aircraft. If arrows were used for aircraft instruction and present system used for traffic info, this could be avoided.

NIMO: Good: Size, easy to read except as noted below. Lighting.

Bad: Only limited info. Requires some conversation which diminishes the usefulness of the system. Numbers are hard to read and their spacing with letters is not acceptable.

Note: For a multiple crew operation, this system would be adequate since info would be written down by crew as is presently done.

APPENDIX C
DEBRIEFING SESSION AND RESULTS

1. THE QUESTIONNAIRE FAILED TO INDICATE ANY CONCENSUS AS TO WHAT WAS THE BEST OF THE FOUR DISPLAYS. WOULD YOU PLEASE RANK-ORDER YOU PREFERENCE, SINCE THIS MAY INDICATE THAT SOME SECOND CHOICE REPRESENTS THE BEST COMPROMISE.

Table C-1 summarizes the rankings given the four displays by seven pilots. By assigning a weight of 4 for a first place ranking, 3 for second, 2 for third and 1 for fourth, the weighted scores shown in Table C-2 were obtained. The 32-window display is clearly first and the 7-window fourth, but second and third remain undecided.

TABLE C-1

RANK ORDER OF PREFERENCE

PILOT	A	C	D	E	F	G	H
1st	32W	32W	NIMO	NIMO	7-W	32W	32W
2nd	3 x 7	3 x 7	3 x 7	32W	32W	NIMO	7-W
3rd	NIMO	(7-w)	32W	3 x 7	3 x 7	3 x 7	3 x 7
4th	7-W	(NIMO)	7-W	7-W	NIMO	7-W	NIMO

TABLE C-2

WEIGHTED SCORES

	7-W	3 x 7	32W	NIMO
1st	1	0	4	2
2nd	1	3	2	1
3rd	½	4	1	1½
4th	4½	0	0	2½
WEIGHTED SCORE	12½	17	24	16½

2. DID THE TWO MEANS OF INITIALLY SCROLLING THROUGH THE 7-WINDOW DISPLAY (WILCO OR MESSAGE PENDING BUTTONS) RESULT IN CONFUSION AND SHOULD THIS BE CHANGED?

There was general agreement among the pilots that the WILCO button should not scroll to the next line of the message, i.e., the Message Pending button would be the sole means for scrolling in the 7-window display. Also, at least one subject inadvertently missed the first line of a new message when it was sent up at the same time that he was scrolling through the previous message.

3. WITH THE 7-WINDOW DISPLAY, WOULD YOU LIKE AUTOMATIC SCROLLING, AND IF SO, WOULD YOU FEEL IT NECESSARY TO PROVIDE AN ADJUSTABLE SPEED CONTROL? WOULD TWO LINES OF INFORMATION BE PREFERABLE TO THREE IN THIS CASE?

"You're just beating a dead horse" was the response of one pilot who did not like the 7-window display. Several pilots felt that such a display would create an annoying condition whereby the pilot, if he could not look continuously at the display to see both lines of a message, may see the same line of the message each time he glanced at the display. A variable speed control was desirable to most pilots, and there was no concensus on three lines versus two.

4. TO REDUCE VISUAL WORKLOAD, WOULD YOU PREFER VOICE ON FINAL APPROACH, EITHER ALONE OR AS BACKUP? WHICH? HOW ABOUT ON DEPARTURE? OTHER CRITICAL TIMES?

The general feeling here was that verbal backup, particularly during approach, should be tried in the next series of experiments, although one pilot indicated that he preferred the total elimination of voice that data link could provide.

5. A VOICE SYNTHESIZER COULD PROVIDE AUTOMATIC CALLOUT OF ALTITUDE DURING FINAL APPROACH. WHOULD YOU CONSIDER THIS DESIRABLE?

Same response as #4. They felt this may be more useful in the single man cockpit.

6. RESPONSE TIMES WERE EXTREMELY LONG ON MESSAGES CONTAINING COMBINED RADIO FREQUENCY CHANGES WITH TRANSPONDER CODE SETTINGS. HOW IS THIS HANDLED WITH EXISTING VOICE COMMUNICATION, AND IS A PROCEDURAL CHANGE NECESSARY FOR DATA LINK?

Normally, the pilot sets these into the appropriate instrument as the ground controller gives them, and then "reads it back" from the settings on the instrument. The delay on this particular type of message was primarily due to the pilot setting in both the new frequency and transponder code before responding with a WILCO, since he knew that once the WILCO was depressed, a new message may be transmitted and he may forget the information if he had not already set it in. The pilots felt this delay may be reduced in a two-man crew situation where one pilot could handle the transponder and the other the radio.

7. WOULD YOU LINK A DEDICATED DISPLAY OF HEADING, ALTITUDE AND SPEED COMMANDS, OR WOULD YOU PREFER TO BE ABLE TO CALL THESE UP AT WILL ON YOUR PRESENT DATA LINK DISPLAY? A THIRD ALTERNATIVE WOULD BE TO DEDICATE A PORTION OF THE DISPLAY (e.g., THE LAST NINE DIGITS OF 32-WINDOW) TO HEADING, ALTITUDE, AND SPEED.

All pilots were in favor of some form of heading and altitude "scratch pad" capability. The need for speed information was not felt to be as important, but may become more so in the future. Also, the preference for a particular form of scratch pad capability could not be determined without trying the various options in a simulator.

8. WITH A DEDICATED HEADING, ALTITUDE AND SPEED, IS IT CORRECT TO ASSUME THAT ONLY THE ALTITUDE CLEARANCE SHOULD BE DISPLAYED WHEN THE FLIGHT IS PROCEEDING AS FILED? (V OR J AIRWAY INFORMATION COULD ALSO BE DISPLAYED).

The assumption is correct that only altitude should be displayed. Also, displaying the V or J airway presents a tracking problem on the ground in determining when to change the displayed information.

9. WOULD YOU BE IN FAVOR OF COUPLING THE DATA LINK SYSTEM TO EXISTING HEADING, ALTITUDE AND SPEED BUGS/ANNUNCIATORS, SO THAT THESE WOULD BE AUTOMATICALLY CHANGED WHEN THE "WILCO" BUTTON IS PRESSED?

Most of the pilots were in favor of trying out this concept under simulation and/or flight tests. One response was that it sounded "delightful." There was no apparent feeling on the part of the pilots that this would encroach upon their role of flying the plane.

10. HOW MUCH AUTOMATION OF RADIO FREQUENCY SETTINGS, TRANSPONDER CODE SETTINGS ETC. WOULD YOU LIKE WITH DATA LINK?

The pilots view the transponder setting as something necessary for ground control, not flying the aircraft, and were in favor of automating this function via data link. They were also in favor of automating radio frequency settings on the condition that the frequency would still be displayed on the control head as it is now and that a manual override be available to the pilot.

11. WOULD IT BE USEFUL FOR A DATA LINK DISPLAY TO ALSO HAVE THE CAPABILITY OF STORING AND RECALLING ANY SINGLE MESSAGE RECEIVED BY THE PILOT, AT HIS DISCRETION, SO THAT IT WOULD NOT BE LOST UPON RECEIPT OF THE NEXT MESSAGE?

This idea was liked by all the pilots and several urged that it be incorporated into the experiments as soon as possible. A suggestion was made that the display have the ability to store more than just one message. One pilot commented that perhaps just a "Standby" button is all that would be needed to allow the pilot time to respond to any message without fear of it being replaced before he is through with it.

12. THE USE OF "STOP-MOTION" OR SEGMENTED SCENARIOS RATHER THAN CONTINUOUS FLIGHTS COULD SAVE APPRECIABLE TIME. DO YOU THINK THAT THIS WOULD DETRACT FROM THE REALISM TO A POINT WHERE IT WOULD INFLUENCE THE DATA OBTAINED?

Opinions varied on this question. Some pilots were all for the idea of cutting down on the amount of time "wasted" during routine cross-country portions of a scenario that introduced very little exercise of the Data Link. Others felt that the experiments as they were conducted simulated a very real environment and the fatigue introduced by the length of the scenarios was an important factor in the evaluation.

13. WHAT ARE THE CONSIDERATIONS ON LOCATING DISPLAYS AND CONTROLS TO FAVOR THE RIGHT VERSUS THE LEFT SEAT?

It was agreed that the display must be visible from both seats, but if either is favored, it should be the right seat. This is generally where the communications are handled.

14. WHAT ARE YOUR FEELINGS CONCERNING THE IMPACT ON PILOT WORKLOAD IF DATA LINK BECOMES AVAILABLE?

The consensus was that, if properly applied, Data Link could result in a significant reduction in pilot workload.

15. ON SUBSEQUENT SIMULATOR TESTS, DO YOU FEEL THAT WE NEED TO SIMULATE BOTH DAY AND NIGHT OPERATIONS?

At least a portion of the tests sould be conducted under both night and day conditions, but not necessarily all of them.

16. WHAT ABOUT THE POSSIBILITY OF PRESETTING CERTAIN RESPONSES DURING LOW WORKLOAD PERIODS; FOR EXAMPLE, PRESETTING INFO AS TO YOUR LOWEST POSSIBLE SPEED DURING CROSS-COUNTRY SO THAT IT WILL BE AVAILABLE TO AN APPROACH CONTROLLER WHEN HE WANTS IT? IS THIS A SUBJECT WORTH INVESTIGATING?

There was no real opinion generated from this question as it was only touched on briefly. The pilots had a positive attitude toward trying it, however.

17. WOULD YOU LIKE OCCASIONAL AUDITORY COMMANDS SO THAT YOU CAN BE SURE THAT YOUR RADIO IS WORKING?

The majority of the pilots did not see a need for this, especially once Data Link is accepted and the pilots have confidence in it. It may be a good idea during the early transitional stages of Data Link implementation. One pilot expressed concern for being sure his radio volume was high enough if no verbal transmissions were present.

18. DO YOU FEEL THAT THE PRESENT INABILITY TO DISPLAY IDENTIFIERS SUCH AS "ACY" OR "PHL" IS A SERIOUS DEFICIENCY OF THE NIMO?

Opinions were mixed on this point, but most did agree that the identifiers probably would not be as important in a Data Link environment.

19. SHOULD WE HAVE A DUAL AUDIO ALERT, ONE FOR ROUTINE MESSAGES AND ONE FOR URGENT MESSAGES?

No firm opinions were generated, but to many of the pilots, it seemed unnecessary and redundant. One pilot felt this question really depended upon what type of response the ground wants to urgent versus routine messages.

20. A NEW GAS DISCHARGE (PLASMA) PANEL IS AVAILABLE HAVING HIGHER BRIGHTNESS BUT IT HAS SPACE FOR ONLY 24 CHARACTERS. DO YOU THINK THAT THIS SUBSTITUTION MIGHT CHANGE YOUR EVALUATION OF THE GAS DISCHARGE TECHNOLOGY, AND IF SO, IN WHICH DIRECTION?

It was agreed that the display would have to be evaluated all over again as a new display.

APPENDIX D
THE SCENARIOS AS DISPLAYED

These are the scenarios as they were presented on the four displays. With the 3 x 7-window display, the dots appearing to the right and left of certain messages represent the pilot lights which were turned on to delineate new information. It should also be understood that when more than one line of information appears in a message on the 7-window display, these lines required successive presentation.

SCENARIO "A"

"You have been cleared IFR from PVD to BOS via V139 to HTM after which you should expect radar vectors to Logan. Expect a clearance to 5000 ft."

Starting conditions: On taxiway at PVD, heading 070, 200' from end of Rwy 34, holding as instructed; Radio @121.9 (PVD Gnd Control); Altimeter @ 2990; Transponder @ 1000.

32-WINDOW	3x7W	7-W	NIMO
CLEARED TO TAXI	•CLEARED• •TO • •TAXI •	CLRTAXI	CLEARED TO TAXI
PVD TOWER 120.7	•PVD TWR• •120.7 •	T 120.7	CONTCT TOWER 1207
TAXI TO POSITION & HOLD RWY 34	•TAXI TO• •POS HLD• •RWY 34 •	TXIHLD RWY 34	TURN ←← 340
CLEARED FOR TAKEOFF, RUNWAY 34	•CLEARED• •TAKEOFF• •RWY 34 •	TKOF 34	CLEARED TAKOFF RY 34
MAINTAIN RWY HDG & ALT 010	•ALT 010• •MAINTN • •RWY HDG•	↑↑ 010 RWY HDG	CLIMB ↑↑ 010
QUONSET DEP 124.5 SQUAWK 1025	•QUONSET• •DEP • •124.5 •	QUONSET D 124.5 SQK1025	CONTCT DEPRTR 1245
	•SQK1025• •HDGR090• ALT 010		SQUAWK 1025
RADAR CONTACT. CLIMB TO 3000 FT	•RADR CT• •ALT 030• HDG 090	RADR CT 030	RADAR CONTCT
		→→090	CLIMB ↑↑ 030
TURN RIGHT HDG 090 ALT 030			TURN →→ 090

32-WINDOW	3x7-W	7-W	NIMO
POSN 2 MLS W V139 RES NORM NAV	●POS 2 ● ●W V139 ● ●RES NAV●	POS 2 W V139 RES NAV	(Verbal- ized)
CLIMB TO 5000 FT	●ALT 050●	↑↑050	CLIMB ↑↑ 050
CLEARED HTM V139 ALT 050	●CLR HTM● ●V139 ● ALT 050	CLR HTM V139	(Verbal- ized)
BOS CENTER 132.65 SQUAWK 1050	●BOS CTR● ●132.65 ● ●SQK1050●	BOS C132.65 SQK1050	CONTCT CENTER 13265
			SQUAWK 1050
RADAR CONTACT ALT 050 V139	●RADR CT● ALT 050 V139	RADR CT ALT 050 V139	RADAR CONTCT
MAINTAIN SPD 090 ALT 050 V139	●SPD 090● ALT 050 V139	SPD 090	MAINTN SLEED 090
MAINTAIN HDG 558	SPD 090 ALT 050 ●HDG 558●	HDG 558	MAINTN HEADING 558
V139 ALT 050 SPD 090	SPD 090 ALT 050 V139	V139 ALT 050 SPD 090	MAINTN ALTUDE 050
TRAFFIC 11 3MLS ALT 060 S-BOUND	●TFC11 3● ●ALT 060● ●S-BOUND●	TFC11 3	TRAFIC 11 3 ML
CLR TFC V139 ALT 050 SPD 090	●CLEAR ● ●OF ● ●TRAFFIC●	CLR TFC	MAINTN ALTUDE 050
	SPD 090 ALT 050 V139		
DESCEND TO 040 SPD 110 V139	●SPD 110● ●ALT 040● V139	↓↓040 SPD 110	DESCND ↓↓ 040

32-WINDOW	3x7-W	7-W	NIMO
DESCEND TO 030 SPD 110 V139	●ALT 030● SPD 110 V139	↓↓030	DESCND ↓↓ 030
BOS APPR 120.6 SQUAWK 0405	●BOS APP● ●120.6 ● ●SQK0405●	BOS A 120.6 SQK0405	CONTCT APPRCH 1206
			SQUAWK 0405
RADAR CONTACT DESCEND TO 2000 FT	●RADR CT● ●DEP HTM● ●HDG 055●	RADR CT DEP HTM HDG 055	RADAR CONTACT
			DESCND ↓↓ 020
DEPART HTM HDG 055 SPD 090	●ALT 020● ●SPD 090● HDG 055	↓↓020 SPD 090	MAINTN HEADING 055
EXPCT VECT ILS RWY 33L APP	●EXP VEC● ●ILS APP● ●RWY 33L●	VEC ILS RWY 33L	(Verbal- ized)
BOS ALTIMETER 2985	●BOS ● ●ALTMTR ● ●2985 ●	BOS ALT 2985	ALTMTR 2985
ALT 020 HDG 055 SPD 090	ALT 020 SPD 090 HDG 055		MAINTN ALTUDE 020
TRAFFIC 01 2MLS W-BOUND	●TFC01 2● ●ALT 030● ●W-BOUND●	TFC01 2	TRAFIC 01 2ML
CLR TFC ALT020 HDG055 SPD 090	●CLEAR ● ●OF ● ●TRAFFIC●	CLR TFC	MAINTN ALTUDE 020
TURN LFT HDG 010 ALT020 SPD090	●HDGL010● ALT 020 SPD 090	←←010	TURN ←← 010
DESCEND TO 015 HDG010 SPD090	●ALT 015● HDG 010 SPD 090	↓↓015	DESCND ↓↓ 015

32-WINDOW	3x7-W	7-W	NIMO
TURN RT HDG065 SPD080 ALT015	•HDGR065• •SPD 080• ALT 015	→→065 SPD 080	TURN →→ 065 MAINTN SPEED 080
TURN LEFT HDG ALT015 SPD080	•HDGL360• SPD 080 ALT 015	←←360	TURN ←← 360
POSN 5MLS SW OUTMKR RWY 33L	•POS 5 • •SW LOM • •RWY 33L•	POS 5 SW LOM	(Verbal- ized)
CLEARED ILS RWY 33L APPROACH	•CLR FOR• •ILS APP• •RWY 33L•	CLR ILS RWY 33L	
OUTMKR 1 MILE BOS TWR 119.1	•LOM 1 • •BOS TWR• •119.9 •	LOM 1 T119.1	CONTCT TOWER 1191
CLEARED TO LAND, RUNWAY 33L	•CLR LND• •RWY 33L•	CLR LND RWY 33L	CLEARD TOLAND RY 33L
BOS GROUND 121.9	•BOS GND• •121.9 •	G 121.9	CONTCT GROUND 1219

SCENARIO "B"

"You are in the middle of a flight for which you have been cleared IFR to BOS via V106 to GDM, V431 to Revere. You should expect radar vectors to Logan after Manjo."

Starting conditions: On V106 @ 8000 over Lakeside; Radio @ 132.65 (BOS Center); Altimeter @ 3000; Transponder @ 1055; Speed 100 kts.

32-WINDOW	3x7-W	7-W	NIMO
TRAFFIC 12 4MLS ALT 100 E-BOUND	•TFC12 4• •ALT 100• •E-BOUND•	TFC11 3	TRAFIC 12 4ML
CLEAR OF TRAFFIC	•CLEAR • •OF • •TRAFFIC•	CLR TFC	MAINTN ALTUDE 080
BOS CTR 129.5 SQUAWK 1000	•BOS CTR• •129.5 • •SQK1000•	BOS C 129.5 SQK1000	CONTCT CENTER 1295 SQUAWK 1000
RADAR CONTACT HLD SW GDN ON V106	•RADR CT• •HLD GDM• •SW V106•	RADR CT HLD GDM SW V106	RADAR CONTCT (Balance verbalized)
EXPCT FURTHER CLEARANCE IN 5 MIN	•EXPECT • •CLRNCE • •05 MIN •	EXP CLR 05 MIN	EST DELAY 05 MIN
DESCEND TO 7000 FT HLD GDM	•ALT 070• HLD GDM	070	DESCND 070
DEPART GMD 1 MIN V431 ALT 070	•DEP GDM• •01 MIN • •V431 •	DEP GDM 01 MIN V431	DEPART STACK 1 MIN MAINTN ALTUDE 070
RESUME NORMAL NAV V431 ALT 070	•RES NAV• V431 ALT 070	RES NAV	**(Verbal-ized)**
TRAFFIC 11 3MLS ALT 060 W-BOUND	•TFC11 3• •ALT 060• •W-BOUND•	TFC11 3	TRAFIC 11 3ML

32-WINDOW	3x7-W	7-W	NIMO
CLR TRAFFIC V431 ALT 070	●CLR TFC● V431 ALT 070	CLR TFC	MAINTN ALTUDE 070
DESCEND TO 6000 FT V431	●ALT 060● V431	↓↓060	DESCND ↓↓ 060
BOS APP 120.6 SQUAWK 0455	●BOS APP● ●120.6 ● ●SQK0455●	BOS A 120.6 SQK0455	CONTCT APPRCH 1206
			SQUAWK 0455
RADAR CONTACT BOS ALTMTR 2975	●RADR CT● ●BOS ALT● ●2975 ●	RADR CT HDG 110	RADAR CONTCT
			MAINTN HEADING 110
		BOS ALT 2975	ALTMTR 2975
DESCEND TO 040 SPD 110 V431	●ALT 040● ●SPD 110● V431	↓↓040 SPD 110	DESCND ↓↓ 040
			MAINTN SPEED 110
EXPCT VECT LOC BC RWY 22L APP	●EXP VEC● ●LOC BC ● ●RWY 22L●	VEC LOC BC 22L	(Verbal- ized)
ALT 040 SPD 110 V431	ALT 040 SPD 110 V431		MAINTN ALTUDE 040
SPEED 900 ALT 040 V431	●SPD 900● ALT 040 V431	SPD 900	MAINTN SPEED 900
SPEED 090 ALT 040 V431	●SPD 090● ALT 040 V431	SPD 090	MAINTN SPEED 090

32-WINDOW	3x7-W	7-W	NIMO
TURN LFT HDG 100 ALT040 SPD090	●HDGL100● ALT 040 SPD 090	←←100	TURN ←← 100
DESCEND TO 030 HDG 100 SPD 090	●ALT 030● HDG 100 SPD 090	↓↓030	DESCND ↓↓ 030
TURN LEFT HDG 055 ALT030 SPD090	●HDGL055● ALT 030 SPD 090	←←055	TURN ←← 055
DESCEND TO 015 HDG 055 SPD090	●ALT 015● HDG 055 SPD 090	↓↓015	DESCND ↓↓ 015
TURN RT HDG 130* ALT015 SPD 090	●HDGR130● ALT 015 SPD 090	→→130	TURN →→ 130
TRAFFIC 10 4MLS ALT 025 W-BOUND	●TFC10 4● ●ALT 025● ●W-BOUND●	TFC10 4	TRAFIC 10 4ML
CLR TFC HDG130 ALT015 SPD090	●CLEAR ● ●OF ● ●TRAFFIC●	CLR TFC	MAINTN HEADING 130
TURN RT HDG 175 ALT015 SPD090	●HDGR175● ALT 015 SPD 090	→→175	TURN →→ 175
POS 2MLS N SEW NDB	●POS 02 ● ●N SEW ● ●NDB ●	POS 2 N SEW	(Verbal- ized)
CLEARED LOC BC RWY 22L APP	●CLR LOC● ●BC APP ● ●RWY 22L	CLR LOC BC 22L	
BOS TWR 119.1	●BOS TWR● ●119.1 ●	BOS T 119.1	CONTCT TOWER 1191
TRAFFIC 01 1ML ON FINAL FOR 22R	●TFC01 1● ●FINAL ● ●FOR 22R●	TFC01 1 FNL 22R	TRAFIC 11 1ML

32-WINDOW	3x7-W	7-W	NIMO
CLEARED TO LAND RWY 22L	●CLR LND● ●RWY 22L●	CLR LND RWY 22L	CLEARD TOLAND RY 22L
BOS GND 121.9	●BOS GND● ●121.9 ●	G 121.9	CONTCT GROUND 1219

SCENARIO "C"

"You have been cleared IFR BOS to BED (Hanscom Field) and expect radar vectors for the entire flight. Expect a clearance to 5000'. Your alternate is returning to BOS."

Starting conditions: On Taxiway 200' from end of Rwy 09, heading 180, holding as instructed; Radio @ 121.9 (Bos Ground Control); Altimeter @ 2995; Transponder @ 1025.

32-WINDOW	3x7-W	7-W	NIMO
CLEARED TO TAXI	●CLEARED● ●TO TAXI●	CLRTAXI	CLEARD TO TAXI
BOS TOWER 119.1	●BOS TWR● ●119.1 ●	T 119.1	CONTCT TOWER 1191
TAXI TO POSITION & HOLD RWY 09	●TAXI TO● ●POS HLD● ●RWY 09 ●	TXINHLD RWY 09	**(Verbal- ized)**
CLEARED FOR TAKEOFF RWY 09	●CLEARED● ●TAKEOFF● ●RWY 09 ●	TKOF	CLEARD TAKOFF RY 09
MAINTAIN RWY HDG & ALT 020	●ALT 020● ●MAINTN ● ●RWY HDG●	↑↑020 RWY HDG	MAINTN HEADING 090 CLIMB ↑↑ 020
BOS DEP 127.2 SQUAWK 1005	●BOS DEP● ●127.2 ● ●SQK1005●	BOS D 127.2 SQK1005	CONTCT DEPRTR 1272 SQUAWK 1005
RADAR CONTACT TURN LEFT HDG 060	●RADR CT● ●HDGL060● ALT 020	RADR CT ←←060	RADAR CONTCT TURN ←← 060

32-WINDOW	3x7-W	7-W	NIMO
EXPCT VECT BED ALT 020 HDG 060	●EXP VEC● ●MED ●	VEC BED	(Verbal- ized)
CLIMB TO 4000 FT HDG 060	●ALT 040● HDG 060	↑↑040	CLIMB ↑↑ 040
TURN LEFT HDG 360 ALT 040	●HDGL360● ALT 040	←←360	TURN ←← 360
TRAFFIC 01 3MLS ALT 020 NW-BOUND	●TFC01 3● ●ALT 020● ●NW-BND ●	TFC01 3	TRAFIC 01 3ML
CLR OF TRAFFIC ALT 040 HDG 360	●CLR TFC● HDG 360 ALT 040	CLR TFC	MAINTN ALTUDE 040
TURN LEFT HDG 310 ALT 040	●HDGL310● ALT 040	←←310	TURN ←← 310
TURN LEFT HDG 290 ALT 040	●HDGL290● ALT 040	←←290	TURN ←← 290
TRAFFIC 02 2MLS ALT 035 NW-BOUND	●TFC02 2● ●ALT 035● ●NW-BND ●	TFC02 2	TRAFIC 02 2ML
CLIMB TO 5000 FT HDG 290	●ALT 050● HDG 290	↑↑050	CLIMB ↑↑ 050
CLEAR OF TRAFFIC ALT 050 HDG 290	●CLR TFC● ALT 050 HDG 290	CLR TFC	
TURN RT HDG 360 TRAFFIC 12 2MLS	●HDGR360● ●TFC12 2● ●S-BOUND●	→→360 TFC12 2	TRAFIC 12 2MLS TURN →→ 360

32-WINDOW	3x7-W	7-W	NIMO
TURN LFT HDG290 CLR TFC ALT050	●HDGL290● ●CLR TFC● ALT 050	←←290 CLR TFC	TURN ←← 290
			MAINTN ALTUDE 050
BED CLOSED--WEATHER--RTN BOS	●BED ● ●CLSD WX● ●RTN BOS●	BED CLSD WX RTN BOS	(Verbal- ized)
BOS APP 120.6 SQUAWK 0425	●BOS APP● ●120.5 ● ●SQK0425●	BOS A 120.6 SQK0425	CONTCT APPRCH 1206
			SQUAWK 0425
RADAR CONTACT TURN LEFT HDG 250	●RADR CT● ●HDGL250● ALT 050	RADR CT ←←250	RADAR CONTCT
			TURN ←← 250
EXPCT VECT ILS RWY 04R APP	●EXP VEC● ●ILS APP● ●RWY 04R●	VEC ILS RWY 04R	(Verbal- ized)
BOS ALTMTR 3001 ALT050 HDG250	●BOS ● ●ALTMTR ● ●3001 ●	BOS ALT 3001	ALTMTR 3001
	ALT 050 HDG 250		MAINTN ALTUDE 050
TURN LEFT HDG 200 ALT 050	●HDGL220● ALT 050	←←220	TURN ←← 220
DESCEND TO 3000 FT HDG 220	●ALT 030● HDG 220	↓↓030	DESCEND ↓↓ 030
TRAFFIC 11 3MLS ALT 015 SE-BOUND	●TFC11 3● ●ALT 015● ●SE-BND ●	TFC11 3	TRAFIC 11 3ML

32-WINDOW	3 x 7-W	7-W	NIMO
TURN LFT HDG180 CLR TFC ALT030	•HDGL180• •CLR TFC• ALT 030	←←180 CLR TFC	TURN ←← 180
			MAINTN ALTUDE 030
TURN LFT HDG 140 ALT 030	•HDGL140• ALT 030	←←140	TURN ←← 140
DESCEND TO 1500 FT HDG 140	•ALT 015• HDG 140	↓↓015	DESCEND ↓↓ 015
TURN LFT HDG 110 SPD080 ALT 015	•HDGL110• •SPD 080• ALT 015	←←110 SPD 080	TURN ←← 110
			MAINTN SPEED 080
BOS ALTIMETER 2992	•BOS • •ALTMTR • •2992 •	BOS ALT 2992	ALTMTR 2992
HDG 110 ALT 015 SPD 080	HDG 110 ALT 015 SPD 080		MAINTN HEADING 110
TURN LFT HDG 070 POS3 SE OUTMKR	•HDGL070• •POS 3 • •SW LOM •	←←070 POS 3 SW LOM	TURN ←← 070
CLR ILS RWY 4R APP BOS TWR 119.1	•CLR ILS• •RWY 04R• •APP •	CLR ILS RWY 04R	(Verbal- ized)
	•BOS TWR• •119.1 •	T 119.1	CONTCT TOWER 1191
CLEARED TO LAND RWY 4R	•CLR LND• •RWY 04R•	CLR LND RWY 04R	CLEARED TOLAND RY 4R
BOS GND 121.9	•BOS GND• •121.9 •	G 121.9	CONTCT GROUND 1219

SCENARIO "D"

"You are completing a flight to BOS for which you have been cleared IFR to HTM after which you expect radar vectors to Logan."

Starting Conditions: Heading 055 @ HTM @ 4000'; Radio @ 132.65 (BOS Center); Altimeter @ 2987; Transponder @ 1055; Speed 100 kts.

32-WINDOW	3x7-W	7-W	NIMO
BOS APP 120.6 SQUAWK 0420	●BOS APP● ●120.6 ● ●SQK0420●	BOS A 120.6 SQK0420	CONTCT APPRCH 1206 SQUAWK 0420
RADAR CONTACT TURN LFT HDG 030	●RADR CT● ●HDGL030●	RADR CT ←←030	RADAR CONTCT TURN ←← 030
EXPCT VECT ILS RWY 33L APP	●EXP VEC● ●ILS APP● ●RWY 33L●	VEC ILS RWY 33L	(Verbal- ized)
MAINTAIN ALT 040 BOS ALTMTR 2992	●BOS ● ●ALTMTR ● ●2992 ●	BOS ALT 2992	MAINTN ALTUDE 040 ALTMTR 2992
SPEED 100 ALT 040 HDG 030	●SPD 100● ALT 040 HDG 030	SPD 100	MAINTN SPEED 100
DESCEND TO 015 SPD 100 HDG030	●ALT 015● SPD 100 HDG 030	↓↓015	DESCND ↓↓ 015
TRAFFIC 03 4MLS ALT 030 SE-BOUND	●TFC03 4● ●ALT 030● ●SE-BND ●	TFC03 4	TRAFIC 03 4MLS
CLR TFC ALT015 HDG030 SPD100	●CLEAR ● ●OF ● ●TRAFFIC●	CLR TFC	

32-WINDOW	3x7-W	7-W	NIMO
TURN LFT HDG360 SPD 090 ALT015	●HDGL360● ●SPD 090● ALT 015	←←360 SPD 090	TURN ←← 360
			MAINTN SPEED 090
POS 5MLS SW OUTMKR RWY33L	●POS 5 ● ●SE LOM ● ●RWY 33L●	POS 5 SW LOM	(Verbal- ized)
CLEARED ILS RWY 3LL APPROACH	●CLEARED● ●ILS APP● ●RWY 3LL●	CLR ILS RWY 3LL	(Verbal- ized)
CLEARED ILS RWY 33L APPROACH	●CLEARED● ●ILS APP● ●RWY 33L●	CLR ILS RWY 33L	(Verbal- ized)
BOS TWR 119.1	●BOS TWR● ●119.1 ●	T 119.1	CONTCT TOWER 1191
RWY CLSD CLIMB TO 020 MNT RWY HDG	●RWYCLSD● ●CLIMB ● ●ALT 020●	↑↑ 020 RWY HDG RWYCLSD	CLIMB ↑↑ 020
EXPCT VECT VOR RWY 22L APP	●MAINTN ● ●RWY HDG● ALT 020	VEC VOR RWY 22L	MAINTN HEADING 330
BOS APP 120.6 SQUAWK 0455	●BOS APP● ●120.6 ● ●SQK0455●	BOS A 120.6 SQK0455	CONTCT APPRCH 120.6
	●EXP VEC● ●VOR APP● ●RWY 221●		SQUAWK 0455
RADAR CONTACT ALT 020 HDG 330	●RADR CT● ALT 020 HDG 330	RADR CT	RADAR CONTCT
TURN RT HDG 350 ALT 020	●HDGR350● ALT 020	→→350	TURN →→ 350

APPENDIX E
MESSAGE FORMATS AND RAW DATA FOR SECTION 2

All reaction times are in seconds. An "E" indicates a response error, and reaction times for these errors were not recorded.

DM = Dot Matric Characters; ST = Stencil Type Font; SEG = 16-Segment Characters.

A blank in these data indicates a failure of a slide to drop into the projector properly or a failure of the timer to reset.

MESSAGE	CONTACT GROUND CONTROL ON 1237			CONTACT TOWER 1191			CT 1172			H260A040 S170*CONTACT TWR 1245*		
SLIDE	1.23 1	1.23 49	1.23 97	1.23 2	1.23 50	1.23 98	1.23 3	1.23 51	1.23 99	1.23 4	1.23 52	1.23 100
FONT	DM	ST	SEG	DM	ST	SEG	DM	ST	SEG	DM	ST	SEG
S1	2.04	7.59	2.19	E	1.04	1.24	1.21	-	1.75	2.30	E	E
S2	0.75	1.03	E	0.87	0.98	1.02	2.63	2.06	1.66	1.48	2.72	1.61
S3	2.35	1.75	1.57	1.79	3.20	1.40	3.29	3.34	-	2.38	3.75	3.55
S4	-	2.79	3.63	2.21	2.86	-	3.03	3.69	2.79	3.06	4.23	3.31
S5	2.36	2.17	-	2.22	1.99	3.25	1.77	5.07	3.42	2.88	-	2.93
S6	1.96	2.35	4.85	1.69	2.17	3.65	1.62	7.85	3.82	E	3.24	3.74
S7	1.05	1.39	2.02	-	1.22	1.46	1.29	2.42	1.67	2.25	2.64	2.26
S8	4.83	1.28	2.11	-	2.34	1.17	4.14	2.84	8.82	1.60	2.99	2.56
MEAN	2.19	2.54	2.72	1.75	1.97	1.88	2.37	3.89	3.41	2.27	3.26	2.85

MESSAGE	CA 1205			RADIO 1213			*CONTACT TWR 1234* H120 A200 S200			*CG11845* HDG 070 ALT 110		
SLIDE	5	53	101	6	54	102	7	55	103	8	56	104
FONT	DM	ST	SEG	DM	ST	SEG	DM	ST	SEG	DM	ST	SEG
S1	1.77	2.42	5.53	1.57	1.14	6.33	1.51	2.73	1.44	-	2.87	3.20
S2	1.02	0.93	1.39	4.22	0.98	1.47	-	1.36	1.45	1.98	1.73	-
S3	2.77	1.94	3.02	1.76	1.96	1.30	2.76	2.09	2.26	-	5.23	2.82
S4	2.55	2.50	4.03	2.81	3.34	2.95	3.12	3.08	2.83	2.85	4.48	2.89
S5	2.42	1.53	3.68	2.26	3.10	2.54	-	2.81	7.43	2.33	E	3.16
S6	3.65	2.37	-	2.26	2.37	2.62	-	2.32	2.07	9.75	3.29	2.89
S7	1.93	2.09	2.56	2.00	1.26	1.22	-	2.06	1.74	2.21	2.11	1.40
S8	2.32	2.02	4.64	1.99	3.56	1.80	E	3.15	2.65	4.13	5.75	3.87
MEAN	2.30	1.97	3.55	2.35	2.21	2.52	2.46	2.45	2.73	3.87	3.63	2.89

MES-SAGE	HDGL210			HDG←230			*HDG←070* ALT 191 SPD 210			TURN LEFT 180		
SLIDE	9	57	105	10	58	106	11	59	107	12	60	108
FONT	DM	ST	SEG	DM	ST	SEG	DM	ST	SEG	DM	ST	SEG
S1	6.27	1.39	2.27	1.19	2.11	1.53	2.10	-	2.20	0.89	1.40	1.30
S2	E	2.00	-	1.14	0.84	1.09	1.48	-	1.47	0.91	1.10	0.87
S3	2.36	1.68	3.49	1.51	2.05	2.19	3.10	-	3.38	1.69	1.61	1.75
S4	3.11	1.81	4.51	2.31	1.93	2.38	2.92	-	2.50	1.73	1.76	1.87
S5	2.02	2.08 *	2.77	1.67	1.34	2.76	-	-	2.49	1.46	1.66	3.17
S6	6.82	-	4.10	2.70	2.26	4.50	-	-	2.84	1.55	1.39	1.61
S7	1.82	1.98	2.52	1.42	1.28	1.74	1.51	-	1.69	-	1.42	1.32
S8	2.03	1.10	4.11	1.71	1.36	1.45	2.09	-	2.35	1.55	1.41	1.49
MEAN	3.49	1.72	3.39	1.70	1.64	2.20	2.20	-	2.36	1.39	1.46	1.67

MES-SAGE	*HDG←260*			LEFT			←←			TURN ←← 290		
SLIDE	13	61	109	14	62	110	15	63	111	16	64	112
FONT	DM	ST	SEG	DM	ST	SEG	DM	ST	SEG	DM	ST	SEG
S1	2.13	2.68	4.18	1.45	1.17	-	0.89	0.82	0.85	1.55	-	1.54
S2	1.63	-	1.54		0.65	-	0.84	0.79	0.75	1.25	1.01	0.69
S3	3.17	-	1.89		0.89	-	1.16	0.78	1.18	1.20	1.92	1.91
S4	2.55	4.51	1.98	-	1.37	-	1.40	1.28	1.56	1.85	1.86	2.18
S5	2.98	-	1.63	-	1.04	-	2.08	1.10	1.09	3.84	1.85	1.37
S6	2.86	-	4.18	-	1.18	-	1.72	0.82	1.07	3.18	2.23	2.29
S7	1.43	1.67	1.54	-	1.30	-	1.65	0.87	0.97	1.71	1.23	1.28
S8	2.24	-	2.20	1.10	0.63	-	0.87	0.60	0.82	1.09	-	1.97
MEAN	2.37	2.95	2.39	1.27	1.02	-	1.32	0.88	1.03	1.95	1.68	1.65

MES-SAGE	A↑120			CLMB210			HDG 160 *ALT↑140* SPD 240			↑↑ ALT 150		
SLIDE	17	65	113	18	66	114	19	67	115	20	68	116
FONT	DM	ST	SEG	DM	ST	SEG	DM	ST	SEG	DM	ST	SEG
S1	2.41	1.16	2.73	5.46	1.21	2.05	2.52	2.99	-	1.05	1.08	1.28
S2	1.54	1.40	1.63	1.19	0.85	1.29	1.74	1.47	2.60	1.17	1.43	1.39
S3	2.02	1.54	3.83	1.51	3.27	5.13	1.71	3.99	2.92	1.14	1.41	1.85
S4	2.40	2.33	3.73	2.60	2.49	3.01	2.48	2.96	3.16	1.77	1.76	1.50
S5	3.53	1.80	1.60	1.55	1.40	3.25	2.98	3.03	3.72	1.89	1.77	3.00
S6	6.80	2.56	1.90	3.09	1.55	2.20	6.74	2.18	4.53	3.67	3.32	3.30
S7	1.59	1.62	1.07	1.21	0.89	1.13	2.96	1.39	2.58	1.23	1.13	1.35
S8	1.42	1.28	E	1.42	1.91	3.63	2.80	2.94	4.30	0.81	0.84	1.45
MEAN	2.71	1.71	2.35	2.25	1.69	2.71	2.99	2.68	3.40	1.59	1.59	1.89

MES-SAGE	HDG 190 *ALT 110* SPD 165			CLIMB			↑↑↑			UP 130		
SLIDE	21	69	117	22	70	118	23	71	119	24	72	120
FONT	DM	ST	SEG	DM	ST	SEG	DM	ST	SEG	DM	ST	SEG
S1	E	E	5.84	1.00	0.96	0.93	1.05	0.78	1.75	1.22	2.40	1.06
S2	1.71	2.33	3.14	0.82	0.73	0.74	0.84	0.68	0.89	1.03	1.01	1.02
S3	1.64	4.18	3.80	0.69	1.24	1.18	1.47	0.86	1.03	2.72	1.16	1.42
S4	2.06	3.03	2.80	1.38	1.63	1.49	1.40	1.34	1.29	2.60	1.63	2.10
S5	2.22	2.18	-	-	-	1.10	0.98	1.70	0.94	1.71	1.19	1.41
36	3.06	2.69	2.80	1.08	0.94	1.45	1.28	1.47	1.32	1.32	1.95	2.46
S7	1.33	1.44	1.70	0.74	0.76	1.08	0.63	1.11	0.83	1.29	0.92	1.16
S8	2.09	2.58	2.94	0.88	0.99	1.15	0.82	0.87	0.94	1.38	0.88	1.05
MEAN	2.01	2.63	3.28	0.94	1.03	1.14	1.05	1.10	1.12	1.65	1.39	1.46

APPENDIX G
STATISTICAL TERMINOLOGY

The following brief appendix is provided for the reader who may be unfamiliar with or requires review of statistical methods and terminology.*

Statistically, it is never possible to prove that one set of measurements is different from those obtained in measurement of a different parameter or variable; that is, the numerical comparison of two populations. Statistics, instead provide means for determining how often differences measured for two or more parameters would occur by chance; this is the probability value. Thus a probability of .01 indicates that by chance the determined differences in measurements would occur only one time in a hundred, and for a probability of .001, only one time in a thousand.

Calculations of such probabilities utilize the properties inherent in the variability of measurements of data points. Three data points have values of 2, 2 and 2 have a mean (average) value of 2; similarly, three data points having values of 1, 2 and 3, also have a mean value of 2, but here the values vary around this mean. "Variance" is the measure of such dispersion of values, and is based upon the square of the differences between the individual measurements and the mean value.

When two such sets of measurements having different means values are available, a t-test permits computation of the probability that these differences might occur by chance. Tables of required values of t for different levels of statistical significance are available in any standard text on statistics.

The technique of analysis of variance extends the concept to permit the simultaneous comparison of variables in multidimensional arrays. Here, because of the different computational

*This discussion appeared previously in the Report FAA-RD-72-150.

procedure, different numerical values are required to establish various levels of confidence. Appropriate values here are found in tables of F-ratio, again available in any standard text on statistics.

As the number of measurements of any discrete parameter is increased, we obtain increased confidence that the mean of the measurements becomes increasingly closer to the true value of that parameter, and lower values are required in tables of t and F for a given level of statistical significance. "Degrees of freedom" is the term used to indicate the number of measurements, and is defined as one less than the total number of measurements being evaluated. Similarly, in computing F-ratios, the concept of degrees of freedom is used to indicate the number of levels in each dimension of the experimental design. The difference between the sum of the degrees of freedom taken up by these levels and the total degrees of freedom available represents the degrees of freedom attributable to interaction among or between the variables. The variances associated with these degrees of freedom for interaction are defined as the "error term," and this is utilized in portions of the computation of the F-ratio.