A FLIGHT INVESTIGATION OF SIMULATED DATA LINK COMMUNICATIONS DURING SINGLE-PILOT IFR FLIGHT

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ABSTRACT

A Flight Data Console (FDC) was developed to allow simulation of a digital communications link to replace the current voice communication system used in Air Traffic Control. The voice system requires manipulation of radio equipment, read-back of clearances, and mental storage of critical information items, all contributing to high workload, particularly during single-pilot operations. This was an inflight study to determine how a digital communications system might reduce cockpit workload, improve flight proficiency, and be accepted by general aviation pilots.

Results show that instrument flight, including approach and landing, can be accomplished quite effectively using a digital data link system for ATC communications. All pilots expressed a need for a back-up voice channel. When included, this channel was used sparingly and principally to confirm any item of information about which there might be uncertainty. Workload for single-pilot flight, using the FDC, matched that found when a qualified copilot was present. Comments by subject pilots identified a number of human factors issues (placement, size, message format, etc.) which influence the acceptance of a data link system.

PROJECT OBJECTIVES

The safety record of general aviation is not excellent, with 1200 to 1500 fatalities occurring regularly each year. In general aviation, single-pilot instrument flight operations are known to be very demanding, with cockpit data management (information processing) representing a key issue.

The objective of this project was to study data management during single-pilot IFR. The initial project period was spent in developing an item of cockpit instrumentation, the Flight Data Console (FDC), which could be used to simulate use of a digital data link to replace the current voice communications system used in ATC. In the second project period, an inflight evaluation was conducted using the FDC. Results led to a number of recommendations for improvements in cockpit data management in general aviation.

- **STUDY PROBLEMS OF DATA MANAGEMENT DURING GA SINGLE-PILOT IFR FLIGHT**
- **DESIGN AND CONSTRUCT A COCKPIT FLIGHT DATA CONSOLE (FDC)**
  - **PRESENT ATC REFERENCE AND COMMAND DATA**
  - **REMOVE PILOT FROM ATC VOICE LOOP**
- **CONDUCT AN INFLIGHT EVALUATION**
- **PREPARE RECOMMENDATIONS ON**
  - **IMPROVED COCKPIT DATA MANAGEMENT**
  - **USE OF AN FDC–TYPE SYSTEM IN A FUTURE ATC ENVIRONMENT**

FLIGHT EVALUATION PLAN

The flight evaluations were conducted in two phases. Phase 1 used only terminal area approaches to airports in the Washington, DC area. In this phase, four kinds of flight were flown:

Copilot - In this flight, which provided baseline data, the subject pilot flew with an instrument-rated copilot and was free to use the copilot in any way desired. This flight was considered optimum in terms of reducing workload and making the flight as proficient and safe as possible.

Flight Data Console/Memory - Here the subject pilot used the FDC as an electronic data storage system (memory aid) solely to assist during each instrument approach.

Single-Pilot IFR - This is the customary single-pilot instrument flight. A safety pilot was present but did not participate in any way. The FDC was not used.

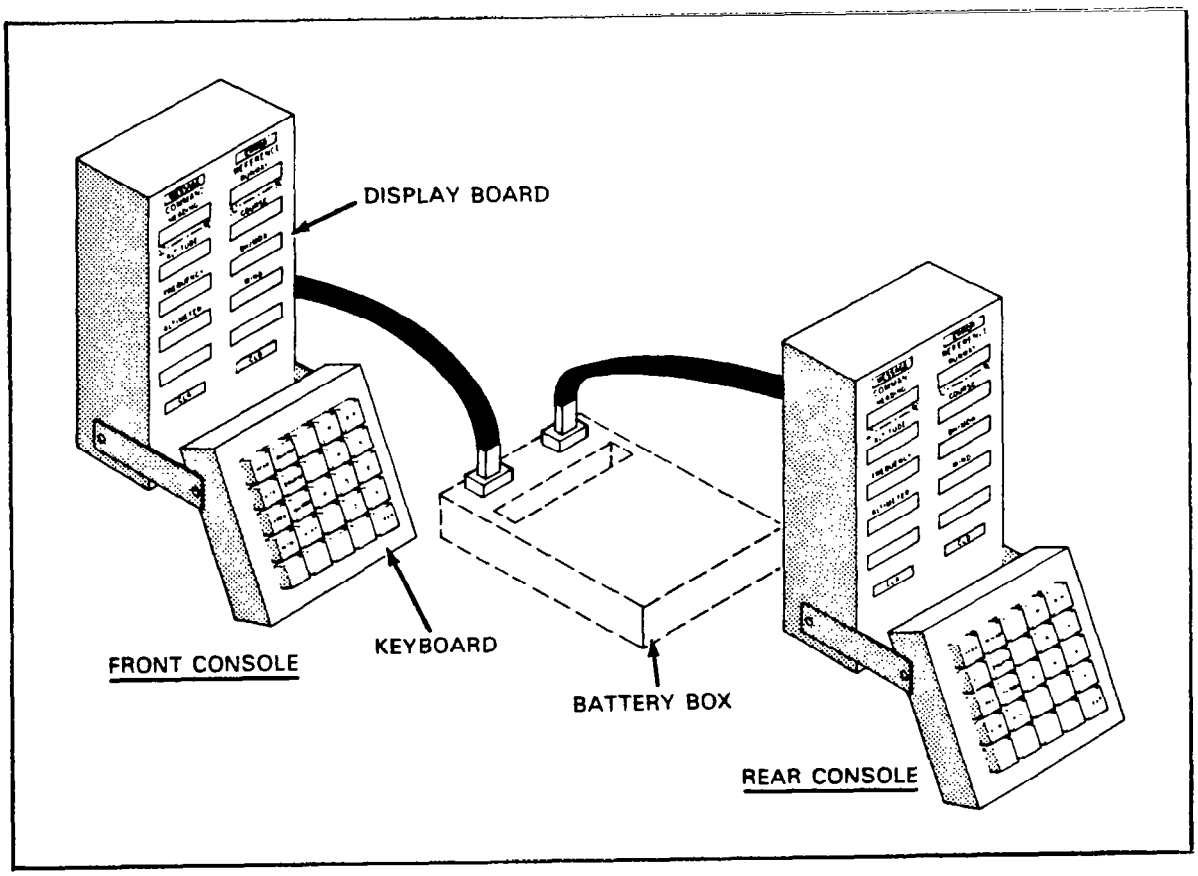
Flight Data Console/ATC - In this flight, all approaches were flown using Air Traffic Control information provided through the Flight Data Console.

FLIGHT EVALUATION PLAN

PHASE 1	NO. OF SUBJECTS
● TERMINAL AREA APPROACHES	8
– CO-PILOT	
– FLIGHT DATA CONSOLE / MEMORY	
– SINGLE-PILOT IFR	
– FLIGHT DATA CONSOLE / ATC	
PHASE 2	
● TERMINAL AREA APPROACHES	9
– FLIGHT DATA CONSOLE / ATC (VOICE BACK-UP)	
● ENROUTE (250 n.mi., FULL IFR)	4
– SINGLE-PILOT IFR	
– FLIGHT DATA CONSOLE / ATC (VOICE BACK-UP)	

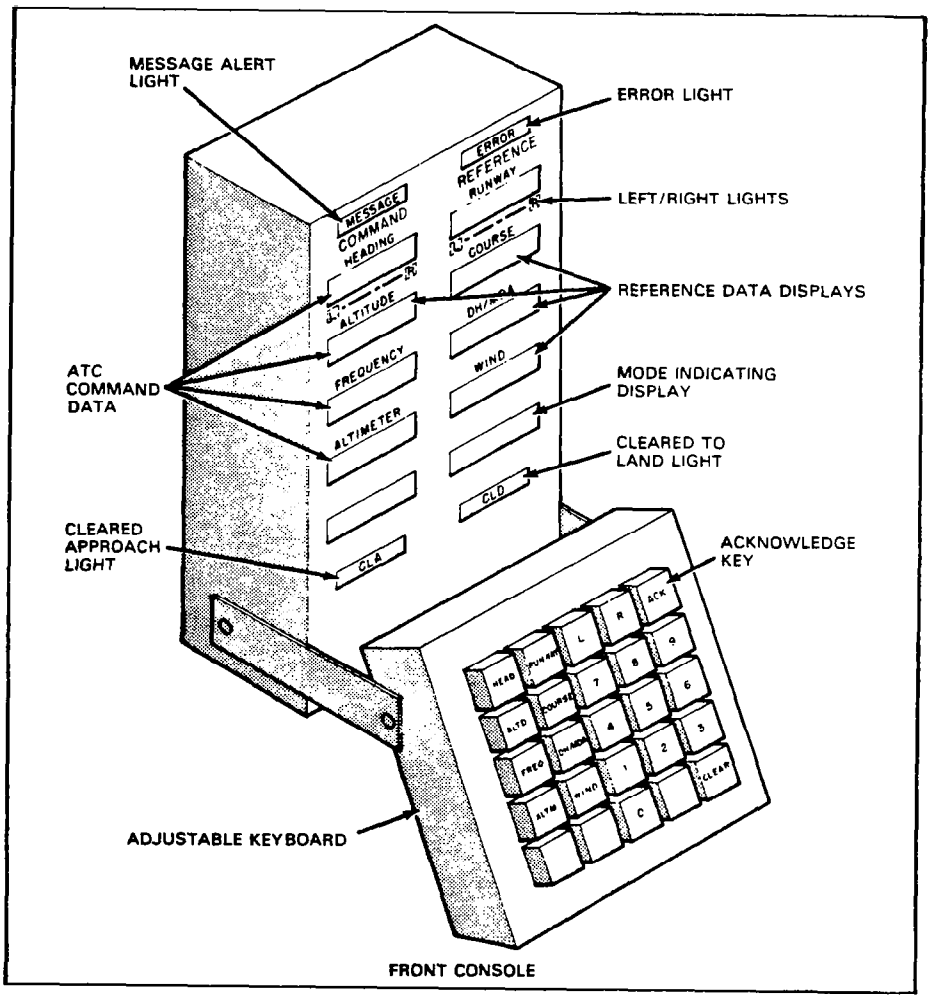
COMPONENTS OF FLIGHT DATA CONSOLE

The Flight Data Console is made up of three principal parts: a front seat display and data entry panel for use by the pilot, a rear seat display and data entry panel whereby a console operator serves as a transducer for ATC instructions (entering ATC commands and immediately transmitting these commands to the front seat display), and a battery power unit which makes the system independent of the aircraft.



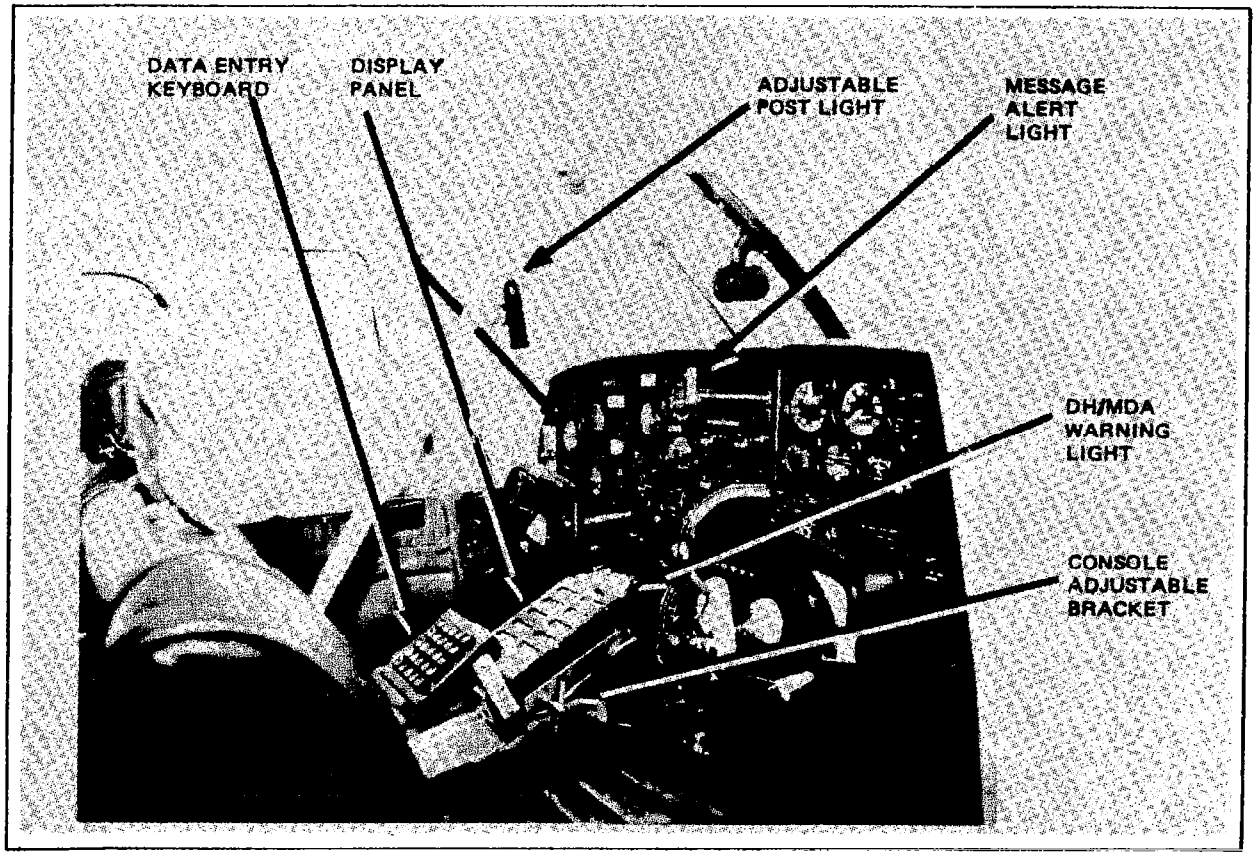
PILOT'S DISPLAY AND KEYBOARD

The unit which presents ATC information uses liquid crystal displays, each of which can present up to eight digits. The right column presents and stores flight data items as entered by the pilot. Using this capability, the FDC can serve as a memory aid and, in essence, take the place of a paper and pencil kneepad. The left column presents command information from Air Traffic Control. This includes instructions for changes in heading (including direction of turn), changes in altitude, new frequencies, updated altimeter settings, and, as shown in the bottom two display windows, "Cleared for Approach" and "Cleared to Land" instructions. When the pilot receives this information from ATC, he depresses the acknowledge key, completes the instruction, and presses another key to indicate completion.



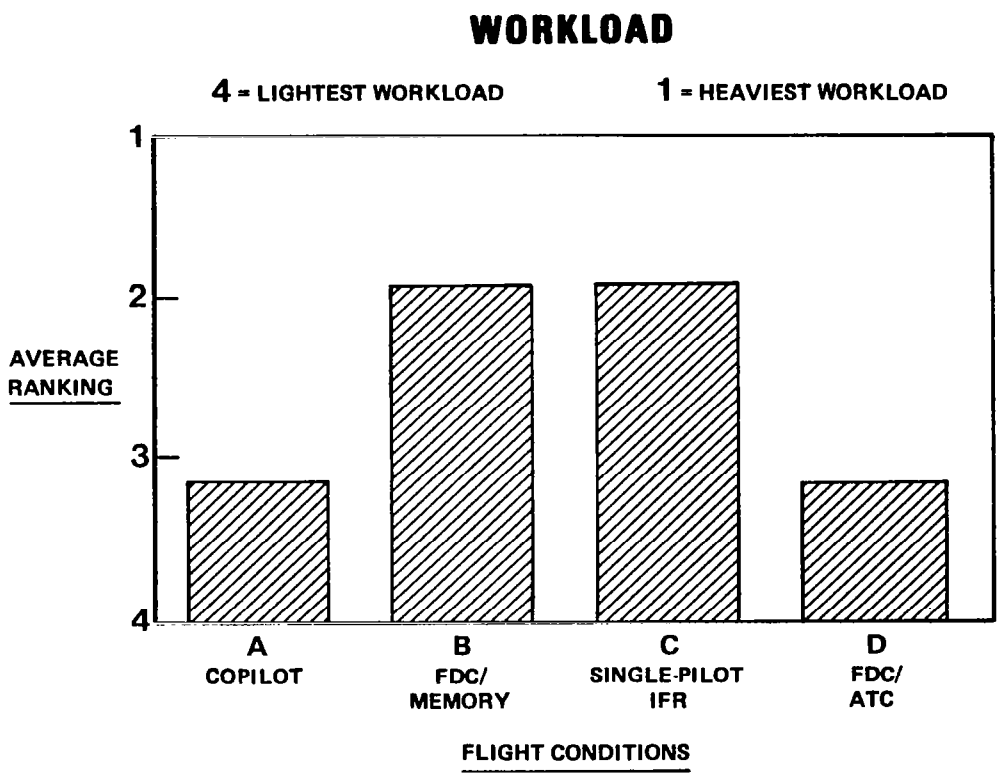
INSTALLATION OF FLIGHT DATA CONSOLE

The Flight Data Console was installed in a twin-engine Piper Aztec aircraft used for all flight evaluations. Because the system could not be permanently installed, the FDC display was positioned just behind the throttle quadrant with the data entry keyboard just right of the pilot's elbow position. This installation proved workable although far from optimal in terms of ease of viewing and operation.



WORKLOAD

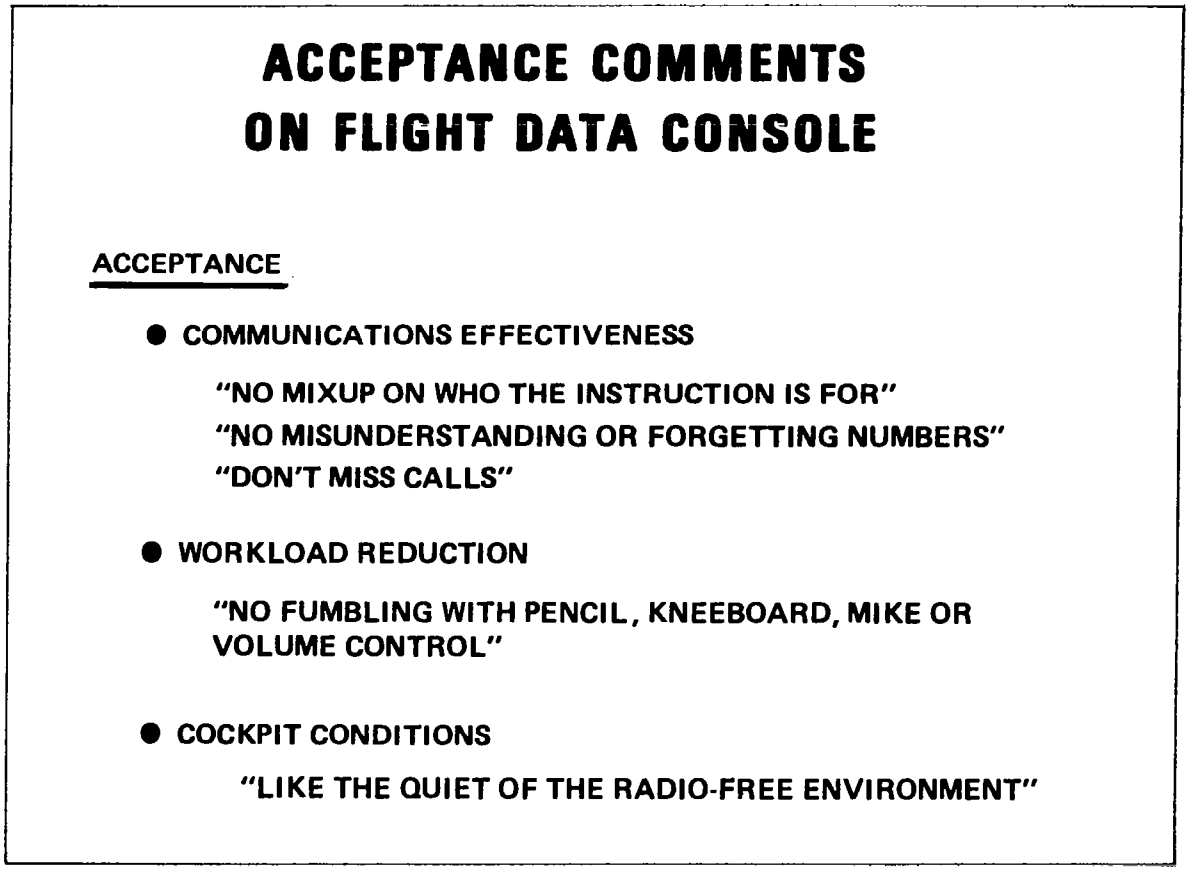
At the completion of all terminal area approaches, subject pilots ranked the four flight conditions in terms of workload imposed. Based on these rankings, the presentation of ATC instructions through the Flight Data Console results in a cockpit workload equal to that found when flying with a fully qualified instrument copilot. Workload is substantially heavier both for the single-pilot IFR condition and for those flights in which the FDC is used simply as an electronic memory aid.



ACCEPTANCE OF FLIGHT DATA CONSOLE

(Positive)

One project objective was to determine the extent to which a data link communications system would be accepted by general aviation pilots. Many comments and recommendations were received. It was found that the Flight Data Console was well received, with its acceptance seeming to involve three basic dimensions. These are (1) communications effectiveness, (2) workload reduction, and (3) an improvement in cockpit conditions.

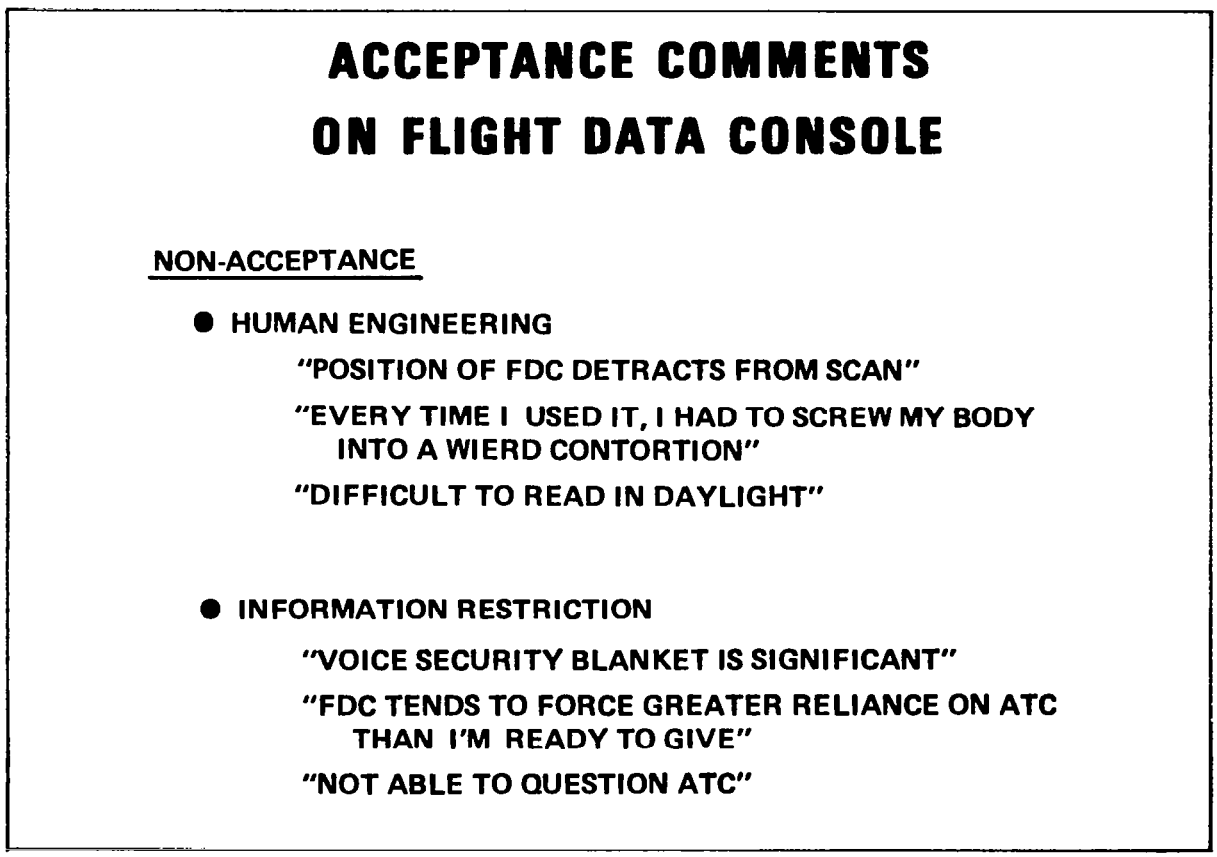


ACCEPTANCE OF FLIGHT DATA CONSOLE

(Negative)

A number of problems were identified with use of the Flight Data Console. Many of these were a function of it being a temporary installation. The human engineering aspects were far from optimum. This means that a number of human factors issues must be addressed if a data link system is to achieve its potential. Care must be taken in placing the system in the cockpit. Message content must be matched to pilot needs, instrument scan must be considered, and display complexity should not be great.

A second negative comment deals with the information restriction imposed through use of a data link system. In some measure, these comments were relieved by the incorporation of a backup voice channel for later project flights.



VOICE CHANNEL

The consensus of pilots who flew in the Phase I program was that a backup voice channel was needed with the Flight Data Console. This backup system was included in the Phase II flights. During the terminal area evaluations, the voice channel was used sparingly and principally to obtain confirmation of flight data provided through the Air Traffic Control system.

USE OF BACK-UP VOICE CHANNEL IN TERMINAL AREA OPERATIONS

NUMBER OF USES	INFORMATION
4	REQUESTED ATIS INFORMATION
4	VERIFIED TYPE OF APPROACH
3	CHECKED WIND CONDITIONS
1	CONFIRMED ALTITUDE AND VECTOR COMMANDS
1	VERIFIED MINIMUM ALTITUDE
1	VERIFIED CLEARANCE

Four pilots flew IFR missions under full instrument weather conditions over routes on the order of 250 nautical miles. The purpose was to develop a typical flight scenario as an aid in studying problems of pilot workload and information acquisition.

The performance ratings given the subject pilots by the safety pilot, who was a qualified instrument flight instructor, ranged from eight (quite a good score) to one (marginally above unsatisfactory). The number of unsafe occurrences noted, each of which would have been disqualifying in a flight test, ranged from zero to eleven. The differences in the evaluation data among the four pilots were considerable; a much wider disparity than expected. In an attempt to account for this, several variables were examined, principally dealing with flight time. The correlation between "rating by safety pilot" and "instrument time - last six months" was quite high. Since this measure of time ranged from eight to 40 hours, it is apparent that maintenance of instrument proficiency requires that one fly quite frequently under instrument conditions.

COMPARISON OF PERFORMANCE AND EXPERIENCE FOR SUBJECT PILOTS (ENROUTE FLIGHTS)

	SUBJECT PILOTS (N = 4)
RATING BY SAFETY PILOT[1]	1 - 8
TOTAL TIME (HRS.)	425 - 2000
TOTAL INSTRUMENT TIME	30 - 250
INSTRUMENT TIME-LAST SIX MONTHS	8 - 40
UNSAFE OCCURRENCES (NO.)	0 - 11

[1] 10 = EXCELLENT, 0 = UNSATISFACTORY

SINGLE-PILOT IFR VERSUS FDC WITH VOICE

The performance of the four pilots who flew IFR missions under full instrument weather conditions with no aid (FDC or copilot) was compared to their performance in four comparable flights over different routes using the Flight Data Console with the backup voice channel. In all, a measure of improvement was seen when the FDC was used. Performance ratings improved on the low end from a rating of one to three. The number of unsafe occurrences noted in any one flight decreased from 11 to five.

ENROUTE FLIGHT PERFORMANCE COMPARING FLIGHT DATA CONSOLE WITH VOICE AGAINST SINGLE-PILOT IFR

	SUBJECT PILOTS (N = 4)
SINGLE-PILOT IFR	
PERFORMANCE RATING BY SAFETY PILOT[1]	1 - 8
UNSAFE OCCURRENCES (No.)	0 - 11
FDC WITH VOICE	
PERFORMANCE RATING BY SAFETY PILOT	3 - 8
UNSAFE OCCURRENCES (No.)	1 - 5

[1] 10 = EXCELLENT, 0 = UNSATISFACTORY

COMPARISON OF THREE FLIGHT CONDITIONS

At the completion of the final full-mission flight, the four subject pilots were asked to rank the three flight conditions, shown in this Table, along the three dimensions of safety, workload, and pilot preference. Some caution must be expressed with respect to the validity of these relative rankings. Subjects were asked to compare flight conditions for which their recency of experience varied greatly. In one case, they had just completed a certain flight condition (Flight Data Console/Voice) and could judge it with some validity. With the other two conditions, the evaluation was based on long-term memory and is open to some question. In any event, the results did show that the flight condition represented by the use of the Flight Data Console with a backup voice channel was considered to be safest, to impose the lightest workload, and to be most preferred by these pilots.

RANKINGS OF THREE FLIGHT CONDITIONS FOLLOWING FULL-MISSION IFR FLIGHTS

FLIGHT CONDITION	SAFETY	WORKLOAD	PREFERENCE
FLIGHT DATA CONSOLE / VOICE	3.0	1.3	3.0
FLIGHT DATA CONSOLE	1.5	2.0	1.5
SINGLE-PILOT IFR	1.5	2.8	1.5

SAFETY: 3 = MOST, 1 = LEAST
WORKLOAD: 3 = HEAVIEST, 1 = LIGHTEST
PREFERENCE: 3 = MOST, 1 = LEAST

CONCLUSIONS

The current voice communications system used in Air Traffic Control requires manipulation of radio equipment, read-back of clearances, and mental storage of critical information items, all of which contributes to high workload and an excessive error rate, particularly during single-pilot operations. This study indicates that use of a data link communications system has considerable potential for alleviating these problems and improving cockpit data management during general aviation operations. The specific conclusions of this project are presented in succinct form below.

DATA LINK COMMUNICATIONS

- WELL RECEIVED AND USED BY GA PILOTS
- SHOULD IMPROVE PROFICIENCY OF SINGLE-PILOT IFR SIGNIFICANTLY
- REQUIRES BACK-UP VOICE CHANNEL
- RESEARCH NEEDS
  - HUMAN ENGINEERING
  - INFORMATION SELECTION AND FORMATTING

SINGLE-PILOT IFR

- WORKLOAD HEAVIEST DURING LANDING APPROACH
- DIFFICULT TO ACCOMPLISH SAFELY WITHOUT CONSIDERABLE PROFICIENCY FLYING