NASA Contractor Report 3653

A Flight Investigation of Simulated Data-Link Communications During Single-Pilot IFR Flight

Volume II - Flight Evaluations

James F. Parker, Jr., and Jack W. Duffy

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James F. Parker, Jr., and Jack W. Duffy
BioTechnology, Inc.
Falls Church, Virginia

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FOREWORD

This publication is the second volume of a two-part human factors study of single-pilot instrument flight operations in which a Flight Data Console presents Air Traffic Control (ATC) information through a simulated digital data link. The first publication, *A Flight Investigation of Simulated Data-Link Communications During Single-Pilot IFR Flight, Volume 1—Experimental Design and Initial Tests* (NASA CR-3461, August 1981).

Ms. Catherine C. Connor and Ms. Joyce E. Klein served as Inflight Experimenters during this project, and their help is gratefully acknowledged.

Finally, once again, a particular note of appreciation must go to the subject pilots for their contributions. Their willingness to rearrange schedules, appear on short notice, and give opinions and suggestions freely is greatly appreciated. They are:

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INTRODUCTION

Civil aviation in America is being restructured in dramatic fashion today through the interaction of three forces. These are (1) Federal planning and control, (2) quantum advances in computer and display technologies, and (3) a rapidly changing national economy. The changes produced by these three forces in aviation operations conducted five to ten years from now will have great impact on the responsibilities and activities of the pilot. This will be true both for commercial and for general aviation. To gain a feeling for the kinds of changes likely to occur, the three driving forces will be reviewed briefly.

The Federal Aviation Administration announced in 1982 the "National Airspace System Plan." This is a twenty-year modernization program, estimated to cost more than ten billion dollars during the first decade, to completely redo the nation's air traffic control system. The key feature of the plan is the acquisition of a new generation of faster and more versatile computer systems. The greatly expanded computing capacity will allow more activities to be automated which, in turn, will permit a reduction in the number of facilities and personnel. The basis for the modernization is to improve system effectiveness and to reduce costs for operations and maintenance. The increased automation, coupled with the introduction of new equipment, will result in a much different operating environment for both controllers and pilots.

A major updating of ATC will be through the introduction of an automated enroute traffic control service (AERA), scheduled for system-wide operational use by 1996. The purpose of AERA is to improve both the efficiency and safety of air traffic control procedures. It also is intended as a means of dealing with projected traffic growth in the next two decades without the need for increased numbers of controllers. The system, operating from stored flight plans and information concerning aircraft capabilities, will forecast each aircraft's trajectory in the four dimensions of location, time, altitude, and vertical climb/descent profile. These trajectories will be forecast for at least 30 minutes ahead of the actual aircraft position, and will provide automatic rerouting if a potential conflict is predicted.

Communications between a pilot and the AERA system will be through a digital data link to aircraft equipped with a Mode S transponder, the international term for what previously was known as the Discrete Address Beacon System. Clearances received through a Mode S transponder can be displayed either on a cathode ray tube or by a miniature cockpit printing system capable of furnishing hard-copy messages. In an aircraft without Mode S capability, clearances will be received from a computer-generated voice system. In all, the AERA computer will observe airspace use, develop appropriate initial and amended clearances for aircraft, and communicate directly with the pilot. The controller will monitor over-all system operation, deal with unusual requests, and provide a backup capability in the event of system malfunction.

Improvements in aviation and in airspace use over the next twenty years will be possible in large measure through the dramatic developments in computer sciences and in display systems now being seen. The most notable recent advance, of course, is the microprocessor, a bit of silicon smaller than a fingernail capable of performing the basic functions of a general-purpose business computer, although requiring a printed circuit board with support chips to control operations and to store information. The associated memory chips are being improved remarkably. Whereas the initial U.S.-developed chip was 1K (1,000 memory units), industry has proceeeded through 4K and then to 16K chips. At this time, 64K chips are coming into use and those with a capacity of 256K are under development. By the end of this century, designers expect to produce dynamic random access memory chips with more than one million memory cells placed on a single chip the size of a baby's fingernail, a density approaching that of neurons in the human brain (Bylinsky, 1981). Computer systems with memory elements such as these will be able to do remarkable things when incorporated either into general aviation flight instrumentation or into air traffic control equipment.

Matching the advances in computer sciences have been those in display technologies. For some years, the cathode ray tube has been the standard electronic display device. Now, a number of new systems are coming into use, referred to as "flat panel displays." These include liquid crystal, light-emitting diodes, electroluminescent displays, and gas plasma panels. Still others are in various stages of research and development. Flat-panel technology offers considerable savings in panel space, behind-the-panel depth, weight, power, cooling, and life cycle costs, while at the same time offering vastly improved reliability and flexibility of format. All of these systems have potential in general aviation flight systems; indeed, many now are being incorporated into the flight deck instrumentation for commercial air carriers.

The changing scene in civil aviation is occurring during a period of rapidly rising costs. It now is difficult to justify acquiring an airplane simply as a sport vehicle. The cost of a new airplane, even a two-place craft with fixed landing gear, when instrumented properly can be in the order of fifty thousand dollars. Also, operating costs have kept pace. With general aviation fuel prices frequently exceeding two dollars per gallon, a simple Sunday afternoon of flying can prove quite expensive. All of which explains why the attention of those who wish to experience the pure joy of flight is turning to new airplanes such as the ultralights. For others, the conventional airplane more and more will be evaluated in terms of its strict utility, just as with any other piece of industrial equipment.

The changing economy means that general aviation aircraft must show a better return on investment. Improving utility certainly implies an all-weather capability, both for the aircraft and the pilot. At the moment, the pilot lags behind the aircraft in this respect. The quest for ways to make instrument flight easier and safer for general aviation pilots must continue.

Project Background

This study addresses one facet of general aviation, that of single-pilot operations under instrument flight conditions. This is a difficult kind of flight, possibly as difficult as exists in all of aviation. The conditions of single-pilot IFR flight, as well as its safety record, are reviewed in detail in Volume I of this report series (Parker et al., 1981). In general, the earlier study concluded that the principal difficulties with single-pilot IFR were in the management of flight data and the processing of cockpit information during conditions of heavy workload. It was also noted, as has been found in a number of investigations, that the controller/pilot voice communications link is subject to error of several kinds.

Communications problems in general aviation have been singled out in many analyses as requiring special attention. Billings (1981), the scientist responsible for much of the design and implementation of the NASA Aviation Safety Reporting System (ASRS), stated in a recent address:

> If ASRS has told us anything, it has told us that the most pervasive single problem in the system is the failure to transfer information accurately, unambiguously, and in timely fashion among the various elements of the system. We find information transfer problems in 75 percent of all the reports we receive. The causes of such problems are largely due to human failings, but some of the problems are inherent in the design of the system itself. In a complex system which is information-bound, and in which much of the information is highly dynamic, this is an important problem.

Bergeron (1980) reviewed in detail those ASRS reports dealing with single-pilot IFR operations. He cataloged the incidents into five major problem areas, one of which was "ATC and pilot communication problems." Bergeron found that the communication problems were of the following four types:

- Misunderstanding of instructions
- Frequency congestion
- Excessive frequency changes
- Excessive/impeding procedural requirements.

These categories serve to guide any program of improving communications in general aviation and, in turn, its efficiency and safety.

Flight Data Console

The objective of the earlier phase of this project was to evaluate use of a digital data link as an alternative to the current voice link for pilot/ATC communications in general aviation. Consideration of a digital data link is consistent with planning for the future National Airspace System in which the Mode S transponder will serve most communication needs.

In the project, a prototype system, termed a Flight Data Console (FDC), was developed to allow simulation of a digital communications link. While much project effort went toward hardware development, the thrust of the study was a human factors evaluation of the extent to which such a system might reduce cockpit workload, improve flight proficiency, and be accepted by general aviation pilots.

The Flight Data Console will allow a pilot to fly an actual instrument approach with no voice communication between the aircraft and the ground controller. The system presents both reference and command data from Air Traffic Control. It also is capable of storing information until acted upon by the pilot and of providing certain warning signals.

The Flight Data Console is made up of three principal parts (Figure 1): a front seat display and data entry panel for use by the pilot, as shown in Figure 2, 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. A more detailed description of these components, including dimensions and installation, is presented in Parker et al. (1981).

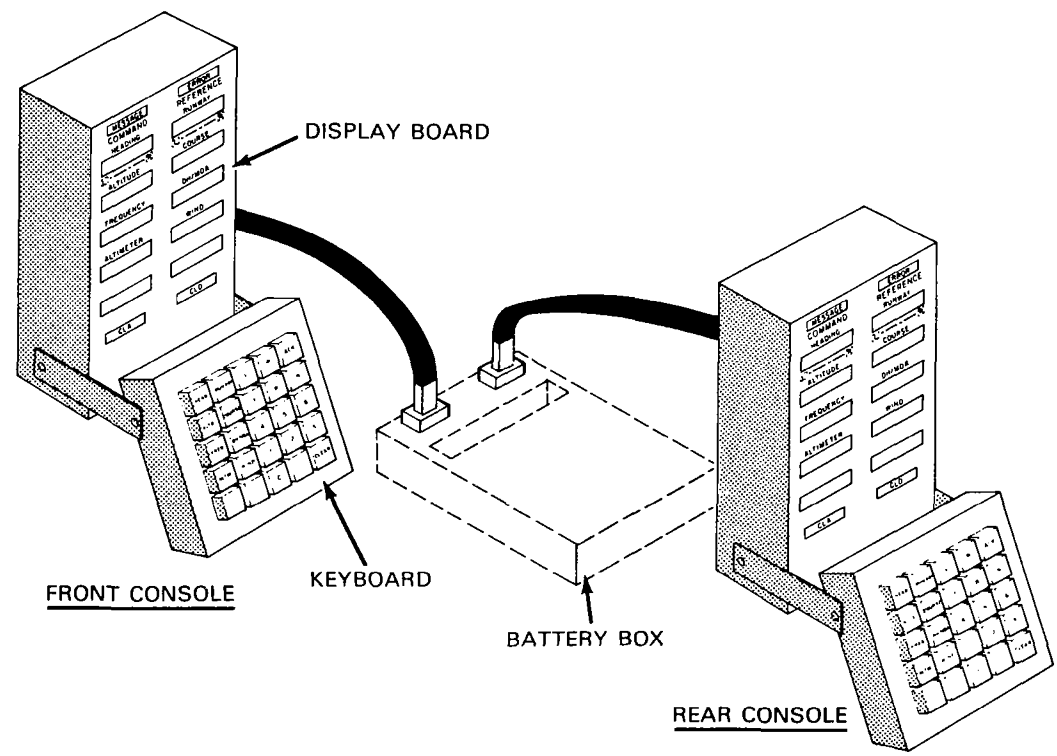

Figure 1. Principal components of Flight Data Console.

The unit which presents ATC information (Figure 2) uses liquid crystal displays, each of which can present up to eight digits. These were chosen because of ease of legibility during daylight conditions. For night flights, a small floodlight illuminates the display panel. The pilot's entry keyboard uses a standard telephone-type touch system, with approximately one-quarter inch movement required for switching.

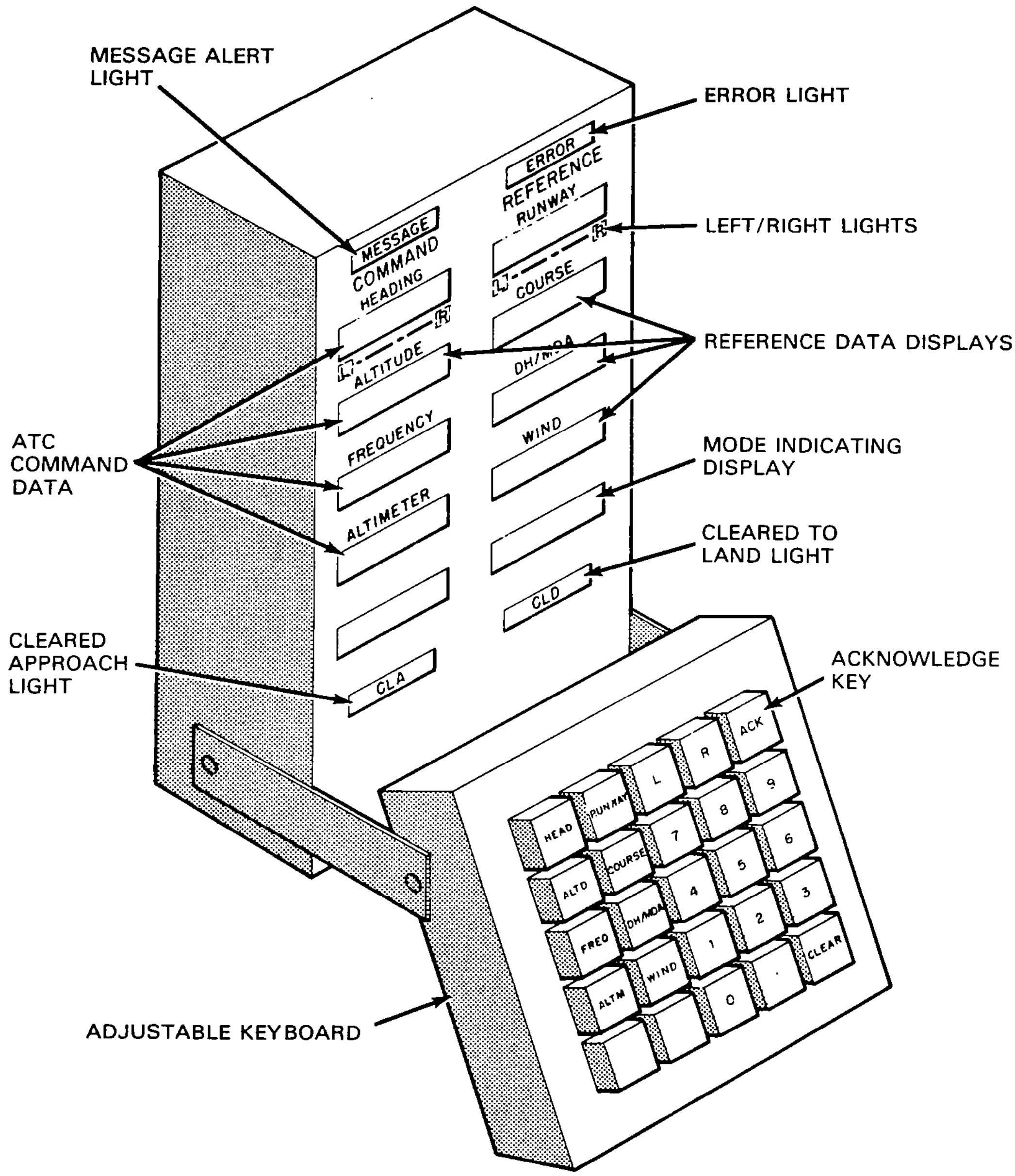

Figure 2. Features of pilot's display and keyboard.

Operation. The Flight Data Console has two modes of operation. In Mode 1, the system presents and stores information (reference data) as entered by the pilot. The FDC in this mode serves as a memory aid and, in essence, takes the place of a paper-and-pencil knee pad. In Mode 1, most information items, such as data obtained from the Automatic Terminal Information Service (ATIS), appear in the right column of the display, although the pilot may enter information in the left column if he desires.

When operating in Mode 2, the Flight Data Console receives command information from Air Traffic Control and presents it principally in the left column of the display. 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 button to indicate completion.

In actual operation, an ATC instruction is received by the console operator in the rear seat. He enters the information in his entry keyboard and views it on his display, both of which are essentially identical to the front seat system, the only difference being that the front seat "acknowledge" key is now a "send" key. After the data are entered, the console operator depresses the send key, thereby transferring all information to the front seat display. At this time the command data item (heading change, for example) and the message light, mounted on the front panel, both blink to indicate arrival of a new ATC transmission. The pilot then depresses the acknowledge key to indicate receipt of the message and completes the maneuver. As the pilot descends to within 30.5 m (100 ft) of his Decision Height or Minimum Descent Altitude, a red light mounted at the top of the FDC holding bracket begins to flash as a warning for the pilot to monitor carefully his descent altitude.

The Flight Data Console was evaluated in an Aztec twin-engine aircraft operated on an instrument flight plan. Nine pilots, each of whom possessed either a private or commercial license and had multi-engine and instrument ratings, flew as test subjects. Each evaluation flight consisted of a number of instrument approaches to airports in the Washington, D.C. area. The flights were conducted so that comparisons could be made among the following conditions:

Flight A (two pilots)—In this flight, the subject pilot flew with an instrument-rated copilot and was free to use the copilot in any way he desired. The only restriction was that the copilot could not actually fly the aircraft. This flight, using a fully qualified instrumented-rated copilot, was intended to provide baseline data since it was considered optimum in terms of reducing workload and making the flight as proficient and safe as possible.

Flight B (one pilot-FDC memory)—Here the pilot was alone, in the sense that the safety pilot did not participate. The subject pilot used the Flight Data Console as a data storage system (memory aid).

Flight C (one pilot-no FDC)—This is the customary single-pilot instrument flight. No special aids were available to the pilot and again the safety pilot did not participate. This is the type of flight which apparently needs improvement if the accident rate is to be reduced.

Flight D (one pilot-FDC/ATC)—In this flight, all approaches were flown using air traffic control information provided through the Flight Data Console.

Conclusions of Earlier Study

Results of the evaluation flights, both with and without use of the Flight Data Console, led to a number of conclusions. Certain of these conclusions, as they support three topics of concern, are presented below:

1. *Inflight Data Management.* There are no formalized rules for the management of inflight data in general aviation except as imposed by the nature of the tasks. This results in considerable variability in the manner in which information processing is done. Some pilots jot data on kneepads; others rely entirely on memory; still others manipulate panel instruments as an aid. Results of this study indicate more elaborate electronic devices, serving only as memory aids, are of little value.

2. *Digital Communications Link.* Instrument flight, including approach and landing, can be accomplished by general aviation pilots receiving all air traffic control communications through a digital data link system such as the Flight Data Console.

The cockpit workload during an instrument approach with ATC providing information through the Flight Data Console was judged by subject pilots to be less than that found when flying alone and using the normal voice communications link. This is possibly the most significant finding of the study. Use of the FDC, in its ATC interactive mode, reduced workload to the point where it matched that found when an instrument-qualified copilot was present.

3. *Human Factors Considerations.* A digital data link communications system is entirely feasible for general aviation flight operations. There are, however, a number of human factors issues which must be addressed if such a system is to achieve its potential. Great care must be taken in placing the system in the cockpit. Human engineering considerations regarding size, location, and ease of use are most important. Message content must be matched to pilot needs, instrument scan must be considered, and display complexity should not be great.

There was a clear-cut expression of need for a back-up voice channel for use in conjunction with the Flight Data Console. The voice channel would be used principally to verify information received through the FDC if any question concerning either accuracy or appropriateness of the information should arise.

Project Objectives

The present study represents a continuation of the effort just described. It encompasses two key objectives, each of which is aimed at achieving a better understanding of the problems which exist in single-pilot instrument flight operations and insight into ways of aiding such flights.

The first objective was to provide an extensive documentation of the flight conditions for single-pilot IFR flight and the activities performed by the pilot. This was to be based on a log of pilot activities combined with both audio and video recordings of selected portions of these flights. Documentation was to be sufficiently extensive that pilot workload might be determined for any segment of the flight. Problem areas related to current methods of weather dissemination, air traffic control procedures, and controls and displays were to be identified and recommendations for solutions made. Finally, these labors were to lead to the development of a typical flight scenario for a full mission IFR flight, covering take-off to touch-down.

A second objective was to extend the evaluation of the Flight Data Console with back-up voice channel to cover its use during operations in an airport terminal area and for a full IFR mission, including the complete enroute segment. A major purpose was to determine the extent to which the voice channel improved operation with the FDC and the specific manner in which the voice channel was used.

It was desired that the results of these flight evaluations be as relevant as possible to the real problems of general aviation operations. For this reason all enroute flights were to be performed under full IFR conditions to the extent feasible. These flights also were to be planned for high density ATC traffic areas.

PROCEDURES

Conduct Terminal Area Flights

The initial effort in this project was to continue the evaluation of the Flight Data Console as an aid during a landing approach under instrument conditions. Each subject pilot flew one data-collection flight at night using the FDC while on an instrument flight plan. These flights differed from those conducted earlier in that a back-up voice channel was provided. This could be used by the pilot in the event he wished to verify some item of information provided through the FDC or if he wanted additional information not provided. In order to preclude the pilot from routine ATC communications, the back-up voice channel was simulated through a headphone intercom system in which the pilot's request to ATC was heard only by the safety pilot. The safety pilot then replied over the intercom, acting as if he were the ground controller.

Nine subjects participated in the terminal area flights. Every effort was made to use subjects who had participated in the earlier part of this project. Of the nine subjects, five had participated previously. All subjects were instrument and multi-engine rated. Those participating for the first time were given a 45-minute ground indoctrination, a flight of approximately 20 minutes to familiarize them with the Aztec aircraft, and a flight of 30 to 45 minutes using the Flight Data Console without voice back-up. This latter flight was necessary if the subject was to be able to evaluate the additional benefit provided by the addition of the voice channel.

The terminal area flights consisted of the same four approaches used earlier: an ILS approach into Dulles International Airport, a VOR approach into Warrenton-Fauquier Airport, an NDB approach into Harry P. Davis field at Manassas, concluding with an ASR approach into Dulles International Airport. As before, all command information (heading changes, altitude changes, frequency settings, altimeter updates, and landing clearances) was provided through the Flight Data Console. Additional details are provided in Volume I (Parker et al., 1981).

Develop IFR Flight Scenario

As an aid in studying single-pilot IFR flight and in identifying problem areas, four flights were made for purposes of developing a scenario for a typical IFR mission. The objective was to make these flights in full IFR conditions (in actual weather for virtually the entire flight, including take-off and landing) and without use of the Flight Data Console. Each flight was planned to cover at least 250 nautical miles. Flight distances had to be juggled, of course, as particular routings were available which offered the desired weather conditions. Table 1 shows the routings used for these flights.

Table 1
Flight Program for Development of
IFR Flight Scenario

Flight	Route	Approximate Distance (nm)	Weather
1	Manassas–Newport News–Lynchburg–Manassas	390	Low overcast ceilings, rain, and generally low visibility. Night.
2	Manassas–Newport News–Richmond–Manassas	260	Low overcast ceilings, rain, good visibility.
3	Manassas–Newport News	160	Low overcast ceilings, rain, low visibility.
4	Manassas–Charleston, W.V.	200	Low overcast, heavy rain, low visibility.

Each flight was conducted as if only the pilot were in the aircraft. The safety pilot served as a data recorder, but in no way assisted the pilot. The safety pilot kept a log of performance with which to judge the adequacy of the flight, documented all problems which arose, operated the tape recorder which provided a full audio record of the flight, kept a listing of any unsafe performances by the pilot, and maintained a safety watch. In these flights, the pilot was free to use normal voice communications (via headset) with Air Traffic Control as he might desire.

An important objective of the documentation was to provide a time-line of pilot activities throughout the flight. This information is most important in assessing both the magnitude and change in workload at different points during a flight. The activities of the pilot were recorded by the rear-seat experimenter who monitored a clock (provided through the elapsed time indicator associated with the panel Automatic Direction Finder) and listed each activity occurring within each minute of time. Each time the pilot touched a control or an item of panel equipment (throttle, radio, etc.), it was listed as an activity. To expedite the recording, each equipment was coded numerically, as shown in the Recording Guide presented in Table 2.

Table 2
Pilot Activity Analysis
Recording Guide

Flight Profile

Segment	Begin	End
Take-off	Application of Power	Gear up, power adjusted
Climb & departure	Climb heading	Final altitude reached
Cross-country cruise	Attitude stabilized	Begin descent
Let-down	Descend	Appr. alt. reached
Vectoring	ATC headings	Initial approach
Initial approach	Change to approach speed	Cleared for approach
Final approach	Final fix inbound	Cleared-land
Land (Missed appr.)	Cleared	Roll-out complete

Pilot Control Actions

Communication	Navigation	Flight Path Control	Power	Aircraft Control
1. Boom mike	3. Chart	12. DG	17. Throttle	26. Gear
2. Radio freq.	4. Radio (Nav)	13. AI	18. Props	27. Gear pump
	5. HSI	14. Altimeter	19. Mixture	28. Alternator/Battery
	6. VOR	15. Trim	20. Pumps	29. Lighting
	7. ADF	16. Flaps	21. Fuel	30. Cowl flaps
	8. DME		22. EGT	
	9. Marker Beacon		23. Friction Lock	
	10. Clock/ Timer		24. Power Chart	
	11. Transponder		25. OAT	

Four pilots, selected from the nine who participated in the terminal area flights, served as subjects for this phase. At the conclusion of each flight, the subject pilot completed a questionnaire concerning the adequacy of his performance and any problems encountered. He rated his workload for the eight segments comprising the entire flight. He also discussed the features which contributed to high workload in those segments rated as such. Finally, the pilot discussed specific aspects related to weather acquisition, ATC procedures, aircraft controls and displays, plus any other topics of concern.

Conduct Enroute Flights Using FDC

In the final phase of the flight evaluations, the same four pilots again flew enroute flights under comparable conditions but in this case using the Flight Data Console for communications from Air Traffic Control. Again, each flight was conducted under actual IFR conditions and over a distance in the order of 250 nautical miles. Table 3 shows the routes flown. The purpose was to evaluate use of the Flight Data Console with voice back-up channel over a full IFR mission, examining for the first time its effectiveness for enroute communications. Voice communications between the pilot and Air Traffic Control were accomplished by having the subject pilot talk to the safety pilot over the restricted intercom system; the safety pilot then speaking directly with ATC. As with the flights conducted in terminal areas, this precluded the pilot from hearing routine ATC communications. He was, however, allowed to communicate through normal procedures with any service other than ATC, such as a Flight Service Station or the recorded Automatic Terminal Information System. As before, all voice communications were recorded.

Table 3
Flight Program for Enroute Evaluation of
Flight Data Console

Flight	Route	Approximate Distance (nm)	Weather
1	Manassas—Lynchburg—Richmond—Manassas	270	Low overcast ceilings, moderate rain, low visibility, thunderstorms.
2	Manassas—Harrisburg—Wilmington—Manassas	300	Low overcast ceilings, turbulent, low visibility. Thunderstorms.
3	Newport News—Lynchburg—Manassas	270	High overcast, turbulent. Good visibility.
4	Charleston, W.V.—Roanoke—Washington (Dulles)	290	Low overcast ceilings, Low IFR minimums, fog. Night.

The safety pilot rated flight performance, on a ten-point scale, at the conclusion of the flight. Both he and the subject pilot also discussed problems noted with the voice channels and made recommendations for improvement. The subject pilot again rated his workload during the eight segments of flight. He also discussed problems with acquisition of weather information, ATC procedures, controls and displays, and other topics. Finally, the pilot provided rankings which compared single-pilot instrument flight, use of the Flight Data Console alone, and use of the Flight Data Console with voice back-up. The comparisons were made on the dimensions of safety, workload, and pilot preference.

RESULTS AND DISCUSSION

Emphasis in this project is on human factors issues in single-pilot instrument flight. We are concerned with the problems encountered by the pilot, the workload imposed on him, and specific features of these flights that might affect safety adversely. There is a particular interest in the forces of change operating in civil aviation and the likely impact of these changes on the general aviation pilot.

As part of this project, an item of cockpit instrumentation, the Flight Data Console (FDC), was developed. This instrument served as a vehicle with which to examine some of the human factors issues in using a digital data link system to replace the current voice channel for pilot/ATC communications. The Flight Data Console was constructed solely to study pilot performance. The adequacy of the Flight Data Console as a possible item of cockpit instrumentation is of little concern. In fact, many problems, such as size, location, illumination, and ease of operation, have been identified. However, the only real question concerning the FDC is whether it provides appropriate simulation of a digital data link system for communications. If the simulation is adequate, and reactions of pilots would indicate that it is, the true interest of the investigation turns to the concept of the digital data link itself. What advantages does it provide? What problems are associated with its use?

Evaluation of Flight Data Console for Terminal Area Operations

The pace of operations in any instrument flight increases significantly when the pilot enters a high density terminal area, contacts the approach controller, flies the designated approach, and completes the landing. The pilot must comply with numerous ATC instructions presented rapidly, make a number of frequency changes, fly the specified approach, maintain airport orientation, and prepare the airplane for landing. It is a demanding operation, one for which the system offers little, if any, margin for error. Any assistance given the pilot, particularly if he is flying alone, or any help which reduces the likelihood of error, can be used to advantage.

The Flight Data Console was evaluated in the earlier part of this project for its utility in terminal area operations. The key finding of this evaluation was that pilots judge the cockpit workload during an instrument approach with the FDC to be less than that found when flying alone and using the normal voice communications link. Use of the FDC by a single pilot during instrument approach appears to reduce workload to the point where it matches that found when a qualified copilot is aiding the pilot. On this basis, the concept of a digital data link is worth pursuing.

One comment made several times in the earlier evaluation concerned the need for a back-up voice channel for use with the Flight Data Console. The capability of contacting the controller directly by voice, if circumstances appeared to require it, was considered desirable. For this reason, a voice channel was added to the FDC and the current evaluation conducted to determine how this combination would be used, any problems in its use, and the benefits it provides.

Performance

The performance of pilots was examined for the four types of instrument approaches flown. Results of the different ways of assessing performance are presented in Table 4. These results are virtually identical with those obtained during the terminal area evaluation flights in the earlier project phase.

Table 4
Flight Performance in Terminal Area Operations
(Averaged for Nine Pilots)

	ILS	VOR	NDB	ASR
Performance Rating[1] (Safety Pilot)	5.5	4.4	5.2	5.5
Performance Rating (Subject Pilot)	5.6	5.0	6.0	6.0
Workload Rating[2] (Subject Pilot)	5.3	5.2	4.9	7.2
Unsafe Occurrences (No.)	0	4	2	0

[1] 10 = Excellent, 0 = Unsatisfactory

[2] 10 = Very heavy, 0 = Light

Ratings of performance by both the safety pilot and the subject pilot show that all approaches were considered to be about average. As before, there is a very slight tendency, of no real consequence, for subject pilots to rate performance higher than the safety pilot. No difference in performance can be seen among the different approaches, although one might expect the ILS approach, because of its precision radio guidance, to be somewhat superior. The only difference worth noting is in the workload rating given to each approach. Here it appears that the workload involved in flying an ASR approach is perceived as heavier than that for the other three approaches.

The workload rating for the ASR approach may be more an experimental artifact than a real difference. In two flights, difficulties were experienced with the directional gyro compass, so a "no gyro" approach was flown. This is a more demanding task. Also, in an ASR approach, the pilot gets all of his directional information from the FDC, as opposed to a VOR approach in which much information is obtained from the VOR needle (the CDI). Because of the poor location of the FDC (aft of the throttles), considerable work is involved in maintaining a constant scan of the FDC. Were this instrument to be located more appropriately on the panel, the workload undoubtedly would be less.

The safety pilot, who was a qualified instrument flight instructor, provided an additional measure of performance. Using the criteria which would be applied in any instrument flight test, the safety pilot listed any event during an evaluation flight which could be termed an "unsafe occurrence." These were maneuvers or activities which, if left uncorrected, could threaten the safe completion of the flight. As seen in Table 4, there were six unsafe occurrences, four during VOR approaches and two during NDB approaches. The occurrences included events such as "turned 180 degrees in the wrong direction after a missed approach," and "descended 120 feet below the Minimum Descent Altitude during an NDB approach." Although the grouping of occurrences would indicate the VOR approach to be the most difficult, the limited number of events would make this a tenuous conclusion. In addition, the other ratings do not support such a conclusion.

Use of Voice Channel

The principal purpose of the terminal area flights was to evaluate use of a back-up voice channel with the Flight Data Console. In these flights, if the subject pilot wished to verify any information presented on the FDC or obtain any additional information from ATC, he was free to use the voice channel. Table 5 shows that the voice channel was used 14 times during these flights. For whatever reason, greater use was made of the voice channel during the ILS approach than in any of the others. Most requests were for information from the Automatic Terminal Information Service (ATIS) and for verification of the type of approach assigned by ATC. In the future, if the FDC concept is expanded, this type of information might be usefully added.

Table 5
Use of Back-Up Voice Channel
in Terminal Area Operations

	Approach				
Number of Uses	ILS	VOR	NDB	ASR	Total
	7	2	2	3	14

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

Pilot evaluations of the inclusion of a voice channel with the Flight Data Console were quite favorable, as shown in Table 6. Without exception, the nine subject pilots felt that the voice channel improved the safety of flight operations. At essentially the same level, they felt that use of this back-up system improved the acceptance of the Flight Data Console concept for a pilot. The majority of the pilots concluded that use of the voice channel reduced their workload during instrument approaches in a high density terminal area.

Table 6
Pilot Evaluations of Back-Up Voice Channel for Terminal Area Operations
(Nine Pilots)

	Yes	No
Use of Voice Channel		
– increases safety	9	0
– reduces workload	6	3
– improves FDC acceptance	8	1

Rankings

At the completion of the terminal area flights, subject pilots were asked to rank three flight conditions, as shown in Table 7, along the dimensions of safety, workload, and pilot preference. This was done with some trepidation since the procedure violated any number of psychometric considerations. Not the least of these was the fact that subjects were asked to compare a flight condition (Flight Data Console with voice channel) with which they had had immediate past experience against two others for which their experience might be one year or more old. Valid comparisons require that immediacy of experience be controlled. This could not be done in this instance. However, recognizing the possible lack of validity in these conclusions, the results did show that the flight condition represented by use of the Flight Data Console with voice channel was considered to be safest, to impose the lightest workload, and to be most preferred by these pilots.

Table 7
Rankings of Three Flight Conditions

Flight Condition	Safety	Workload	Preference
Flight Data Console/Voice	2.4	1.3	2.7
Flight Data Console	1.5	2.1	1.3
Single-Pilot IFR	2.2	2.4	2.0

Safety: 3 = most, 1 = least
Workload: 3 = heaviest, 1 = lightest
Preference: 3 = most, 1 = least

Documentation of Single-Pilot Instrument Flight

This project afforded an opportunity to document, in a reasonably objective manner, pilot functions performed in flying a complete instrument mission. There were several reasons for collecting this information. First, this offered a chance to examine pilot workload for all segments in a complete flight, instead of focusing only on the approach to landing segment as had been the case in the earlier tests. The second was to collect information relating to current methods of weather dissemination, air traffic control procedures, and use of intra-cockpit systems during an IFR mission. Finally, it was believed that preparation of a typical flight scenario for an IFR mission (take-off to touchdown) would provide a useful research tool. Accordingly, four pilots flew IFR missions under full instrument weather conditions over routes in the order of 250 nautical miles. The following results are based on these flights.

Performance

Each cross country IFR flight was flown as if by a single pilot. A safety pilot was present but did not participate in flight activities in any manner. The safety pilot plus the rear-seat experimenter served principally as research data recorders.

At the completion of each cross-country IFR flight, the subject pilot was rated by the safety pilot, using a ten-point scale, as to his overall adequacy. The results show a surprising disparity among pilots, with ratings ranging from one to eight. A rating of eight, quite a good evaluation, would indicate the pilot was in complete control of the various situations and demands which arose during his flight. At the other extreme, a rating of one indicates performance only marginally better than unsatisfactory. This is quite a low score for a qualified and current instrument pilot.

Table 8
Comparison of Enroute Performance and
Experience for Subject Pilots
(N = 4)

	Range
Rating by Safety Pilot[1]	1 – 8
Unsafe Occurrences (No.)	0 – 11
Total Time (Hrs.)	425 – 2000
Total Instrument Time	30 – 250
Instrument Time–Last Six Months	8 – 40

[1] 10 = Excellent, 0 = Unsatisfactory.

The differences in the ratings among the four pilots were considerable, a much wider disparity than expected. What could account for this? One possibility, of course, is the amount of previous flight time, particularly instrument flight time. Table 8 shows the flight experience for the four subject pilots. One measure, "instrument time in last six months," varies in a direct relationship with the safety pilot ratings. The correlation between these two variables was calculated as 0.92. This correlation is quite high, although not significant statistically due to the limited number of cases. This correlation, however, does reinforce the belief that if instrument proficiency is to be maintained, one must fly frequently under instrument conditions.

The second measure of performance, seen in Table 8, is the number of unsafe occurrences noted by the safety pilot. Each of these occurrences represents an out-of-tolerance event which would be considered disqualifying during an instrument flight check. These results, ranging from zero to eleven such occurrences, closely parallel the performance ratings given by the safety pilot. This reinforces the conclusion that full IFR flight is difficult to accomplish, even for qualified instrument pilots, unless proficiency is maintained in peak condition.

Workload

Since heavy workload is believed to be a reason for the poor safety record of general aviation instrument flight, one of the desired end products of this project was a better understanding of the extent of the workload and the way in which it varies during flight. Such understanding should be useful in developing programs to improve safety. Two methods for measuring workload were used. This is consistent with Wierwille and Williges (1979), who surveyed the literature on workload measurement and concluded that "No one single technique can be recommended as *the* definitive measure of operator workload. Because of the multidimensionality of workload, it also appears unlikely that any one single measure will ever suffice completely. Consequently, multiple measures including the dimensions of subjective opinions, spare mental capacity, primary tasks, and physiological correlates should be considered."

In this study, workload was measured through the use of subjective opinions and through a count of primary tasks (activities) of the pilot. Results of these analyses are presented in Table 9. The final column in Table 9 shows ratings obtained in a study conducted at the NASA Ames Research Center (Hart et al., 1981) in which 12 instrument rated general aviation pilots rated some 155 tasks required for flight under either instrument or visual flight rules. Tasks, and the related ratings, were selected from this list which matched, to the extent possible, the general activities subsumed within the flight segments used in the present project.

The three methods for measuring workload shown in Table 9 show a reasonable measure of agreement. As one might expect, the heaviest workload is found during the initial part of a flight, the "takeoff" and "climb and departure" segments, and in the final flight segments, the "vectoring"

Table 9
Workload Assessments for Flight Segments
of IFR Mission

Flight Segment	Subject Pilot Ratings[1]	Activity Counts[2]	ARC Ratings[3]
Take-off	4.3	3.8	3.1
Climb and departure	4.8	2.7	3.0
Cross-country cruise	2.0	2.0	2.5
Let-down	3.8	2.8	2.9
Vectoring	4.3	3.8	2.8
Initial approach	5.8	4.1	4.3
Final approach	6.3	3.6	4.3
Land/missed approach	5.3	2.3	3.5

[1] 10 = Very heavy, 0 = Light

[2] Average activity count/minute

[3] 5 = Fully occupied, 1 = Little or no activity (Hart et al., 1981)

through "land/missed approach" portions. By all measures, the landing approach is the period of heaviest workload. If heavy workload operates as a stress variable to impair performance, this is the point at which one should look for such impairment. This is the point at which safety problems will be paramount.

Problems

The questionnaire completed by subject pilots following each flight requested information concerning problems encountered during the flight. Topics of interest included acquisition of weather information, procedures and practics of Air Traffic Control, use of cockpit controls and displays, and any other point of concern. A number of problems were discussed. These are presented below as combined and summary statements.

Weather. Several comments were received concerning difficulties in obtaining weather information while enroute. To obtain the latest weather information, a pilot must obtain ATC permission to leave his assigned frequency while he calls a Flight Service Station for the weather data. One pilot noted that he tries to avoid this by using two radios at once, obviously not a satisfactory solution. Another spoke of turning quickly to the Flight Service Station frequency, thereby missing an ATC instruction on occasion. In all, the requirement to leave the ATC frequency while dealing with an FSS is considered disruptive and inefficient.

Obtaining weather information for uncontrolled airports (those without an FAA tower) was a problem. For example, one pilot discussed difficulties in obtaining information concerning weather at the Lynchburg airport prior to making an instrument approach. Lynchburg recently has gone to part-time tower service, with the tower not in operation at this time. The altimeter setting, which was two hours old, was obtained from the Roanoke FSS, a distance of almost 50 miles. The combination of the time delay plus the distance could result in significant inaccuracy in the altimeter setting, a matter of some concern when entering an approach to minimum altitude.

Another comment was made concerning the trouble experienced at an airport prior to takeoff in contacting the nearest Flight Service Station on the telephone. Due to the volume of calls, the FSS telephone seemed to be busy constantly. This resulted in a noticeable delay in departure.

All of the comments concerning acquisition of weather information centered on the poor procedures now in use for providing such information. Any system which would make such information more readily available in the cockpit during flight would be of considerable value.

Work at Ohio University (McFarland, 1982) has considered the desirability and feasibility of providing weather information to general aviation pilots through some type of data uplink. In initial tests, the VOR frequency has been used satisfactorily for this purpose. It was concluded that "real-time weather data being available on call in the cockpit will improve safety and reliability of general avaiation operations to include, specifically, single-pilot IFR operations." Results of BioTechnology's studies support these conclusions.

Air Traffic Control. Difficulties were experienced in obtaining IFR clearances at uncontrolled airports prior to takeoff, even though the landing had been only a temporary stop. In one instance, due to the poor communication channel to ATC, it was necessary to relay the clearance request through another aircraft which was enroute at the time.

Other comments related to the flight restrictions, and their impact on general aviation operations, imposed by the FAA immediately after the controllers' strike. In one case, a flight plan was lost in the ATC computer. Inasmuch as IFR flights require reservations, with a limited number of departures allowed, it was necessary to spend six hours on the ground before a new clearance could be activated.

IFR Flight Scenario

In order to describe all pilot activities and the operational environment during an instrument flight, a scenario was prepared which documents an IFR mission from takeoff to touchdown. All communications by the pilot and by ATC shown in this scenario were taken directly from tape recordings made during flight. The pilot activities shown for each segment were recorded by an experimenter in the rear seat. The flight scenario is presented as Appendix A. In order to provide comprehensive coverage of different mission requirements and weather conditions, results from several flights are blended into this scenario.

Enroute Evaluation of Flight Data Console with Back-Up Voice Channel

The first part of this project evaluated the Flight Data Console with a back-up voice channel for terminal area operations. In this part, this evaluation is extended to cover the full IFR mission, flown in instrument weather conditions. The terminal area flights were conducted at night, with all procedures carried out in accordance with full instrument flight. The present part of the evaluation carries this one step further, into actual instrument weather.

Instrument flight operations impose considerable stress, particularly if the flight is being flown by a single pilot. Even a flight as short as one hour can produce real fatigue due to the constant attention required and the considerable workload experienced at a number of points during the flight. The objective of the flight evaluation described here was to determine if use of the Flight Data Console with voice channel, and its presumed reduction in workload associated with current voice communication activities, would reduce flight stress and consequently improve performance.

Performance

The performance measures obtained for the four subject pilots are presented in Table 10. The four subjects are the same as those who flew the enroute flight earlier as a typical single-pilot IFR mission, without using the Flight Data Console. Subjects always flew the single-pilot IFR flight first so that they would have an established baseline against which to evaluate use of the Flight Data Console. The rationale was that the first flight showed a subject what a typical single-pilot IFR flight was like. Did using the Flight Data Console, with voice channel, in the second flight help the situation?

Table 10
Enroute Flight Performance Comparing Single-Pilot IFR Against Flight Data Console With Voice
(N = 4)

	Range
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

In order to keep the practice effect at a minimum, the second flight always followed a different route than the first. This made it a completely new experience for each subject.

The range for the performance measures for the two types of flight—single-pilot IFR and IFR using the Flight Data Console—is shown in Table 10. The performance ratings for FDC flight reflects a measure of improvement for those subjects who had performed poorly during the earlier single-pilot IFR missions. In addition, the number of unsafe occurrences was reduced substantially. In all, performance using the Flight Data Console with voice channel shows a measure of improvement over those flights in which the system was not used.

Workload

Assessing the workload imposed during single-pilot instrument operations was a key objective of this project. A particular question concerned the extent to which use of the Flight Data Console during operations under actual instrument conditions might improve the workload. Thus, each subject pilot was questioned concerning the workload he felt he was under during each flight segment of the complete mission. Results are presented in Table 11. The workload ratings obtained following the evaluation flight with the Flight Data Console are compared with those obtained following the single-pilot instrument flight.

Table 11
Workload Ratings Comparing Flight Data Console with Voice Against Single-Pilot IFR

	Subject Pilot Ratings[1]	
Flight Segments	FDC with Voice	Single-Pilot IFR
Take-off	3.8	4.3
Climb and departure	4.8	4.8
Cross-country cruise	2.8	2.0
Let-down	4.8	3.8
Vectoring	4.5	4.3
Initial approach	5.8	5.8
Final approach	5.8	6.3
Land/Missed approach	4.8	5.3

[1] 10 = Very heavy, 0 = Light

The results in Table 11 show considerable consistency among the two flight conditions, with no evidence presented for any real improvement in workload through use of the Flight Data Console. In each flight condition, a heavy workload is found initially during the "take-off" and "climb and departure" segments, with peak conditions appearing during the "initial approach" and "final approach" segments. Considering that a ten-point scale was used to obtain these ratings, however, there is no indication that the workload reaches unmanageable proportions for any of the flight segments.

Use of Voice Channel

Just as for the terminal area flights, subjects here were asked to evaluate the use of the back-up voice channel with the Flight Data Console. Each pilot indicated that the voice channel was used on a number of occasions during the cross-country flight. Table 12 shows the different classes of information which were sought by pilots through use of this channel. These results confirm the findings for the terminal area evaluations. The voice channel was used to obtain terminal information from the Automatic Terminal Information Service, to verify information provided from the controller, to obtain updated weather information, and, in general, to confirm any item of information about which there might be uncertainty.

Table 12
Use of Back-Up Voice Channel for
Full-Mission Instrument Operations

Number of Pilots Noting Use	Information
2	Obtain ATIS data
2	Verify ATC data (heading, runway in use, etc.)
2	Obtain weather information
1	General confirmation of all flight data

One pilot noted that "The FDC seems to provide an opportunity to acquire weather information without having to listen to two radio frequencies at once. ATC commands come through the FDC and are visually presented to the pilot while the weather information can be obtained aurally from the radio. I like this aspect."

Another pilot made the comment that "I think that back-up voice capability is necessary in case there are problems, such as mistakes in FDC transmission, confusion, etc. However, it is clear the FDC would drastically reduce necessary voice communication."

As a final part of the voice channel evaluation, pilots responded to the items shown in Table 13. These results are quite consistent with those found for terminal area operations. There is complete agreement that use of a voice channel with the Flight Data Console serves to increase safety and improves the acceptance of the FDC for instrument flight. Again, there is no particular feeling that use of the voice channel reduces the workload for the pilot.

Table 13
Pilot Evaluations of Back-Up Voice Channel
for Full-Mission Instrument Operations
(Four Pilots)

Use of Voice Channel	Yes	No
— increases safety	4	0
— reduces workload	1	3
— improves FDC acceptance	4	0

Rankings

At the completion of the final enroute flight, subject pilots were asked to rank the three flight conditions, as shown in Table 14, along the three dimensions of safety, workload, and pilot preference. As with the rankings obtained following the terminal area flights, considerable caution must be expressed against placing heavy reliance on these relative rankings. Here again subjects were asked to compare flight conditions for which their recency of experience varied greatly.

Table 14
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

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 back-up voice channel was considered to be safest, to impose the lightest workload, and to be most preferred by these pilots.

Recommendations

Recommendations were requested from subject pilots following each of the three evaluation flights. Recommendations were solicited for improving the utility of the Flight Data Console, incorporating a voice channel, improving the acquisition of weather information, operating with Air Traffic Control, and using aircraft controls and displays. Subjects also were free to present recommendations concerning any other topic of interest. The principal recommendations offered covered the following issues:

Flight Data Console

Most of the recommendations concerning the Flight Data Console were for improvements in its human engineering features. Suggestions were made concerning the value of smaller size, better location within the pilot's scan pattern, improved lighting, use of light-emitting diodes to replace the liquid crystal displays, incorporation of an audio tone with the altimeter warning light, and more consideration for ease of operation. One aspect of FDC operation apparently was confusing in some instances. Once a pilot has been "cleared for the approach," the last ATC heading remains on the console, even though the pilot now is free to fly whatever heading he chooses in completing the approach. A means should be incorporated for clearing the heading representing the last ATC command.

One insightful recommendation was received concerning the specificity or quality of information presented on the Flight Data Console. This pilot recommended that the system include a means for distinguishing between a heading given by ATC as part of radar vectors and one given to intercept an airway. He stated that "Just seeing the heading 090 does not tell the pilot whether to anticipate airway intercept or to await further vectoring." This point certainly is worth considering in any later redesign.

Use of Voice Channel

Without exception, every pilot recommended that any digital data link system include a back-up voice channel. Many advantages were noted for this dual communications system. Principal among these was the ability to verify through voice communications any discrepancies or points of confusion when dealing with Air Traffic Control. As stated by one pilot, "I think the two systems (digital data link and voice) used together is safer than either one alone."

The typical expression of support for a voice system is reflected in the comment, "There are not a lot of times when voice channel is required, but when it's needed, it's needed. I particularly enjoy the 'silent cockpit' which the FDC permits, but do need a few items of information additionally."

Air Traffic Control

As a rule, the subject pilots in this study operated rather well in an air traffic control environment. No serious problems arose with respect to ATC interactions, except in one instance which was an unavoidable function of the flight reservations imposed following the controllers' strike. Specific problems, with supporting recommendations, follow:

1. Clearance delivery at uncontrolled airports is difficult to obtain. This would be improved if clearances could be received after take-off on a cockpit display system or printer.
2. The Flight Service Station frequency (122.2) frequently is so busy that it is difficult to contact the station. More frequencies or a different system is required.
3. Communications with an ATC facility frequently are blocked by transmissions from other aircraft. Use of a discrete address system such as the Flight Data Console is an improvement and is recommended.

General Recommendation

One comment was made in the recommendations section by a pilot which is so favorable toward the Flight Data Console concept that one cannot resist including it as the final comment. This pilot said, "Fantastic! Makes cockpit organization a breeze and reduces paperwork. Also reduces airwaves congestion. Makes IFR easier."

SUMMARY AND CONCLUSIONS

Civil aviation in the United States is in a period of real change. This is particularly true for general aviation, which is being buffeted by three significant pressures. The recently announced revisions to the "National Airspace System Plan" inevitably will lead to a more complex and controlled operating environment. Advances in computer technology are moving toward increased sophistication of instrumentation and more automation. Finally, rapidly rising costs in aviation are causing the small airplane to be viewed less as a sport vehicle and more as a business investment. These pressures all imply an all-weather capability for both aircraft and pilot.

This study addresses one facet of general aviation, that of single-pilot operations under instrument flight conditions. This is a difficult kind of flight, possibly as difficult as exists in all of aviation. The conditions of single-pilot IFR flight, as well as its safety record, are reviewed in detail in Volume I of this report series (Parker et al., 1981). In general, the earlier study concluded that the principal difficulties with single-pilot IFR are in the management of flight data and the processing of cockpit information during conditions of heavy workload. It was also noted that the controller/pilot voice communications link contributes to the workload and is a source of considerable error within the system. This is supported by Billings (1981), who reviewed data in the NASA Aviation Safety Reporting System (ASRS) and concluded that 75 percent of all reports were based on information transfer problems.

In this project, a Flight Data Console (FDC) was developed to allow simulation of a digital communications link to replace the current voice communications system. The project represents a human factors evaluation of a digital communications system, as represented by the Flight Data Console, to determine how such a system might reduce cockpit workload, improve flight proficiency, and be accepted by general aviation pilots. Results of the first phase, as reported in Volume I, show that instrument flight, including approach and landing, can be accomplished by general aviation pilots receiving all air traffic control communications through a digital data link system like the Flight Data Console. Use of the FDC was judged by subject pilots to reduce cockpit workload during an instrument approach to a point where it matches that found when a qualified copilot is present and helping the pilot. A frequent comment, however, was that a back-up voice channel for use with the FDC would be desirable.

The present study represents a continuation of the efforts just described. There were two principal objectives. The first was to extend the evaluation of the Flight Data Console to cover its use for a full IFR mission, including the complete enroute segment. In view of comments made earlier, these flights were to offer a back-up voice channel in conjunction with the Flight Data Console. The purpose here was to determine the extent to which this voice channel improved operation with the FDC and the specific manner in which the voice channel was used.

The second objective was to provide documentation of the flight conditions for single-pilot IFR flight and the activities performed by the pilot. This was to be based on a log of pilot activities combined with both audio and video recordings of selected portions of these flights. Documentation was to be sufficiently extensive that workload might be determined for any segment and that problems related to weather dissemination, air traffic control procedures, and use of controls and displays could be identified. These labors were to lead to the development of a flight scenario for a full mission IFR flight, covering takeoff to touchdown.

The results of this project support the following conclusions and recommendations:

Digital Data Link

1. General aviation pilots operate well with a digital data link communications system. The prototype system in use in this project suffered from any number of human engineering problems related to placement, legibility, size, and ease of operation. Were these problems

to be overcome in some later development of this instrumentation, it can be predicted that a digital data link will be well received in the aviation community, will increase the efficiency of flight operations, and should make single-pilot instrument flight operations safer than is the present case.

2. Should a digital data link be used in the future for receipt of routine ATC communications, considerable study should be given to the kinds of information to be presented. In this study it was noted that a "heading" command is more useful when a pilot knows something of the purpose for the heading, rather than just receiving the information item singly and without context.

Back-Up Voice Channel

1. Pilots were universal in recommending that any digital data link system include a back-up voice channel. Many advantages were noted. These include the ability to verify any points of confusion in ATC instructions, and the capability for checking weather and wind conditions as the pilot feels the need for these data. All pilots in this study made use of the back-up voice channel when it was available. However, they did not use it in any manner to undercut the operation of the Flight Data Console. The two items appear to be mutually supportive.

Air Traffic Control

1. All comments relating to air traffic control concerned communications issues. No complaints or comments were received that reflected directly on ATC procedures, method of control, or interaction with general aviation. The communications difficulties noted with ATC included transmissions blocked by other aircraft, difficulties in obtaining weather data while monitoring an ATC frequency, and congestion of Flight Service Station frequencies. All of these problems, it would seem, could be improved were such information to be provided through a discrete digital data link.

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APPENDIX A

SINGLE-PILOT INSTRUMENT FLIGHT SCENARIO

Page	Route	Flight Segment	Comments
Full Mission:			
32-35	Byrd International to Manassas Municipal (Harry P. Davis Field) (RIC to W-10)	Take-off to cruise	Flight was diverted due to adverse weather
36-41	Byrd International to Manassas Municipal (RIC to W-10)	Cruise to letdown	
42-48	Byrd International to Manassas Municipal (RIC to W-10)	Letdown to landing	Changed from VOR to visual approach
Additional Mission Segments:			
49-54	Patrick Henry International to Lynchburg Municipal (Preston Glenn Field) (PHF to LYH)	Letdown to landing	ILS approach to (near) ceiling and visibility minimums
55-63	Manassas Municipal (Harry P. Davis Field) to Patrick Henry International (W-10 to PHF)	Cruise to letdown	
64-67	Patrick Henry International to Byrd International (PHF to RIC)	Take-off to cruise	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

		Communications			
Flight Segment	Time	ATC	Pilot	Principal Pilot Activities	Remarks
Take-off to Cruise	00:00	76 Yankee. After departure, turn left on course. Cleared for take-off			Communication with Richmond Tower.
			After departure, left on course. Cleared for take-off. 76 Yankee	Mike	
				Throttles forward	Time starts
				Gear up	
	00:30	76 Yankee. 5676 Yankee, contact departure			
	00:33		76 Yankee to departure. Good day	Mike	
				COM radio adjusted	
				Throttles adjusted	
				Trim adjusted	
				Props adjusted	
				Throttles adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	ATC	Pilot	Principal Pilot Activities	Remarks
		Communications			
Take-off to Cruise	01:08		Richmond departure 76 Yankee with you. Climbing to five, out of one point three	Mike	
	01:13	76 Yankee, Richmond departure control. Radar contact and let's see, intercept the 332 radial, climb and maintain 5000			
	01:23		Up to five, and intercept the 332 radial	Mike	
				HSI adjusted	
				Pumps off	
				Chart check	
				Mixtures adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Take-off to Cruise	03:30	Check your transponder. Not receiving you, 4760			
	03:38		4760 for 76 Yankee. We're recycling	Mike	
				Transponder recycled	
	05:00			Throttles adjusted	
				Trim adjusted	
	05:59	76 Yankee, still not receiving your transponder at all. You may try to reset for me please, 4760			
				Throttles adjusted	
				Props adjusted	
	06:15		OK. 76 Yankee. We'll try again	Mike	
				Transponder recycled	
				Mixtures adjusted	
				Power chart checked	
				OAT checked	
				Mixtures adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Take-off to Cruise	08:40			VOR adjusted	
	13:32	76 Yankee you can turn right now. Proceed direct Brooke, tune in Brooke. Proceed direct Brooke, direct Manassas. They've got weather moving in from the west.			Diverted at this time from original filed flight plan due to adverse weather.
	13:50		OK, direct Brooke and then direct Manassas from Brooke. Thank you	Mike	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Cruise to Letdown	00:00	76 Yankee Washington Center now 123.9			Time starts over
	00:03		123.9. Thank you, sir	Mike	
				COM radio adjusted	
				Chart check	Pilot verified VOR frequency
				HSI adjusted	
	00:53		Washington Center, 76 Yankee with you at 5000	Mike	
	00:55	76 Yankee Roger and you're proceeding direct Brooke, direct Manassas			ATC confirmed new routing
	00:58		Understand direct Brooke, then direct Manassas	Mike	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Cruise to Letdown	01:00	76 Yankee, after Brooke you can expect a heading around the restricted area there at Quantico for Manassas. We've got weather I'm showing right on Victor 223 all the way up to Fluky, some areas of very heavy precip. This new routing will keep you east of what I'm showing.			Further ATC diversion and vectors to avoid adverse weather.
	01:16		Uh, 76 Yankee, Roger	Mike Chart check NAV radio adjusted HSI adjusted DG adjusted	Pilot verified routing and VOR frequencies.

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications ATC	Communications Pilot	Principal Pilot Activities	Remarks
Cruise to letdown	02:00			HSI adjusted	
				DME adjusted	
	03:00			AI adjusted	
				DG adjusted	
				Chart check	Pilot verified VOR frequencies and probable future routing.
	04:00			Approach chart checks	Pilot studied Manassas VOR and ADF approach charts.
	05:00			HSI adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Cruise to Letdown	06:00			HSI adjusted DG adjusted Trim adjusted	
	06:26		Center, 76 Yankee. We've been having a little trouble with our transponder. It appears to be working normal now, are you reading us in Mode C?	Mike	
	06:33	76 Yankee, I'm getting you about every second or third sweep on my radar but it be, uh, 15 to 18 seconds. I'm getting the transponder in between, then it's intermittent, sir			
	07:00			DG adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Cruise to Letdown	08:00			VOR adjusted	
	09:00			HSI adjusted	
				DG adjusted	
				DG adjusted	
	11:00			VOR adjusted	
				DG adjusted	
				COM radio adjusted	Pilot tuned in Dulles ATIS
	12:00	ATIS		Altimeter adjusted	
	12:47		76 Yankee's at Brooke	Mike	
	12:53	76 Yankee fly heading of 010. Vectors around the restricted area for Manassas			
	12:59		Heading 010, vectors	Mike	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Cruise to Letdown	13:30			DG adjusted	
	14:05	5676 Yankee Dulles approach on 120.45			
	14:09		120.45 Thank you, good day	Mike	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Letdown to Landing	00:00			COM radio adjusted	Time starts again
			Dulles approach 5676 Yankee with you at five	Mike	
	00:04	5676 Yankee, Dulles, you're in radar contact. The latest Dulles weather is 2500 scattered, 4000 overcast. Visibility four miles in light rain showers and fog, Dulles winds are calm, the altimeter is 3012			
	00:22		3012, 76 Yankee	Mike Altimeter adjusted	
	00:25	76 Yankee Roger, and would you like a vector to try to get the airport in sight or would you like the VOR approach?			

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Letdown to Landing	00:35		VOR approach would be fine for 76 Yankee	Mike	
	00:41	Roger. You can plan on a VOR approach to Manassas			
	01:00			Approach chart check DG adjusted	
	02:00			Approach chart check VOR adjusted HSI adjusted	
	03:00			Approach chart check DME adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Letdown to Landing	04:06	5676 Yankee descend and maintain 3000			
	04:11		76 Yankee's out of five for three	Mike Throttles adjusted Trim adjusted	
	05:00			Approach chart check Trim adjusted	
	05:44	5676 Yankee had another aircraft, just, uh, he got the airport in sight there at Manassas six miles out. If you want, I'll vector you over by the airport			
	06:00		76 Yankee, Roger	Mike	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC   Route: RIC to W-10

Flight Segment	Time	Communications ATC	Communications Pilot	Principal Pilot Activities	Remarks
Letdown to Landing	06:02	All right 76 Yankee, continue descent to maintain 2000			
	06:10		76 Yankee is out of 3½ for 2000	Mike	
	06:14	76 Yankee Roger, turn left heading 280			
	06:17		Left to 280, 76 Yankee	Mike	
	07:00			Mixtures adjusted Throttles adjusted Trim adjusted DG adjusted	Pilot adjusting speed for visual approach.
	07:58	5676 Yankee the Manassas airport is out at your one o'clock position, out about four miles, turn right heading 300			

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Letdown to Landing	08:08		Right 300, 76 Yankee	Mike	
	08:10	76 Yankee, Roger, advise when you get it in sight			
	08:16		76 Yankee, Roger	Mike	
				Throttles adjusted	
				Approach chart check	
				VOR adjusted	
				HSI adjusted	
	09:17	76 Yankee, airport's now at your 12 to one o'clock position, about a mile and one half			
	09:24		76 Yankee has the airport in sight	Mike	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Letdown to Landing	09:27	Roger, advise canceling IFR			
	09:29		Roger	Mike	
	09:48		76 Yankee's going to cancel IFR now	Mike	
	09:52	76 Yankee Roger, squawk VFR, radar service terminated, frequency change approved, good day			
	09:57		76 Yankee, good day	Mike Gear down Mixtures adjusted Throttles adjusted Landing lights on	Pilot configuring aircraft for landing.
	10:30			COM radio adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: RIC to W-10

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Letdown to Landing	11:00			Trim adjusted	
	11:19		Manassas traffic, 76 Yankee entering downwind, 34 left	Mike	
				Throttle adjusted	
				Props adjusted	
				Flaps adjusted	
				Trim adjusted	
				Pumps on	Pilot prelanding check.
	12:40		Manassas traffic, 76 Yankee turning base, 34 left	Mike	
				Trim adjusted	
				Flaps adjusted	
	13:13		Manassas traffic, 76 Yankee turning final, 34 left	Mike	
				Throttles adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: PHF to LYH

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Letdown to Landing	00:00		Washington Center, 5676 Yankee's level 6000	Mike	
	00:04	Aztec 5676 Yankee, Washington Center. Roger, descend and maintain 5000 and fly heading of 210. Radar vectors for spacing, you're number two for the approach			
	00:13		Out of six for five and heading 210, 76 Yankee	Mike	
				Throttles adjusted	Pilot slowing aircraft speed while descending.
				Mixtures adjusted	
				NAV radio adjusted	
				HSI adjusted	
				Trim adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: PHF to LYH

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Letdown to Landing	02:23	Aztec 76 Yankee, fly heading 230 degrees			
	02:25		230, 76 Yankee	Mike	
	02:30	November 5676 Yankee fly heading 230			HSI tumbled
				HSI adjusted	
				HSI adjusted	
	03:08	5676 Yankee, Washington			
	03:10		76 Yankee we're coming around 230	Mike	
	05:13	76 Yankee, fly heading of 260 degrees			
	5:15		260, 76 Yankee	Mike	Pilot performing pre-approach check.
				Fuel adjusted	
				HSI adjusted	
				Chart scan	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: PHF to LYH

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Letdown to Landing	07:40	5676 Yankee, turn right heading 290			
	07:43		290, 76 Yankee	Mike	
	07:54	76 Yankee, descend and maintain 4000			
	07:56		Down to four, 76 Yankee	Mike	
				Throttles adjusted	
				Mixtures adjusted	
				Throttles adjusted	
	08:30	Lynchburg altimeter 3006 and that's about two hours old			
	08:38	The Roanoke altimeter is 3005			
	08:40		OK, thank you	Mike	
				Altimeter adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: PHF to LYH

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Letdown to Landing	09:27	5676 Yankee, turn right, heading 350			
	09:30		350 for 76 Yankee	Mike	
				Throttles adjusted	
	10:11	5676 Yankee, fly heading 010, intercept the localizer, proceed inbound		Throttles adjusted	
	10:15		010 for the localizer, 76 Yankee	Mike	
				HSI adjusted	
				Mixtures adjusted	
				Throttles adjusted	Pilot performing first prelanding check.
				Gear adjusted	
				Trim adjusted	
				Flaps adjusted	
				Trim adjusted	
				Props adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: PHF to LYH

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Letdown to Landing				Throttles adjusted	
				Flaps adjusted	
	11:12	76 Yankee cleared for straight in ILS approach, runway three and the tower is closed			
	11:17		76 Yankee cleared for the approach	Mike	
	11:22	76 Yankee report your down time or cancellation on this frequency. If unable, Roanoke radio			
	11:28		Roanoke radio Roger, 76 Yankee	Mike	
				Throttles adjusted	
				Trim adjusted	
				Mixtures adjusted	
				Throttles adjusted	
				VOR adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC   Route: PHF to LYH

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Letdown to Landing	14:09			(OM) Gas is on, pumps on, undercarriage 3 in the green, mixtures rich	Pilot performing final prelanding check.
	16:14		Washington Center, Aztec 76 Yankee, I'd like to cancel IFR at Lynchburg	Mike	Runway in sight
				Throttles adjusted	
				Flaps adjusted	
				Throttles adjusted	
	16:20	76 Yankee Roger, good day, sir			

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: W-10 to PHF

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Cruise to Letdown	00:00		76 Yankee level 5000	Mike	
	00:05	Roger, Aztec 76 Yankee			
	00:49		76 Yankee's over Casanova at this time	Mike	
	00:53	Roger, 76 Yankee is radar contact over the Casanova VOR, proceed on course, maintain 5000			
	00:58		76 Yankee	Mike	
				Throttle adjusted	
				Trim adjusted	
				HSI adjusted	
				Trim adjusted	
				VOR adjusted	
				Chart scan	Pilot confirmed VOR frequencies and flight route.

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: W-10 to PHF

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Cruise to Letdown				Throttle adjusted	
				VOR adjusted	
				DG adjusted	
				DME adjusted	
				Chart scan	Pilot verified VOR frequencies and airway direction.
				NAV radio adjusted	
	04:44	5676 Yankee contact the Washington Center now, 123.9. So long now			
	04:46		123.9, have a good day	Mike	
				COM radio adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: W-10 to PHF

		Communications			
Flight Segment	Time	ATC	Pilot	Principal Pilot Activities	Remarks
Cruise to Letdown	05:03		Good afternoon Washington Center, Aztec 5676 Yankee, 5000	Mike	
				HSI adjusted	
	05:09	5676 Yankee Washington Center Roger, 5000. Washington altimeter is 3006			
	05:11		Zero six	Mike	
				Altimeter adjusted	
				Chart scan	Pilot verified airway heading and VOR frequencies.
				NAV radio adjusted	
				VOR adjusted	
				DME adjusted	
				Chart scan	
				Altitude indicator adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: W-10 to PHF

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Cruise to Letdown				HSI adjusted	
				Chart scan	Pilot verified new heading out of Brooke VOR
				HSI adjusted	
				HSI adjusted	
	15:04	5676 Yankee contact Washington Center on 132.55			
				COM radio adjusted	
	15:06		32.55, good afternoon	Mike	
	15:18		Good afternoon, Washington Center, Aztec 5676 Yankee at 5000	Mike	
	15:22	Several aircraft called			Several aircraft called ATC simultaneously on the same frequency.
	15:36	Aircraft called			
	15:38		Aztec 5676 Yankee at 5000	Mike	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: W-10 to PHF

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Cruise to Letdown	15:40	76 Yankee, Roger at 5000			
				DME adjusted	
				VOR adjusted	
				Chart scan	Pilot adjusted power and mixture for economy cruise.
				Props adjusted	
				OAT checked	
				Power chart checked	
				Throttles adjusted	
				Mixtures adjusted	
				Approach chart scan	Pilot verified VOR frequencies and headings.
				COM radio adjusted	
	21:30	(ATIS, PHF)			PHF ATIS monitored

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: W-10 to PHF

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Cruise to Letdown	31:08	76 Yankee, contact Norfolk approach on 119.45			
	31:10		119.45	Mike	
				COM radio adjusted	
	31:18		Good afternoon Norfolk, Aztec 5676 Yankee level 5000	Mike	
	31:20	Aztec 5676 Yankee Norfolk approach, maintain 5000. I'll have direct Patrick Henry for you shortly			
	31:24		76 Yankee	Mike	
	31:29	Aztec 76 Yankee, do you have Patrick Henry weather?			

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: W-10 to PHF

		Communications			
Flight Segment	Time	ATC	Pilot	Principal Pilot Activities	Remarks
Cruise to Letdown	31:31		That's affirmative, we have the information	Mike	
				NAV radio adjusted	
				NAV radio adjusted	
				NAV radio adjusted	
				HSI adjusted	
				VOR adjusted	
	33:11	76 Yankee proceed direct Patrick Henry			
	33:13		76 Yankee direct Patrick Henry	Mike	
				COM radio adjusted	
	33:47	(ATIS PHF)			PHF ATIS monitored

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: W-10 to PHF

Flight Segment	Time	Communications		Principal Pilot Activities	Remarks
		ATC	Pilot		
Cruise to Letdown	35:13	Aztec 5676 Yankee contact Norfolk approach 125.05			
				DME adjusted	
				COM radio adjusted	
	35:15		125.05, so long	Mike	
				COM radio adjusted	
	35:20		Norfolk approach Aztec 5676 Yankee level 5000	Mike	
	35:22	5676 Yankee Norfolk altimeter 3005. Proceed direct Patrick Henry			
	35:24		Zero five, 76 Yankee	Mike	
				Marker beacon lights checked	Pilot starting pre-approach check.
				HSI adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: W-10 to PHF

		Communications			
Flight Segment	Time	ATC	Pilot	Principal Pilot Activities	Remarks
Cruise to Letdown	38:10	Aztec 76 Yankee descend and maintain 3000			
	38:12		Out of five for three, 76 Yankee	Mike Throttles adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: PHF to RIC

		Communications			
Flight Segment	Time	ATC	Pilot	Principal Pilot Activities	Remarks
Take-off to Cruise	00:00	Apache 76 Yankee fly runway heading for vectors, caution: turbulence at intersection, arriving Grumman. Cleared for take-off whenever you're ready			
			Cleared to go, 76 Yankee, and we'll maintain runway heading and wait for vectors	Mike	
	00:01			Throttles forward	Time starts
				Gear up	
				Trim	
	00:42	76 Yankee contact departure, so long			
	00:45		OK, 76 Yankee over to departure, good day	Mike	
				COM radio adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: PHF to RIC

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Take-off to Cruise	00:48		Patrick Henry departure, 76 Yankee with you, runway heading	Mike	
	00:57	76 Yankee you're radar contact. Plan direct Hopewell, climb to 4000			
				DG adjusted	
				Throttles adjusted	
	01:09		76 Yankee up to 4000	Mike	
	02:00			Throttles adjusted	
				Pumps off	
				DG adjusted	
				Trim	
				HSI adjusted	
				VOR adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: PHF to RIC

Flight Segment	Time	Communications: ATC	Communications: Pilot	Principal Pilot Activities	Remarks
Take-off to Cruise	03:45	76 Yankee recycle transponder, squawk 4730			
				Transponder recycled	
	04:04		76 Yankee recycled transponder, squawking 4730	Mike	
	04:08	Sir, are you heading direct Hopewell?			
	04:15	5676 Yankee, what's your heading?			
	04:19		76 Yankee is turning, direct Hopewell now	Mike	ATC had indicated to plan direct Hopewell.
	04:26	Were you still on the heading?			
	04:28		Affirmative	Mike	
	04:29	Roger			

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: PHF to RIC

Flight Segment	Time	Communications		Principal Pilot Activities	Remarks
		ATC	Pilot		
Take-off to Cruise	04:39	5676 Yankee, your transponder just came on			
	04:41		76 Yankee, Roger, we're at 4000 now	Mike	
				VOR adjusted	
				HSI adjusted	
				Trim	
				Attitude indicator adjusted	
				Propellers adjusted	
				Throttles adjusted	
	05:40	5676 Yankee climb to 5000, contact Norfolk approach on 120.55			
	05:48		120.55 and 5000. 76 Yankee, good day	Mike	
				COM radio adjusted	

FLIGHT DATA LOG

Type of Flight: Enroute without FDC

Route: PHF to RIC

Flight Segment	Time	Communications ATC	Communications Pilot	Principal Pilot Activities	Remarks
Take-off to Cruise	06:06		Norfolk 76 Yankee with you climbing to 5000	Mike	Pilot tuned in 120.5 initially.
				COM radio adjusted	
	06:21		Norfolk 76 Yankee is with you climbing to five	Mike	
	06:29	76 Yankee Roger, radar contact. 76 Yankee climb and maintain 5000 and proceed direct to Hopewell. I should have lower for you shortly. Report leaving four			
	06:36		OK, 76 Yankee is 5000 now, proceeding direct Hopewell	Mike	
				VOR adjusted	
	06:38	Roger			

LIST OF ABBREVIATIONS

ADF	Automatic Direction Finder
AERA	Automated Enroute Air Traffic Control
AI	Altitude Indicator
ASRS	Aviation Safety Reporting System
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
CDI	Course Deviation Indicator
DG	Directional Gyro Compass
DME	Distance Measuring Equipment
EGT	Exhaust Gas Temperature
FDC	Flight Data Console
FSS	Flight Service Station
HSI	Horizontal Situation Indicator
OAT	Outside Air Temperature
VOR	Very High Frequency Omnidirectional Range

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15. Supplementary Notes

Langley Technical Monitor: Hugh P. Bergeron
Final Report

16. Abstract

Key problems in single-pilot instrument flight operations are in the management of flight data and the processing of cockpit information during conditions of heavy workload. In this project, a Flight Data Console (FDC) was developed to allow simulation of a digital data link to replace the current voice communications system used in Air Traffic Control. This is a human factors evaluation of a data link communications system to determine how such a system might reduce cockpit workload, improve flight proficiency, and be accepted by general aviation pilots. The need for a voice channel as backup to a digital link is examined. The evaluations cover both airport terminal area operations and full-mission instrument flight.

Results show that general aviation pilots operate well with a digital data link communications system. The findings indicate that a data link system for pilot/ATC communications, with a backup voice channel, is well accepted by general aviation pilots and is considered to be safer, more efficient, and result in less workload than the current voice system.

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