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Controller Evaluation of Initial Data Link Air Traffic Control Services, Mini Study 1, Volume II Appendixes

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16. Abstract

This report details the results of Mini Study 1. This mini study was conducted at the Federal Aviation Administration (FAA) Technical Center utilizing the Data Link testbed. Initial Data Link air traffic control services were evaluated under part task simulation conditions in order to identify service delivery methods which optimize controller acceptance, performance, and workload. This report delineates the results for the first of two mini studies and a research and development operational evaluation which comprise the Phase I Data Link services package.

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PREFACE

This two-volume report documents the first Federal Aviation Administration controller evaluation of a group of three en route air traffic control services planned for implementation on the Mode S Data Link system. Volume 1 contains the main body of the report. Volume II contains seven appendixes which support the Test Description and Test Results (sections 2 and 3, respectively) portions of the main body of the report.

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EXECUTIVE SUMMARY

INTRODUCTION.

The Federal Aviation Administration (FAA) Test Plan for the Mode S Data Link defines a two-stage process for controller evaluation of candidate air traffic control (ATC) services. In the first stage, "mini" design studies will be conducted under controlled conditions which simulate only the essential components of the controller's tasks associated with the services (Part Task Simulation). These studies will be used to identify service delivery methods which optimize controller acceptance, performance, and workload. In the second stage, full-scale simulation studies will be performed in order to verify the safety and efficiency of Data Link within the context of realistic operational scenarios. This report presents the results of the first FAA controller mini study of en route ATC services developed for implementation on the Data Link system.

OBJECTIVES.

The specific objectives of this mini study were: (1) to evaluate and refine Data Link controller procedures and displays for the Altitude Confirmation, Transfer of Communication, and En route Minimum Safe Altitude Warning (EMSAW) services, and (2) to solicit initial opinions from controllers regarding the general utility of the Mode S Data Link.

DATA LINK OPERATION.

Data Link functions were integrated with the Host Computer System (HCS) operational software and the Computer Display Channel (CDC) displays. Capabilities included radar data processing, tracking, and flight data inputs. Operational Data Link functions and procedures were integrated with current operational procedures and computer functions. Data base updates followed altitude clearances; handoffs between sectors included radio frequency assignments; EMSAW alerts were generated upon HCS notification; and altimeter settings were automatically uplinked.

Two modes of operation were evaluated, manual and automatic. In automatic mode, a Data Link message was initiated and delivered via standard National Airspace System (NAS) entries. The message was displayed to the controller as "sent" (transmitted to aircraft transponder), "delivered" (received by the aircraft transponder), and "wilco" (pilot affirmative reply). In manual mode, the status indication "held" was displayed beside the message that appeared in the preview area: Plan View Display (PVD) or Computer Readout Device (CRD). Another sequence of entries resulted in the message triggering the "sent," "delivered," and "wilco" status indicators as appropriate. No pilot composed downlink were tested. Pilot "unable" and no reply ("timeout") conditions were also tested.

APPROACH.

Ten full-performance level air traffic controllers from Dallas/Fort Worth (D/FW) participated in the study as subjects and observers in a series of ATC scenarios presented at work stations at the FAA Technical Center Data

Link test bed. In order to permit the evaluation of Data Link concepts without distracting or overburdening test participants, test scenarios were limited. There were few tracks and no interfacility activity. Traffic

flows were repetitious in nature and control tasks were restricted. No overall system delays were simulated. Figure ES-l projects the expected workload for a Data Link environment in comparison to present ATC field conditions.

Initially, the scenarios required the controllers to complete several altitude assignment/confirmation, transfer of communications, and EMSAW tasks, varying the displays and procedures used to accomplish the three services. Both central (PVD) and peripheral (CRD) locations were tested for the Data Link transaction status display. Various ATC procedures were also evaluated which differed in the number of controller actions required to deliver the services, the requirements for voice interactions between the controller and the pilot, and the requirement for downlinked pilot confirmation of service message delivery.

Following each test condition, the subjects rated the workload that would be induced by the tested options under operational conditions. The technique, called projected subjective workload assessment technique (PROSWAT), asked the controller to project the effect of each test condition on the difficulty of their job during a moderately busy workday. A score of 0 (low workload effort) to 100 (very high workload effort) was derived through a conjoint analysis of PROSWAT ratings. This technique results in interval data capable of being analyzed by parametric means.

Another rating scale was used after each condition to assess controller preferences for each condition. In addition, these formal data were supplemented by group debriefing interviews, a wrap-up questionnaire, and written narrative comments following the test sessions.

PRIMARY RESULTS.

General opinions of Data Link were strongly positive. A majority of the controller subjects felt that Data Link would definitely reduce controller workload and enhance ATC system capacity and safety. Whereas the findings were positive, it should be noted that the acquired data are preliminary and that the simulation environment and scenarios were limited with respect to ATC operations in this mini study.

The specific results of the study clearly show that the subjects preferred the Data Link message preview area in the PVD rather than the CRD display. All subjects felt that Data Link transaction status information should be displayed in a position that does not distract the controller's attention from primary radar data. Furthermore, because the list format of this display may became difficult to monitor when multiple aircraft and services are presented, the subjects indicated that further improvements may be achieved with key transaction data indications in the full data block (FDB). The positive response to Data Link FDB utilization suggests strongly that this function should be included in subsequent evaluations. This capability was not tested, implemented, or evaluated in this mini study.

In general, automated procedures produced lower workload and higher preference ratings than those which required the subjects to manually initiate uplinks and delete completed transactions from the display (see figure ES-1). However, controllers also indicated that a manual option to inhibit automated uplinks per controller action should be available. This inhibit option would control whether a message would be sent to pilot only, NAS computer only, or both. The subjects suggested that it should be

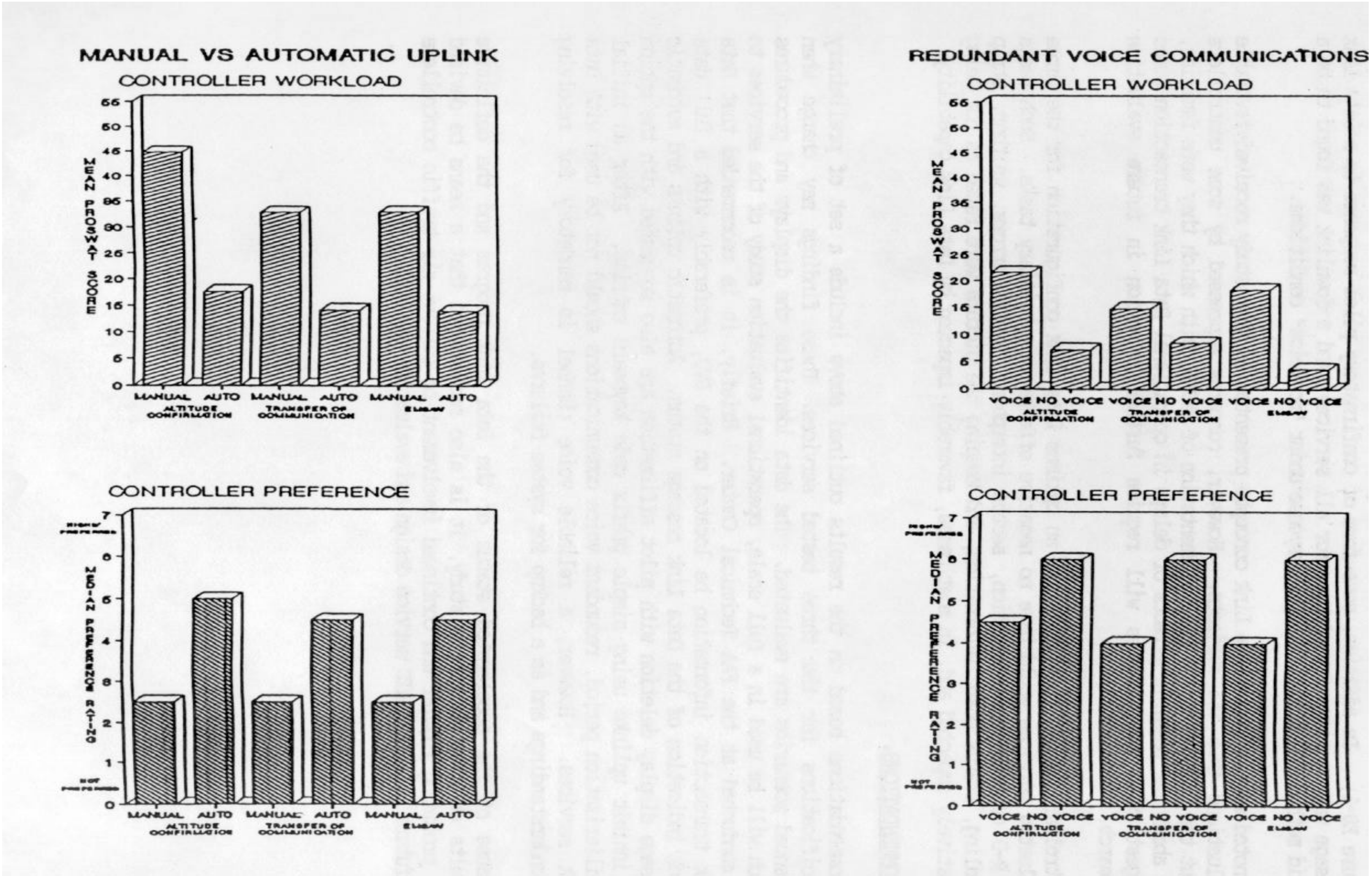

FIGURE ES-1. EFFECTS OF AUTOMATIC PROCEDURES AND ELIMINATION OF REDUNDANT VOICE ON CONTROLLER WORKLOAD AND PREFERENCE possible to exercise such proactive control over uplinks by sector, service type, and individual transaction.

Although the continued availability of a reliable voice radio channel was considered essential, voice communications between the pilot and controller were redundant with Data Link and were not preferred because of increased workload (see figure ES-l). In addition, some form of confirmatory pilot response to a Data Link message was considered mandatory for all services, and a downlink was found to be a valid method for providing this response under "no voice" conditions.

As noted earlier, the Data Link concepts presented in this study received favorable evaluations from the subjects. However, concerns expressed by some controllers about the reliability of the implementation of EMSAW, with which they were familiar, and about the possible effects of delays in operational Data Link transaction times suggest that these issues will require further attention in future evaluation research.

Controllers judged that utilizing an optimum Data Link configuration for the three evaluated services would have no negative effects on subsidiary tasks. Such tasks as R-D controller coordination, sector interphone, system errors, weather, strip handling, status board information, and keeping the picture were rated as not being negatively impacted and, in most cases, favorably impacted by Data Link capability.

RECOMMENDATIONS.

Recommendations based on the results outlined above include a set of preliminary specifications for the three tested services. These findings may change when enhanced scenarios are evaluated. The data identifies the displays and procedures which will be used in a full scale, operational evaluation study of the services to be conducted at the FAA Technical Center. Briefly, it is recommended that Data Link transaction information be located on the PVD, preferably with a full data block indication of the Data Link message status. Automatic uplinks and automatic message display deletion with pilot affirmation are also suggested with the option to inhibit uplinks using simple prefix code keyboard entries. After an initial familiarization period, redundant voice communications should not be used with Data Link services. However, a reliable voice channel is mandatory for resolving and as a backup for system failures.

Because of the accelerated status of the Data Link program and the definitive results obtained from this study, it is also recommended that a means be devised for providing regular and continued involvement of current air traffic controllers in future Data Link ATC service design and evaluation efforts.

APPENDIX A

TEST SCRIPTS

SCRIPT - CONTROLLER SECTOR 17 - PILOT SECTOR 5

System Time	Position	Input	Comments and/or Output
1245	CIOT1	System Startup	
1246	SUA	Sectorization	Live sectors 1,2,12,19
1247	SUA	MR messages	Map requests all Sectors
1251	SUA	AS messages	
1251	SUA	CP DLNK ON	Data Link on

For Test 1 (w/o D/L)

1252	SUA	CP DLNK OFF	No Data Link for this test

For Test 2.1 PVD List, Manual, Voice

1252	03R,17R,07R,l0R	DS D 3	PVD List
1252	03R,17R,07R,l0R	DS 0 0	Manual Mode

For Test 2.2 CRD List, Manual, Voice

1252	03R,17R,07R,l0R	DS D 2	CRD List
1252	03R,17R,07R,l0R	DS 0 0	Manual Mode

For VAX File #17:

Contains DYSIM flight and following settings:

WILCO response will cause WILCO to be displayed in list and clear in display list after 60 seconds.

UNABLE and TIMEOUT will not clear display list entries, will require manual entry at PVD.

No TIMEOUT after delivered message.

For VAX File #18:

Contains DYSIM flight and following settings:

WILCO and TIMEOUT responses will not change display list and list entry will be cleared after 60 seconds.

UNABLE response will display UNABLE and no clear for entry.

No TIMEOUT after delivered message.

SCRIPT - CONTROLLER SECTOR 17 - PILOT SECTOR 5

System Time	Position	Input	Comments and/or Output
1255	Pilot 5R		DYSIM tracks (XXXTW12) start from SIM tape in controller sector 17 and pilot sector 5.
1256	Cont-17R		Say "Piedmont 33 climb and maintain flight level 200."
	Pilot-5R PVD	SIM QAK, Altitude Button 200 XXXPI33	Say "Piedmont 33 climbing to 200."
	Cont-17R	Asgn Alt QAK 200 XXXPI33	

[For Manual Mode Test, Controller must enter DL S AID to send message.]

System Time	Position	Input	Comments and/or Output
	Pilot-5R VAX	(PI33 #) W	Pilot WILCOs D/L message.
1257	Cont-17R		Say "Piedmont 33 climb and maintain flight level 300."
	Pilot-5R		Say "Piedmont 33 UNABLE."
	Cont-17R	Asgn Alt QAK 300 XXXPI33	Assigned altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

System Time	Position	Input	Comments and/or Output
	Pilot-5R VAX	(PI33 #) U	Pilot enters “UNABLE."

[Controller enters DL (QAK 6) D XXXPI33 or CID to clear D/L entry.]

System Time	Position	Input	Comments and/or Output
1258	Cont-17R	XXXAA24	Accepts handoff from sector 3.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

System Time	Position	Input	Comments and/or Output
	Pilot-5		After seeing AA24 added to right side of pilot terminal display and 0-17 in FDB, say “UDS Center, American 24 is

with you at 17
thousand.”

System Time	Position	Input	Comments and/or Output
	Cont-17R		Say "American 24, Roger."
1259	Cont-17R		Say "Piedmont 33 climb and
	Pilot-5R PVD	SIM QAK, Altitude Button 300 XXXPI33	Say "Piedmont 33 climbing to 300."
	Cont-17R	Asgn Alt QAK,	Assigned altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-5R VAX	(PI33 #) W	Pilot enters WILCO on pilot terminal.
1300	Cont-17R		Say "Piedmont 33 descend and maintain flight level 200."
	Pilot-5R PVD	SIM QAK, Altitude Button 200 XXXPI33	Say "Piedmont 33 descending to 200."
	Cont-17R	Asgn Alt QAK, 200 XXXPI33	Assigned altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-5R VAX	(PI33 #) T	Pilot enters TIMEOUT on pilot terminal.

[Controller enters DL (QAK 6) D XXXPI33 or CID to clear D/L entry.]

1301	Cont-17R	03 XXXAA24	Handoff initiated to sector 3. After Sector 3 accepts (0-3 blinking in FDB), say "American 24, contact center on 133.0."
	Pilot-5R VAX	(AA24 #) W H XXXAA24 133.000	Say "American 24 changing to 133.0, Good Day." Pilot enters WILCO and transfer command at pilot terminal

System Time	Position	Input	Comments and/or Output
1302	Cont-17R		Say "Piedmont 33, descend and maintain 10 thousand feet."
	Pilot-5R PVD	SIM QAK, Altitude Button 100 XXXPI33	Say "Piedmont 33 descending to 10 thousand."
	Cont-17R 100 XXXPI33	Asgn Alt QAK entered.	Assigned altitude

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-5R VAX	(PI33 #) W	Pilot enters WILCO.
1303	Cont-17R Say "Piedmont 33, descend and maintain 5 thousand."		
	Pilot-5R PVD	SIM QAK, 050 XXXPI33	Say "Piedmont 33
	Cont-17R 050 XXXPI33	Asgn Alt QAK entered	Assigned altitude.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-5R VAX	(PI33 #) W	Pilot enters Wilco.
1304	Cont-17R		MSAW flashing for XXXTW12, Say "TWA12, low altitude alert, climb to 15 thousand feet immediately."

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-5R PVD	SIM QAK Altitude Button 150 XXXTW12	Say "TWA12 climbing to 15 thousand."
	Pilot-5R VAX	(TW12 #) W	Replies WILCO to EM message on pilot terminal.
1305	Cont-17R	XXXAA24	Accepts handoff for sector 3

[For Manual Mode Test, Controller must enter DL S AID to send message.]

System Time	Position	Input	Comments and/or Output
	Pilot-5R		After seeing AA24 added to right side of pilot terminal and 0-17 in FDB, say 'UDS Center, American 24 with you at 17 thousand."
	Cont-17R		Say "American 24. Roger."

SCRIPT - CONTROLLER SECTOR 3 - PILOT SECTOR 4

System Time	Position	Input	Comments and/or Output
1255	Pilot-4R		DYSIM tracks (XXN23C, XXXNW32, XXXAA24) started from SIM tape.
1256	Cont-3R		Say "23 Charlie climb and maintain 15 thousand.”
	Pilot-4R PVD	SIM QAK, Altitude Button XXXN23C	Say "23 Charlie climbing to 15 thousand.
	Cont-3R	Asgn Alt QAK, 150 XXXN23C	Assigned altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-4R VAX	(N23C #) W	WILCO reply from pilot.
1257	Cont-3R		Say "23 Charlie, climb and maintain flight level 200."
	Pilot-4R PVD	SIM QAK, Altitude Button 200 XXXN23C	Say "23 Charlie climbing to 200."
	Cont-3R	Asgn Alt QAK, 200 XXXN23C	Assigned altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-4R VAX	(N23C #) W	Pilot enters WILCO at pilot terminal.
1258	Cont-3R	17 XXXAA24	Handoff initiated to Sector 17. After controller at sector
17			accepts (0-17 flashing in FDB), say "American 24, contact UDS Center on 133.2."
	Pilot-4R VAX	(AA24 #) W H XXXAA24	Say "American 24 changing to 133.2, Good Day." Pilot enters WILCO and enters transfer at pilot terminal.
1259	Cont-3R		Say “23 Charlie,

			descend and maintain 10 thousand

System Time	Position	Input	Comments and/or Output
	Pilot-4R		Say “23 Charlie UNABLE.”
	Cont-3R	Asgn Alt QAK 100 XXXN23C	Assigned altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-4R VAX	(N23C #) U	Pilot enters UNABLE.

[Controller enters DL (QAK 6) D XXXN23C or CID to clear D/L entry.]

1300	Cont-3R		Say "23 Charlie, descend and maintain 5 thousand.
	Pilot-4R PVD	SIM QAK 050 XXXN23C	Say "23 Charlie descending to 5 thousand.
	Cont-3D	Asgn Alt QAK, 050 XXXN23C	Assigned altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-4R VAX	(N23C #) W	Pilot enters WILCO at pilot terminal.
1301	Cont-3R	XXXXA24	Accepts handoff from sector 17.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-4R		After seeing AA24 added to right side of pilot display and 0-4 in FDB, say “UDS Center, American 24 is with you at 17 thousand.”
	Cont-3R		Say “American 24, Roger.”
1302	Cont-3R		Say “23 Charlie, climb and maintain 10 thousand.”
	Pilot-4R PVD	SIM QAK, 100 XXXN23C	Say “Roger. 23 Charlie Altitude Button climbing to 10 thousand.
	Cont-3R	Asgn Alt QAK, l00 XXXN23C	Assigned altitude entered.

System Time	Position	Input	Comments and/or Output

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-4R VAX	(N23C #) U	Pilot enters TIMEOUT at pilot terminal.

[Controller enters DL (QAK 6) D XXXPI33 or CID to clear D/L entry.]

1303	Cont-3R		Say "23 Charlie, climb and maintain flight level 200."
	Pilot-4R PVD	SIM QAK, Altitude Button 200 XXXN23C	Say "23 Charlie climbing to 200."
	Cont-3R	Asgn Alt QAK 200 XXXN23C	Assigned altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-4R VAX	(N23C #) W	Pilot enters WILCO.
	Pilot-4R PVD	SIM QAK, Altitude Button 004 XXXNW32	Descend NW32 to force EMSAW
		SIM QAK, Climb/Descent Button 99 XXXNW32	Set maximum descent rate.
1304	Cont-3R		MSAW flashing for XXXNW32. Say "Northwest 32, low altitude alert, climb to 9 thousand immediately."
	Pilot-4R PVD	SIM QAK Altitude Button 090 XXXNW32	Say "Northwest 32 climbing to 9 thousand."
	Pilot-4R VAX	(NW32 #) W	Replies Wilco to EM message.

1305	Cont-3R	17 XXXAA24	Handoff initiated to sector 17. After sector 17 accepts, say "American 24, contact UDS Center on 133.2."
	Pilot-4R VAX	(AA24 #) W H XXXAA24 133.200	Say "American 24 changing to 133.2, Good Day."

SCRIPT - CONTROLLER SECTOR 07 - PILOT SECTOR 14

System Time	Position	Input	Comments and/or Output
1255	Pilot-14R		DYSIM tracks (XXXNW02, XXXPA22, XXXUAL1) started from SIM tape.
	Pilot-14R PVD	SIM QAK, Altitude Button 004 XXXPA22	Descend PA22 to force EMSAW.
		SIM QAK, Climb/Descend Button	Set maximum descent rate.
1256	Cont-07R		Say "Northwest 2 descend and maintain flight level 200."
	Pilot-14R		Say "Northwest 2 descend to flight level 200."
	Cont-07R	200 XXXNW02	Asgn Alt QAK Assigned altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

System Time	Position	Input	Comments and/or Output
	Pilot-14R VAX	(NW02 #) W	Pilot wilcos D/L message.
1257	Cont-07R		Say "Northwest 2 climb and maintain flight level 300."
	Pilot-14R		Say "Northwest 2 unable to comply. "
	Cont-07R	Asgn Alt QAK 300 XXXNW02	Assigned altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

System Time	Position	Input	Comments and/or Output
	Pilot-14R VAX	(NW02 #) U	Pilot enters 'UNABLE."

[Controller enters DL (QAK 6) D XXXNW02 or CID to clear D/L entry.]

System Time	Position	Input	Comments and/or Output
1258	Cont-07R		MSAW flashing for XXXPA22. Say "Clipper 22, low altitude alert, climb to 15 thousand immediately."

[For Manual Mode Test, Controller must enter DL S AID to send message.]

System Time	Position	Input	Comments and/or Output
	Pilot-14R PVD	SIM QAK Altitude Button 150 XXXPA22	Say "Roger. Clipper 22 climbing to 15 thousand."
	Pilot-14R VAX	(PA22 #) W	Replies WILCO to EM message on pilot terminal.
1258	Cont-07R	10 XXXUAL1	Handoff initiated to sector 10. After sector 10 accepts (0-10 blinking in FDB), say "United 1, contact center on 123.0."
	Pilot-14R VAX	(UALl #) W	Say "Roger. United 1 H XXXUALl 123.000 Changing to 123.0, Good Day." Pilot enters WILCO and transfer on pilot terminal.
1259	Cont-07R		Say "Northwest 2 climb and maintain flight level 300."
	Pilot-14R PVD	SIM QAK, Altitude Button 300 XXXNW02	Say "Northwest 2 climbing to 300."
	Cont-07R	Asgn Alt QAK 300 XXXNW02	Assigned Altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

System Time	Position	Input	Comments and/or Output
	Pilot-14R VAX	(NW02 #) W	Pilot enters WILCO on pilot terminal .
1300	Cont-07R		Say "Northwest 2 descend and maintain flight level 200."
	Pilot-14R PVD	SIM QAK, Altitude Button 200 XXXNW02	Say "Northwest 2 descending to 200."
	Cont-07R	Asgn Alt QAK 200 XXXNW02	Assigned altitude. entered.
	Pilot-14R VAX	(NW02 #) T	Pilot enters TIMEOUT on Pilot terminal.

[Controller enters DL (QAK 6) D XXXPI33 or CID to clear D/L entry.]

System Time	Position	Input	Comments and/or Output
1301	Cont-07R		Accepts handoff from sector 10.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

System Time	Position	Input	Comments and/or Output
	Pilot-14R VAX		After seeing UALl dded to right side of pilot display and 0-14 in FDB, say 'UDS Center, United 1 is with you at flight level 300."
	Cont-07R		Say 'United 1, Roger."
1302	Cont-07R		Say "Northwest 2, descend and maintain 10 thousand."
	Pilot-14R PVD	SIM QAK, Altitude Button 100 XXXNW02	Say "Northwest 2 descending to 10 thousand."
	Cont-07R	Asgn Alt QAK 100 XXXNW02	Assigned altitude entered.
1303	Cont-07R		Say "Northwest 2, climb and maintain flight level 200."
	Pilot-14R PVD	SIM QAK, Altitude Button 200 XXXNW02	Say "Northwest 2 climbing to 200."
	Cont-07	Asgn Alt QAK 200 XXXNW02	Assigned altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

System Time	Position	Input	Comments and/or Output
	Pilot-14R VAX	(NW02 #) W	Pilot enters WILCO.
1305	Cont-07R	10 XXXUAL1	Handoff initiated to sector 10. After sector 10 accepts, say "United 1, contact Center on 123.0."
	Pilot-14R VAX	(UAL1 #) W H XXXUALl 123.000	Say "United 1 changing to 123.0, Good day." Pilot enters WILCO and transfer commands on pilot terminal.

SCRIPT - CONTROLLER SECTOR 10 - PILOT SECTOR 15

System Time	Position	Input	Comments and/or Output
1255	Pilot-15R		DYSIM tracks (XXXCS22, XXXAL62) started from SIM tape.
	Pilot-15R PVD	SIM QAK, Altitude Button 004 XXXAL62	Descend AL,62 to force. EMSAW
		SIM QAK, Climb/Descent Button 99 XXXAL62	Set maximum descent rate.
1256	Cont-l0R		Say "Charlie Sierra 22, descend and maintain 15 thousand."
	Pilot-15R PVD	SIM QAK, Altitude Button 150 XXXCS22	Say "Charlie Sierra 22 descending to 15 thousand."
	Cont-l0R	Asgn Alt QAK, 150 XXXCS22	Assigned altitude entered.
	Pilot-15R VAX	(CS22 #) W	WILCO reply from pilot.
1257	Cont-l0R		Say "Charlie Sierra 22, climb and maintain flight level 200."
	Pilot-15R PVD	SIM QAK, Altitude Button 200 XXXCX22	Say "Charlie Sierra 22 climbing to 200."
	Cont-l0R	Asgn Alt QAK, 200 XXXCS22	Assigned altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

System Time	Position	Input	Comments and/or Output
	Pilot-15R VAX	(CS22 #) W	Pilot enters WILCO at pilot terminal.

System Time	Position	Input	Comments and/or Output
1258	Cont-l0	R	MSAW flashing for XXXAL62. Say 'USAir 62, low altitude alert, climb to flight level 9 thousand I immediately."

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-15R PVD	SIM QAK Altitude Button 090 XXXAL62	Say "USAir 62 climbing 9 thousand".
	Pilot-15R VAX	(AL62 #) W	Replies WILCO to EM message.
1258	Cont-l0R	XXXUALl	Accepts handoff from sector 07.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-15R		After seeing UALl added to right side of display and 0-10 in FDB, say 'UDS Center, United 1 is with you at flight level 300."
	Cont-l0R		Say 'United 1, Roger."
1259	Cont-l0R		Say "Charlie Sierra 22, thousand."
	Pilot-15R		Say "Charlie Sierra 22 UNABLE to comply."
	Cont-l0R	Asgn Alt QAK	Assigned altitude entered.

[For Manual Mode Test, Controller must enter DL S AID to send message.]

	Pilot-15R VAX	(CS22 #) U	Pilot enters UNABLE.

[Controller enters DL (QAK 6) D XXXCS22 or CID to clear D/L entry.]

1300	Cont-l0R		Say "Charlie Sierra 22, descend and maintain 5 thousand."
	Pilot-15R PVD	SIM QAK Altitude Button 050 XXXCS22	Say "Roger. Charlie Sierra 22 descending to 5 thousand."
	Cont-3D	Asgn Alt QAK 050 XXXN23	Assigned Altitude entered.

System Time	Position	Input	Comments and/or Output
[For Manual Mode Test, Controller must enter DL S AID to send message.]			
	Pilot-15R VAX	(CS22 #) W	Pilot enters WILCO at pilot terminal.
1301	Cont-l0R	07 XXXUALl	Handoff initiated to sector 07. After controller at sector 07 accepts (0-07 flashing in FDB), say “United 1, contact UDS Center on 132.2."
	Pilot-15R VAX	(UALl #) W H XXXUALl 132.200	Say "United 1 changing to 132.2, Good Day."
1302	Cont-l0R		Say "Charlie Sierra 22, climb and maintain 10 thousand."
	Pilot-15R PVD	SIM QAK, Altitude Button 100 XXXCS22	Say "Charlie Sierra 22 climbing to 10 thousand."
	Cont-l0R	Asgn Alt QAK, l00 XXXCS22	Assigned altitude entered.
[For Manual Mode Test, Controller must enter DL S AID to send message.]			
	Pilot-15R VAX	(CS22 #) T	Pilot enters TIMEOUT at pilot terminal.
[Controller enters DL (QAK 6) D XXXPI33 or CID to clear D/L entry.]			
1303	Cont-l0R		Say "Charlie Sierra 22, climb and maintain flight level 200."
	Pilot-15R PVD	SIM QAK, Altitude Button 200 XXXCS22	Say "Charlie Sierra 22 climbing to 200."
	Cont-l0R	Asgn Alt QAK 200 XXXCS22	Assigned altitude entered.
[For Manual Mode Test, Controller must enter DL S AID to send message.]			
	Pilot-15R VAX	(CS22 #) W	Pilot enters WILCO.
1305	Cont-l0R	XXXUAL1	Accepts handoff from sector 7.

System Time	Position	Input	Comments and/or Output
[For Manual Mode Test, Controller must enter DL S AID to send message.]			
	Pilot-15R		After seeing UALl added to right side of display and 0-15 in FDB, say “UDS Center, United 1 is with you at flight level 300."
	Cont-l0R		Say "United 1. Roger."

APPENDIX B

WORKLOAD AND PREFERENCE RATING MATERIALS

BRIEF DESCRIPTION OF THE PROSWAT WORKLOAD SCALE DEVELOPMENT PROCESS

The Subjective Workload Assessment Technique (SWAT) was developed in the 1980’s by researchers at the Air Force Aerospace Medical Research Laboratory. Using SWAT, human operators make judgments about the workload that they experienced during actual performance of an operational task. Projected Subjective Workload Assessment Technique (PROSWAT) is an application SWAT in which operators make projective estimates of the workload that would be produced by a set of test conditions or system design options. Those projected estimates are based on observations of low fidelity simulations of a system rather than actual performance of the operational task. PROSWAT has been proven useful for workload evaluation of design options prior to the availability of full scale simulators or operational hardware.

SWAT and PROSWAT operate in the same way, and require a two-phase process to generate quantitative workload data. In the first phase, subjects provide information on how time, effort, and stress combine to produce their concept of mental workload.

During this scale development exercise, the subjects are asked to sort a set of 27 cards on which are printed all possible combinations of the descriptors for the time, effort, and stress scales. Subjects sort the cards to produce an ordering that represents situations ranging from low to high workload. The subjects' sorts are then subjected to a computerized conjoint analysis in order to determine the comminatory rule governing the sort. An iterative routine is then used to generate an interval scale value for each of the 27 combinations that fits the comminatory rule and preserves the original ordering. The result of this processing is a look-up table for each subject or subject group that converts the discrete time, effort, and stress workload ratings to the unitary scale.

In the second phase, subjects make actual workload judgments of test conditions using ratings of 1 (low) to 3 (high) on the time, effort, and stress scales. These ratings are then interpreted as quantitative values on the overall workload scale found in the look-up table.

The advantage of the PROSWAT approach to workload judgment is that it adjusts the scale to each subject's or group's conception of workload. In addition, the scale provides more powerful interval scale values rather than the ordinal values typical of most subjective rating techniques. The instructions used in this study for guiding the subject controllers' card sorting task are presented in the following section of this appendix along with the instructions used for the preference/acceptability scale.

(INSTRUCTIONS TO CONTROLLER SUBJECTS)

INTRODUCTION TO THE CONTROLLER WORKLOAD AND OPTION PREFERENCE RATING SCALE

BACKGROUND

The goal of this study is to obtain expert opinions from air traffic controllers about the most appropriate ways in which to implement three air traffic control (ATC) services using the Mode S Data Link. When we start our stimulations in the Data Link Test Bed you will be controlling air traffic in a series of brief scenarios. Each test run will require you to use different displays or procedures to accomplish the Data Link services. In order to evaluate these service design options, we will ask you to provide two quantitative ratings after each test run. The purpose of this document is to familiarize you with the scales that you will be using to make the ratings, and to describe a special procedure that we will ask you to perform to help us interpret your ratings on one of the scales. The material contained in this document will be reviewed in a briefing that you will receive before we start the Data Link Test Bed simulation runs.

PREFERENCE

Although we will be asking you for a wide variety of comments during this study, our primary quantitative data will be derived from your ratings on the two scales mentioned above. Because the rating data will form the basis for a number of Data Link design decisions, it is extremely important that we all agree on what we mean by each type of rating scale.

The first scale that you will complete after each test run is the PREFERENCE/ACCEPTABILITY scale. The form that will be used for this scale is shown in figure B-l.

One of the forms will be used for each procedure and display option that you evaluate. Note that the form actually requires you to make two decisions. First, for each of the services, you will need to decide whether the option under test is acceptable or unacceptable. Second, if you have decided that the option is acceptable, you will need to assign it a value on the 7-point scale that indicates the extent to which you prefer it. Thus, you would assign the option a value of "1" if you found it to be both acceptable and highly preferable. If the option were acceptable but not highly preferred, you would assign it a higher number according to the extent to which it is less preferable. However, if the option were completely unacceptable, you would not assign it any of the numbers, and instead mark the COMPLETELY UNACCEPTABLE blank on the form.

In making your decisions about acceptability and preference, your prime consideration should be the impact of a design option on the SAFETY and EFFICIENCY of controller performance. Once you have made your ratings, please remember to use the comments section on the bottom on the form to briefly explain the reasons for your ratings.

SUBJECT________________________________ SERIES I / II

SECTOR______________________________ ACTIVE / PASSIVE

TEST OPTION____

Rate the display / procedural test option that you have just examined according to how acceptable it would be to controllers involved in each of the three services. In rating the acceptability of this option, you should consider the way in which it would affect the SAFETY and EFFICIENCY of the controller's performance.

Place an "X" next to the number which best describes the acceptability of this option for each service. If this, option is completely unacceptable, place an "X" in the box. Use the space below the scales to briefly explain your ratings.

	HIGHLY PREFERRED ↓				MODERATELY PREFERRED ↓	ACCEPTABLE BUT NOT PREFERRED	↓
	1	2	3	4	5	6	7
ALT CONF	_____	_____	_____	_____	_____	_____	_____
TRAN COMM	_____	_____	_____	_____	_____	_____	_____
EMSAW	_____	_____	_____	_____	_____	_____	_____

COMPLETELY UNACCEPTABLE

COMMENTS:

FIGURE B-. PREFERENCE/ACCEPTABILITY SCALE

WORKLOAD

The second rating that we will be asking for after each test run will be a workload rating. The scale that we will be using for the workload ratings is known as Projective Subjective Workload Assessment Technique (PROSWAT). PROSWAT was developed as a method for collecting quantified data on how hard a person feels he would have to work in his normal duties using different procedures, equipment, etc., to perform them. In this study we will be asking you to provide PROSWAT ratings on the workload that you would experience during a moderately busy shift of work if you were using each of the Data Link options that we will be testing.

If you examine the scale in figure B-2 you will notice that PROSWAT defines workload in terms of a combination of three different dimensions that contribute to the subjective feeling of “working hard.” A workload rating in PROSWAT is accomplished by selecting a 1, 2, or 3 on EACH of the three scales representing the dimensions of TIME LOAD, MENTAL EFFORT, and PSYCHOLOGICAL STRESS LOAD.

Each of these dimensions and their levels are described below:

TIME LOAD.

Time Load refers to the fraction of the total time that you are busy. When Time Load is low, sufficient time is available to complete all of your mental work with some time to spare. As Time Load increases, spare time drops out and some aspects of performance overlap and interrupt one another. This overlap and interruption can come from performing more than one task or from different aspects of performing the same task. At high levels of Time Load, several aspects of performance often occur simultaneously, you are busy, and interruptions are very frequent.

Time Load may be rated on the 3-point scale below:

1. Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.

2. Occasionally have spare time. Interruptions or overlap among activities occur frequently.

3. Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.

MENTAL EFFORT LOAD.

As described above, Time Load refers to the amount of time one has available to perform a task or tasks. In contrast, Mental Effort Load is an index of the amount of attention or mental effort required by a task regardless of the number of tasks to be performed or any time limitations. When Mental Effort Load is low, the concentration and attention required by a task is minimal and performance is nearly automatic. As the demand for mental effort increases due to task complexity of the amount of information which must be dealt with in order to perform adequately, the degree of concentration and attention required

I. TIME LOAD

1. OFTEN SPARE TIME. INTERRUPTIONS, OR OVERLAP AMONG ACTIVITIES OCCUR INFREQUENTLY OR NOT AT ALL.

2. OCCASIONALLY HAVE SPARE TIME. INTERRUPTIONS, OR OVERLAP AMONG ACTIVITIES OCCUR FREQUENTLY.

3. ALMOST NEVER HAVE SPARE TIME. INTERRUPTIONS OR OVERLAP AMONG ACTIVITIES ARE VERY FREQUENT OR OCCUR ALL THE TIME.

II. MENTAL EFFORT LOAD

1. VERY LITTLE CONSCIOUS MENTAL EFFORT OR CONCENTRATION REQUIRED. ACTIVITY IS ALMOST AUTOMATIC. REQUIRING LITTLE OR NO ATTENTION.

2. MODERATE CONSCIOUS MENTAL EFFORT OR CONCENTRATION REQUIRED. COMPLEXITY OF ACTIVITY IS MODERATELY HIGH DUE TO UNCERTAINTY, UNPREDICTABILITY, OR UNFAMILIARITY. CONSIDERABLE ATTENTION IS REQUIRED.

3. EXTENSIVE MENTAL EFFORT AND CONCENTRATION ARE NECESSARY. VERY COMPLEX ACTIVITY REQUIRING TOTAL ATTENTION.

III. PSYCHOLOGICAL STRESS LOAD

1. LITTLE CONFUSION, RISK, FRUSTRATION, OR ANXIETY AND CAN EASILY BE ACCOMMODATED.

2. MODERATE STRESS DUE TO CONFUSION, FRUSTRATION, OR ANXIETY NOTICEABLY ADDS TO WORKLOAD. SIGNIFICANT COMPENSATION IS REQUIRED TO MAINTAIN ADEQUATE PERFORMANCE.

3. HIGH TO VERY INTENSE STRESS IS DUE TO CONFUSION, FRUSTRATION, OR ANXIETY. HIGH TO EXTREME DETERMINATION AND SELF-CONTROL REQUIRED.

FIGURE B-2. PROSWAT SCALE

increases. High Mental Effort Load demands total attention or concentration due to task complexity or the amount of information that must be processed.

Mental Effort Load may be rated using the 3-point scale below:

1. Very little conscious mental effort or almost automatic, requiring little or no attention.

2. Moderate conscious mental effort or concentration required. Complexity or activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.

3. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

PSYCHOLOGICAL STRESS LOAD.

Psychological Stress Load refers to the contribution to total workload of any conditions that produce anxiety, frustration, or confusion while performing a task or tasks. At low levels of stress, one feels relatively relaxed. As stress increases, confusion, anxiety, or frustration increase and greater concentration and determination are required to maintain control of the situation.

Psychological Stress Load may be rated on the 3-point scale below:

1. Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.

2. Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload. Significant compensation is required to maintain adequate performance.

3. High to very intense stress due to confusion, frustration, or anxiety. High to extreme determination and self-control required.

Each of the three dimensions just described contribute to workload during performance of a task or group of tasks. Note that although all three factors may be correlated, they need not be. For example, one can have many tasks to perform in the time available (high time load), but the tasks may require little concentration (low Mental Effort Load). Likewise, one can be anxious and frustrated (high Stress Load) and have plenty of spare time between relatively simple tasks. Since the three dimensions contributing to workload are not necessarily correlated, please treat each dimension individually and give independent assessments of the Time Load, Mental Effort Load, and Psychological Stress Load that you feel would be produced by the Data Link design options we will be testing.

The form that you will be using to make your SWAT ratings during the Data Link test sessions is shown in figure B-3. Note that the descriptions for each level of time, effort, and stress load have been removed to save space. Should you need to review these descriptions during testing, a copy of the full scale will be available at all times.

SUBJECT____ SERIES I / II

SECTOR________________________________ ACTIVE / PASSIVE

TEST OPTION____

Rate the workload associated with the display/procedure option that you have just examined by considering how it would affect the difficulty of your job during a moderately busy workday. With this in mind, rate the workload associated with each service under this option by placing an "X" next to one of the numbers on the TIME, EFFORT AND STRESS scales.

REMEMBER, this is a rating of the WORKLOAD that you would experience using this option. The workload of a task is not necessarily related to your preferences for a test option or its suitability for use in ATC operations.

	1	2	3
ALTITUDE CONFIRMATION			
TIME LOAD	________	________	________
MENTAL EFFORT	________	________	________
STRESS	________	________	________
TRANSFER OF COMMUNICATIONS			
TIME LOAD	________	________	________
MENTAL EFFORT	________	________	________
STRESS	________	________	________
EMSAW			
TIME LOAD	________	________	________
MENTAL EFFORT	________	________	________
STRESS	________	________	________

FIGURE B-3. PROSWAT WORKLOAD SCALE

PROSWAT SCALE DEVELOPMENT CARD SORT

Now that you are familiar with the two rating scales that will be used during the Data Link test sessions, there is one last procedure that must be completed before testing can begin. This procedure is a card sorting task that will allow us to interpret your PROSWAT workload ratings. We will be asking you to do this task during the briefing that will take place to review the rating scales.

One of the most important features of PROSWAT is its unique scoring system. The developers of PROSWAT recognized that different people have different conceptions of how the time, effort, and stress dimensions combine to produce an overall impression of low and high workload. Because of these differences, a special card sorting procedure is used in PROSWAT to define a distinctive workload scale for each person. This individualized scale greatly improves our ability to accurately interpret the actual workload ratings that you will be making during the test sessions.

In order to develop your individual scale, we need information from you regarding the amount of workload that you feel is produced by various combinations of the three levels on the time, effort, and stress dimensions. We get this information by having a person rank order a set of cards. Each card contains a different combination of the levels of time load, mental effort load, and stress load. Since there are three dimensions, and each dimension has three levels, there are 27 cards in the deck that you will be sorting. Your job will be to sort the cards so that they are ranked according to the level of workload represented by each card. Thus, the first card in the deck will represent the lowest workload and the last card will represent the highest workload.

In completing your card sorts, please consider the workload imposed on a person by the combination represented in each card. Arrange the cards from the lowest workload condition through the highest condition. You may use any strategy you choose in rank ordering the cards. One strategy that proves useful is to arrange the cards into a number of preliminary stacks representing high, moderate, and low workload. Individual cards can be exchanged between stacks, if necessary, and then rank ordered within stacks. Stacks can then be recombined and checked to be sure that they represent your ranking of lowest to highest workload. However, the choice of strategy is up to you and you should choose the one that works best for you.

There is no "school solution" to this problem. There is no correct order. The correct order to what, in your judgment best describes the progression of workload from lowest to highest for a general case rather than any specific event. That judgment differs for each of us. The letters you see on the back of the cards are to allow us to arrange the cards in a previously randomized sequence so that everyone gets the same order. If you examine your deck you will see the order on the back runs from A through Z and then ZZ.

Please remember:

1. The card sort is being done so that a workload scale may be developed for you. This scale will have a distinct workload value for each possible

combination of Time Load, Mental Effort Load, and Psychological Stress Load. The following example demonstrates the relationship between the card sort and the resulting workload scale:

Time	Effort	Stress		Workload Scale
1	1	1		0.0
•	•	•	-------------	•
•	•	•		•
•	•	•		•
•	•	•		•
3	3	3		100.0

Note that other than the fact that a 1-1-1 will always represent the lowest workload and that a 3-3-3 will always represent the highest workload, the remaining cards could occur in a number of orders. Your order will depend on how you weight the importance of Time, Effort, and Stress dimensions.

2. When performing the card sorts, use the descriptors printed on the cards. Please remember <u>not</u> to sort the cards based on one particular task (such as controlling air traffic). Sort the cards according to your general view of workload and how important you consider the dimensions of Time, Mental Effort, and Psychological Stress Load to be.

3. During the Data Link test runs, you will accomplish the desired task. Then, you will provide a PROSWAT rating based on your opinion of the mental workload required to perform the task. This PROSWAT rating will consist of one number from each of the three dimensions. For example, a possible PROSWAT rating is 1-2-2. This represents a 1 for Time Load, a 2 for Mental Effort Load, and a 2 for Psychological Stress Load.

4. We are not asking for your preference concerning Time, Mental Effort, and Psychological Stress Load. Some people may prefer to be "busy" rather than "idle" in either Time Load, Mental Effort Load, or Psychological Stress Load dimension. We are not concerned with this preference. We need information on how the three dimensions and the three levels of each one will affect the level of workload as you see it. You may prefer a 2-2-2 situation instead of a 1-1-1 situation. However, you should still realize that the 1-1-1 situation imposes less workload on you and leaves a greater reserve capacity.

The sorting will probably take 30 minutes to an hour. Please feel free to ask questions at any time.

A FINAL NOTE ABOUT YOUR PREFERENCE AND PROSWAT RATINGS

The two scales that we will be using in our Data Link test sessions were chosen to quantify two independent aspects of your evaluations of the Data Link display and procedural test options. As you use the scales to rate the test options, please remember that preference/acceptability and workload may be related, but they are not necessarily the same.

For example, you may find that a particular option is not preferred because it would greatly increase controller workload. In that case, both your preference/acceptability and PROSWAT ratings would be high. However, it is also possible for these two ratings to be disassociated. For example, an option might be acceptable or unacceptable because of its impact on ATC safety. At the same time, the workload that would be associated with delivering a Data Link service using that option could be low or high, depending on how you feel it would affect the time, effort, and stress load associated with performing controller tasks.

In order for us to extract the maximum amount of information from this study, it is very important that you keep these differences in mind as you make your ratings. As experts, your careful consideration of each of the scales will help to insure that Data Link is implemented in a way which will enhance ATC safety and efficiency and aid the controller in meeting his or her responsibilities.

APPENDIX C

ANALYSIS OF GROUP DISCUSSION DATA

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INTRODUCTION

This appendix presents an analysis of data from the debriefing discussion. In the context of the ministudy methodology, the debriefing followed laboratory exercises that allowed the test participants to interact with simulated Data Link services presented under alternative combinations of message display/control and procedural options. In all, ten Air Traffic Control Specialists (ATCS's) participated in the debriefing discussion. Following the group discussion, nine of the ten participants also submitted written responses to the items covered in the debriefing discussion guide.

The appendix is organized into two parts. The first part of the appendix describes the participants and their expertise and reviews the areas of agreement and unresolved issues that came out of the debriefing. The second part provides a copy of the discussion guide and tabulates the categorical responses that were reported individually by the ATCS's.

SUMMARY OF RESULTS

This summary flight takes up the generic themes and then the specific service-related suggestions contained in the ATCS commentary. In the following section, "Test Participants," descriptive characteristics of the test participants are reported. Presented in section are generic themes or principles of Data Link communication that cut across individual services. The principles help explain many of the specific service-related suggestions discussed in section, "Initial Data Link Services."

TEST PARTICIPANTS.

Ten ATCS's were involved in the tests: eight served as test subjects at the control positions and two others were roving observers who spent some time observing each of the positions. All eight test participants represented the Dallas/Fort Worth Center. The two roving observers represented the Dallas/Fort Worth Terminal and the Center. On average, the test participants had 15.7 years experience as full performance level (FPL) controllers and experience levels ranged between 3 and 31 years. Four of the participants also had experience as pilots. Pilot experience ranged between 5 and 20 years with an average of 16 years. Only three of the participants reported any exposure to the Data Link program prior to this evaluation.

GENERAL DATA LINK.

Establishment of a set of basic operational and design principles for Data Link communication is consistent with other, ongoing Federal Aviation Administration (FAA) initiatives to standardize air traffic control (ATC) operations (reference 1). These principles are the ground rules from which directives for operational practices and criteria for system design and validation can be established. The basic principles derived from the debriefing are discussed below.

A Message Not Acknowledged Message Not Sent.

This emerged as a first principle of ATC communication (reference 2, pg C-7). Data Link communication should also follow this principle operationally and in design. In particular, there is a need to ensure that the ATC data base contains the last acknowledged clearance. For a confirmation message, the current test bed design is acceptable because the voice exchange provides an acknowledgment (authorizes a data base update) before any Data Link message is sent. When Data Link becomes the primary communication mode, the ATC data base update should be triggered by the pilot's WILCO, not by the controller's ENTER/UPLINK action.

The current design uses the ENTER action associated with an altitude to accomplish two things: it updates the ATC data base and generates/uplinks a Data Link message. Conceptually, generation and uplink of a message to the pilot should be separable from a data base update. Operationally, the update should be effected by the pilot's acknowledgment. Similarly, the controllers commented that it was not important or necessary to update their status displays to show intermediate stages in the information exchange. For instance, a message status update for a technical acknowledgment was considered unnecessary, only the pilot WILCO was meaningful (operationally). Exceptions/interruptions to the normal sequence should be treated as "alerts" and displayed more prominently, i.e., in the data block.

A positive pilot acknowledgment of a Data Link message was judged to be the best procedure from an operational transition standpoint. Although controller opinion was split on the need for a transitional phase of redundant radio/telephone (r/t) communication with Data Link (d/l) confirmation, there was consensus that even in the transitional phase, a positive acknowledgment of the confirmation message would be more compatible with the procedure followed in a later phase when the voice exchange drops out.

Use r/t Communication for Resolution of Exceptions to Normal d/l Communication and for Time Critical Communications.

With two modes available for communication between pilots and controllers, it is important to specify how these will work together in the future system. Moreover, a mix of d/l equipage in the aircraft population will require continued use of r/t communication procedures as the primary mode for some aircraft. To make things easier, the procedures for d/l and r/t communication should be consistent and explicit criteria should be established for determining the appropriate mode in a given situation (see reference 3). Both the pilot and controller should have a common understanding and expectation about what the other will do under various sets of circumstances.

The advantage of voice communication for handling exceptions and time critical control instructions was mentioned many times during the discussion. The two most commonly agreed on roles of voice and data link communication were: (1) Data Link as the primary mode for most messages, with voice as a backup for handling exceptions, and (2) Data Link as the primary mode for certain types of messages, with voice as the primary mode for other types of messages. Aside from handling exceptions to

control instructions, in-flight emergencies and weather deviations were also identified as situations where voice should be the primary mode. In addition, there was unanimous agreement that voice should be the primary mode for all types of time critical messages.
Controller opinion on the acceptability of a mixed-mode communication system was divided. While most agreed that Data Link would afford the greatest benefit to controllers in their message sending functions and pilots would see the greatest benefit in their message receiving functions, only half endorsed a mixed-mode (controller uplink with pilot voice acknowledgment) approach to pilot controller communication.

Display d/l Communication Status Information in the Data Block.

Controllers expressed a clear preference for encoding Data Link message status information in the data block with a supplementary list presentation on the Plan View Display (PVD). For example, it was suggested that the altitude line of the data block be used to depict the status of an altitude confirmation. One way to implement this suggestion might be to add a new class of indicators to the altitude qualifier field (B4) that displays the status of the exchange: "S" for sent, 'W' wilco, 'V' verify.

As another illustration, the transfer of communication (TOC) message could be displayed in the handoff field (E1-E4). Once the TOC message is sent, a letter identifier, "C" for comm or "F" for frequency, and the identifier of the sector which will be in communication with the aircraft would blink in field E until the pilot acknowledges the TOC. Pilot acknowledgment would replace the "C" with a 'W' and stop the blinking.

After a parameter time, the data block would then be dropped from the losing controller's display and field E would revert to groundspeed on the receiving controller's display.

Controller alerts in the data block for exceptions to a positive acknowledgment were also discussed in some detail. These included a case where the pilot fails to acknowledge the message within a parameter time, a case where the message is not delivered (no technical acknowledge), and a case where the pilot responds with an UNABLE. Regarding display information, the controllers recommended adopting status labels of NO REPLY, UNABLE, and VERIFY in the list and highlighting the corresponding data block indicators to alert the controller. The controller could then opt to resend the message or follow up with voice. In the second case, the current controller should first be alerted to a link failure and follow up with voice. Based on the follow up, the controller may update the aircraft's data link equipage for display to downstream controllers. In the third case, the controllers suggested that if the pilot cannot comply with the clearance then the UNABLE response should be correlated procedurally with a radio call. Voice is probably the simplest way to resolve this kind of situation. If the UNABLE has to do with a possible miscommunication, the controllers recommend that the status display should say something like VERIFY. The controller then has the option to resend the Data Link message or follow up with voice.

Finally, it was suggested that Data Link equipage be encoded near the data block, possibly as an alternate aircraft position symbol, and/or in the data block as a caret symbol over the aircraft call sign.

Provide Proactive control of d/l Message Sending but Minimize Controller Inputs.

Most of the controllers felt that the inputs required to uplink a message manually in the test scenarios were too cumbersome. Accordingly, they recommended that the sequence of inputs required to send a message be simplified and possibly be implied in the message composition sequence. Transferring data entries directly from the existing message composition preview display (without reentry of any fields) for automatic uplink was deemed most efficient. Capabilities to store and recall/resend messages were also suggested.

Overall, an automatic uplink was viewed as the most appropriate default option for message sending with an inhibit option to deselect Data Link by position, service, or message. If Data Link is selected for a position, then automatic uplink is assumed for all services. In the automatic mode, composition and entry of an altitude assignment would automatically uplink the associated altitude confirmation. Acceptance of a handoff offer would automatically uplink a TOC message; generation of an en route minimum safe altitude warning (EMSAW) alert would automatically uplink that alert.

Data link may also be inhibited by service or message. Inhibiting by service inhibits a display of the message; inhibiting by message displays the message but inhibits its uplink. In the manual mode, the controller would be required to make an additional input when composing the altitude assignment message to inhibit the uplink. For a manual TOC, the handoff offer should be initiated by the controller (i.e., automatic handoff is inhibited for that aircraft or the controller offers the handoff early) with an extra input to inhibit the automatic uplink of the TOC. For the EMSAW alert, the controllers suggested that manual mode may be the desired default. This could be accomplished by inhibiting the Data Link EMSAW service.

Ultimately, the schemes used for today's automatic handoff INHIBIT/ENABLE and the EMSAW alert suppression capabilities should be EMSAW message uplink.

In view of the range of planned d/l services, the controller should have the flexibility to configure the workstation to: (1) send a Data Link message to the pilot with no associated data base update, (2) update the data base without sending a message to the pilot, and (3) send a message to the pilot that also updates the data base at the conclusion of the exchange.

Initial Data Link Services.

The next three sections discuss the detailed comments on the standard operating procedures for each service and the special situations that may require nonstandard treatment. Because much of the content is process oriented, it conveys a better understanding of the dynamics of the controller interaction with each service.

Altitude Assignment/Confirmation.

The controllers reached agreement on candidate operating procedures for a simple altitude assignment confirmation and a Data Link (no voice) altitude assignment. Tables C-l and C-2 illustrate the respective procedures. For the altitude confirmation message, the procedure begins with the controller voicing an altitude assignment followed by a pilot readback of the altitude. The

TABLE C-l. ALTITUDE ASSIGNMENT CONFIRMATION (AUTOMATIC MODE)

Event	Responsibility	Action
1. Altitude Assignment	1.1 Controller	1.1.1 Issues altitude assignment to A/C (r/t)
	1.2 Pilot	1.2.1 Acknowledges and reads-back altitude assignment (r/t)
	1.3 Controller	1.3.1 Enters altitude assignment
2. Altitude Confirmation	2.1 ATC Computer	2.1.1 Updates data base with new altitude
		2.1.2 Generates altitude confirmation message, displays message "sent" to controller, and sends message to A/C (d/l)
	2.2 A/C	2.2.1 Receives altitude confirmation message and displays to pilot
	2.3 Pilot	2.3.1 Acknowledges altitude confirmation message (d/l)
		2.3.2 Maneuvers A/C in accordance with controller's instructions
	2.4 ATC Computer	2.4.1 Receives acknowledgment and deletes display of confirmation message

TABLE C-2. ALTITUDE ASSIGNMENT (AUTOMATIC MODE)

Event	Responsibility	Action
1. Altitude Assignment	1.1 Controller	1.1.1 Enters altitude assignment
	1.2 ATC Computer	1.2.1 Generates altitude assignment message, displays message"sent" to controller, and sends message to A/C (d/l)
	1.3 A/C	1.3.1 Receives altitude assignment message and displays to pilot
	1.4 Pilot	1.4.1 Acknowledges altitude assignment message (d/l)
		1.4.2 Maneuvers A/C in accordance with controller's instructions
	1.5 ATC Computer	1.5.1 Receives acknowledgment and deletes display of altitude assignment message
		1.5.2 Updates data base with new altitude

controller then inputs an altitude amendment which, in turn, automatically generates an entry in the Data Link status display and uplinks a confirmation message (at this point the A/C data base and data block displays for the aircraft are updated). The procedure concludes with a pilot WILCO input that automatically deletes the entry from the controller's list. As table C-2 shows, the Data Link altitude assignment (no voice) procedure is nearly identical except that the controller's amendment should not update the ATC data base until the WILCO is received.

The discussion of restricted and interim altitudes uncovered some interesting operational issues and concomitant design considerations. Regarding restricted altitudes, the controllers suggested the "altitude/fix/altitude" format (see reference 4, pg 4-2). This specifies an altitude to be maintained until the fix is reached, then a second altitude to be maintained. According to the controllers, the format is seldom used in the field partly because message construction is complicated. It was suggested that this format be used to construct and store a set of canned instructions for restricted altitudes. For each position, these would comprise routine clearances, including the kinds of standard boundary and fix crossing restrictions currently published in each Center's Standard Operating Procedures.

Another issue came up in the context of interim altitudes. In the past, interim altitudes have been used by controllers to accomplish intersector coordination without a voice communication (see reference 2, pg F-7). While adoption of the National Operational Position Standards should proscribe such controversial practices, similar procedural or design controls may need to be developed for use of Data Link. As an illustration, should the Data Link system apply a similar sector eligibility check ("/0K') to the uplink of all Data Link messages? How does the system ensure that all the affected sectors have current flight intent data? Is use of Data Link considered optional? During this discussion, it was suggested that Data Link may discourage nonstandard practices by remediating some of the coordination and message composition problems that gave rise to them.

Transfer of Communication.

The controllers reached agreement on a candidate operating procedure for the transfer of communication. Table C-3 illustrates the basic procedure, handoff with an associated TOC; and table C-4 illustrates a common variant, the handoff with no TOC. Taking account of current and future practice, the controllers recommended that operationally the TOC should be separable from but related to the transfer of control task as follows:

1. Upon acceptance of a handoff, a TOC message for that aircraft is automatically generated and displayed to the losing sector. The sector that assumes computer control is assumed to be the one that will also communicate with the aircraft on the voice frequency appearing in the TOC message.

2. Depending on how the workstation is configured, the TOC message may be uplinked automatically. The uplink will then generate a notification

on the receiving controller's Data Link list. If the automatic uplink is inhibited, the losing controller may issue an alternative TOC message by voice.

TABLE C-3. HANDOFF WITH TRANSFER OF COMMUNICATION (AUTOMATIC MODE)

Event	Responsibility	Action
1. Sector Handoff	1.1 Transferring Sector Controller	1.1.1 As aircraft approaches sector boundary, offers handoff to receiving controller
	1.2 ATC Computer	1.2.1 Displays handoff offer to receiving controller
	1.3 Receiving	1.3.1 Accepts handoff Sector Controller
2. Transfer of Communication (TOC)	2.1 ATC Computer	2.1.1 Displays TOC message "sent" to transferring and receiving controllers and sends frequency to A/C (d/l)
	2.2 A/C	2.2.1 Receives TOC messages and displays to pilot
	2.3 Pilot	2.3.1 Acknowledges TOC message (d/l)
	2.4 ATC Computer	2.4.1 Deletes display of "sent" to transferring controller
		2.4.2 Displays status of "call" to receiving controller
	2.5 Pilot	2.5.1 Check-ins with receiving controller
	2.6 Receiving	2.6.1 Deletes TOC display Controller

TABLE C-4. HANDOFF WITH NO TRANSFER OF COMMUNICATION (MANUAL MODE)

Event	Responsibility	Action
1. Sector Handoff	1.1 Transferring Sector	1.1.1 As aircraft approaches sector boundary, offers handoff to receiving controller with extra input to inhibit automatic uplink
	1.2 ATC Computer	1.2.1 Displays handoff offer to receiving controller and displays TOC message "held" transferring and receiving controllers
	1.3 Receiving Sector Controller	1.3.1 Accepts handoff
2. Transfer of Communication (TOC)	2.1 Transferring Sector Controller	2.1.1 Issues new frequency to pilot (r/t) or (d/1)
		2.1.2 If d/1 TOC message is sent, both sector displays are updated and deleted as in table C-3
	2.2 Pilot	2.2.1 Acknowledges and readsback new frequency (r/t) or (d/l)
		2.3.2 Changes frequency
	2.5 Pilot	2.5.1 Checks-in with receiving controller (r/t)
	2.6 Receiving Controller	2.6.1 Deletes display of "call" or "held" from TOC list display

3. Upon pilot acknowledgment of the TOC message, the losing sector's display will be cleared and the receiving sector's display will be updated to a status of CALL.

No agreement was reached on a procedural requirement for a radio check-in on the frequency. Some felt it wasn't important; others weren't so sure. Nor was there consensus on a process for clearing the CALL message from the receiving controller’s display. The message could be deleted manually, but cued by the radio check-in or it could time out.

The handoff with no transfer of communications is typically followed to avoid issuing a series of radio frequency changes to the flight crew (see reference 2). For instance, this occurs with departing aircraft climbing through several low, medium, and high altitude sectors to a cruise altitude or with aircraft whose horizontal routes cut the corners of several sectors. In the case of a point out, neither computer control nor radio communication is transferred. While the candidate procedure described in the tables will permit handoff with no TOC by allowing the losing controller to inhibit an automatic TOC message, they are also intended to keep computer control and communication assigned to same controller by making this the easiest way to issue the TOC.

EMSAW.

Indeed, this was a controversial service. Most of the commentary concerned the false alert problem. Generally, it was felt that operating procedures for this service probably needed to be determined locally and input from ATCS's who work in Centers with more mountainous terrain was needed. Beyond that, there was a more fundamental question of whether Data Link would be faster than voice. However, on the assumption that Data Link is a viable way to deliver an EMSAW alert, it was recommended that the message content match the phraseology defined in the Controller's Handbook (reference 5 pg 2-2): "Low Altitude Alert. Check your altitude immediately. The minimum en route altitude in your area is ." Table C-5 illustrates the candidate operating procedure devised for a Data Link EMSAW service.

As an alternative to an EMSAW service, it was suggested that an altitude out of conformance service could be developed to work in conjunction with the "+/-" qualifier that already appears in the data block.

REFERENCES

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2. Kinney, G. C., Bell, G. L., and Ditmore, M. A., The Human Element in Air Traffic Control: Factors in System Recovery and Revitalization (Appendices), MTR-82W151, The MITRE Corporation, McLean, Va., April 1983.

3. Flathers, G.W., Development of an Air-Ground Data Exchange Concept: Flight Deck Perspective, MTR-87W21, The MITRE Corporation, McLean, Va., March 1987.

4. Rucker, R. A., Tutorial on Radar Controller Inputs and Displays in NAS 3d2, WP-84W00010, The MITRE Corporation, McLean, Va., January 1983.

5. FAA Order 7110-65D, Air Traffic Control, 1984.

TABLE C-5. EMSAW ALERT (MANUAL MODE)

Event	Responsibility	Action
1. EMSAW Alert	l.1 Controller	1.1.1 Selects Data Link inhibit for EMSAW alert
	1.1 ATC Computer	1.1.1 Displays Data Link EMSAW inhibit in Data Link service select header
		1.1.2 Projects that A/C will violate minimum safe altitude
		1.1.3 Displays EMSAW alert to controller
	1.2 Controller	1.2.1 Observes alert, examines flight intent, and determines validity
		1.2.2 Deselects data link EMSAW inhibit
	1.3 ATC Computer	1.3.1 Removes EMSAW inhibit indicator in service select header
		1.3.2 Displays EMSAW message "sent" to controller
	1.4 Pilot	1.4.1 Acknowledges EMSAW message (d/l)
		1.4.2 Maneuvers A/C in accordance with controller's instruction
	1.5 ATC Computer	1.5.1 Deletes EMSAW display

Data Link Evaluation

Debriefing Discussion Guide
May 21-22 1988

RESULTS

Test Controller Information

Name (Optional):___________________________

Facility: _ 8__ZFW __2___Other (Specify) DFW Metroplex Task Force DFW TRACON

Experience (Place a check next to your current position):

		Average	Range
__9__	FPL Controller (7 current)	_15.7 Years	(3-31)
__1___	First Level Supervisor	__.5__ Years	
______	Other (Specify)____________________	______ Years	

Test participant role:

__4__ Active Controller __4__ Observer Controller

__1___ Roving Observer

Any experience as a pilot? __5__ No
_4___ Yes _16__ Years experience (5-20)

Prior to this test, were you familiar with the data link prog ram?

__6___ No
__3__ Yes

- In terms of how often you perform it, how much workload is attached to the altitude assignment task compared to other task that make up your job?

_2___	5.	More workload than almost any other task
_3___	4.	More workload than most other tasks
_3__	3.	About average
_1__	2.	Not as much workload as most other tasks
___	1.	One of my least de manding tasks

	Circle One
How about transfer of radio communications?	5 4 3 2 1 2 4 3
EMSAW (low altitude) alert?	5 4 3 2 1 9

Initial ATC Services

- Considering all of the different situation and types of altitude assignments. (e.g., interim altitudes, altitudes with crossing restrictions) that might be issued by a controller, what procedures seem most usable with data link?

Initial ATC Services

- Considering all of the different situations in which a controller might request approval for an aircraft to enter another controller's airspace but retain radio contact (i.e., point out), what procedures for both sector handoff and transfer of radio communications seem most usable with data link?

Initial ATC Services

- Considering all of the different situations in which a controller might decide to issue an EMSAW alert, what procedures seem most usable with data link?

Initial ATC Services

- From the controller's standpoint, how would you compare the current procedures for altitude assignment, transfer of radio communications and EMSAW with a procedure that includes a data link confirmation?

4 Data link procedure much better

3 Data link procedure somewhat better

_ Data link and current procedures about the same

_1_ Current procedures somewhat better

___ Current procedures much better

-- Drop EMSAW

-- Simplify Inputs

Initial ATC Services

- From the pilot's standpoint, how would you compare the current procedures for altitude assignment, transfer of radio communications and EMSAW with a procedure that includes a data link confirmation?

2 Data link procedure much better

3 Data link procedure somewhat better

1 Data link and current procedures about the same

____ Current procedures somewhat better

__1__ Current procedures much better

Initial ATC Services

- Within the context of the tasks that you were able to perform (or observe) in the test sessions, please indicate the combination of display, input, and procedural options that feel would be usable in the majority of operational situations.

Display	___ CRD	_9_ PVD /Data Block	___ Both options selectable by:___________
Uplink	____ Manual input required	- _3_ Automatic uplink	_6_ Both options selectable by:___________
Downlink	_9_ Pilot input required	__ No pilot input	___ Both options selectable by:___________

- Of the ones for which you checked "both options", could a default option? Uplink automatic default with inhibit option.

- Are there any other features that would make the interface more usable? Downlink of cockpit information--airspeed/mach, heading, climb/descent rates.

Initial ATC Services

- Would you be able to use the test displays, inputs, and procedures to perform these tasks in an operational environment?

__3__ Yes

__6__ Yes, with reservations
- Simplify inputs
- Display status information in data block

No, because____

Initial ATC Services

- How logical was the flow of information between the pilot and the controller in relation to the tasks you were performing?

  _2_ Very logical

  _7_ Somewhat logical- TOC is backwards
  - Time out & unable don't provide useful information

  __ Somewhat illogical

  ___ Very illogical

Initial ATC Services

- Was the terminology and phraseology presented in the test displays understandable?

  _2_ Always except for TIMEOUT
  _7_ Sometimes change "TIMEOUT" to "NO REPLY"
  ____ Never

Initial ATC Services

- Was the content of the displayed information complete?

_7_ Complete - change timeout and unable

_1_ Incomplete - label each entry with a reference no. or letter
- display content of altitude or frequency assignment

_1_ To much information is displayed

Initial ATC Services

- Was the content of the displayed information appropriate?

__6__ Appropriate except timeout and unable

__3__ Inappropriate - no timeout or unable
- without showing the altitude or frequency assignment, can't tell "what" message was accepted

Initial ATC Services

- How quickly were you able to identify key pieces of information?

  7 Very quickly

  2 Somewhat quickly

  ___ Somewhat slowly

  __ Very slowly

  Except in manual mode using a CRD list containing several pending D/L messages.

Initial ATC Services

- How easy was it to connect controller and pilot inputs with displayed information and with display updates?

  3 Very easy

  5 Somewhat easy Best display is in data block

  1 Somewhat difficult Information is too spread out

  ___ Very difficult

Initial ATC Services

- Within the context of the tasks you were able to perform (or observe) In the test sessions, please rate the utility of the data link display information.

  3 Very useful

  4 Useful

  1 Marginally useful

  ___ Not useful

Initial ATC Services

- Was sufficient information displayed to permit performance of the test tasks in an operational environment?

_5_ Always

_4_ Sometimes

____ Never

Too much information

Initial ATC Services

- In your opinion, what procedure should be followed when a pilot sends an "unable" reply ?

  - To a confirmation message (voice and data link)?

  - To a data link control instruction (data link only)?

6 controllers: D/L reply should say "call" (to discuss) "verify" (to confirm) then use voice to discuss/negotiate or resend D/L message to verify

Initial ATC Services

- In your opinion, what procedure should be followed when a pilot fails to reply?

  - To a confirmation message (voice and data link)?

  - To a data link control instruction (data link only)?

-- Reissue instruction using voice

-- Resubmit message using D/L

Initial ATC Services

- What if the link itself fails and no technical acknowledgment is received?

  - To a confirmation message (voice and data link)?

  - To a data link control instruction (data link only)?

  3 controllers: use voice to determine status of data link

General Data Link

- Some people feel that a confirmation message (altitude assignment) should be the initial data link service to help familiarize controllers and pilots with the data link communication process. Other people feel that we should eliminate this initial step and use the data link by itself to issue a control instruction without an accompanying radio communication. Which of these best describes your view?

  __5__ Initially, use radio communications to issue an ATC instruction and also use data link for confirmation of the instruction
  (for a test period, then phase out voice)

  __4__ Initially, use data link by itself to issue the instruction

General Data Link

- Some people believe that data link will be most for useful to controllers for sending messages, while it will be most useful to pilots for receiving messages. How do you feel about this?

  8 Agree but require a pilot acknowledgment

  1 Disagree

General Data Link

- What do you feel would be the best arrangement of voice and data link communications in the future ATC system? (Check all that apply.)

  2 Voice as primary mode

  5 Data link a primary mode for most messages

  Have voice as backup

  6 Data link as primary mode for certain types of messages, with voice as the primary mode for other types of messages

  Voice needed for time critical messages

  1 Data link as primary ground-to-air mode, with voice as the primary air-to-ground mode

  __ Other (specify)

General Data Link

- In the long run, what outcomes (sample outcomes include: fewer miscommunications, (2nd) reduced radio frequency congestion, (lst) increased standardization in message (3rd) phraseology) do you feel should be used to judge the success of the data link service?

- Pilots have a permanent copy of messages

- D/L provides a second/redundant way to access cockpit

- Controllers can have access to cockpit (speed/heading) data

- D/L may have negative impact on workload

General Data Link

- In ATC, the timing of the communication is often an important consideration. Some control instructions are dependent on responses to instructions previously issued to other aircraft. Some people feel more confident that the instruction will actually be carried out when they receive a voice reply. Would you consider a mixed-mode communication system (for example, controller uplink of an instruction with a voice acknowledgment by the pilot) to be an acceptable design?

__4__ Yes __4__ No

Yes:
- Ensures quicker response
- Only for verification

No:
- Controller issues instructions in priority order mode doesn't ensure they get carried out in that order
- Either D/L or voice, not both

Why?

General Data Link

- Are there situations or airspaces where data link should not be used?

  Yes 4 - Deviations around wx Emergencies

  No 3 - Eventually the computer will control the A/C, Humans will monitor the system and manage the airspace

APPENDIX D

WRAP-UP QUESTIONNAIRE

WRAP-UP QUESTIONNAIRE

1. How would you rate the simulation realism. (Circle One) (Please disregard small amount of traffic.)

Very Good (VG)	Good (G)	Slightly Good (SG)	Fair (F)	Slightly Poor (SP)	Poor (P)	Very Poor (VP)

2. How can we enhance realism? (Use extra space on back.)

____

____

____

3. Please document any system malfunctions that if worked as designed would have helped you make a better evaluation.

____

____

____

4. Looking back at training, any new ideas as to what training would have aided testing?

____

____

____

5. Please rate the SWAT data collection technique as it applies to ATC mental workload analysis.

SWAT ASPECTS	VG	G	SG	F	SP	P	VP
a. How well does sort separate work loads?							
b. How independent are the loads? Can one load remain at 1 while the others go to 3?							
c. How well does SWAT measure ATC workload?							

Comments on SWAT ____

____

____

6. Please rate these data link aspects regarding possibility of utilization in the field.

ASPECTS	VG	G	SG	F	SP	P	VP
Automatic Mode							
Manual Mode							
Using RCRD for display							
Using PVD for display							
Message response times							

Comments?____

____

____

7. Please select the optimum methods for the three services. (Circle choices.)

	Mode	Control Voice	Pilot Voice	Display
Alt Confirm	Manual Auto	Yes No	Yes No	PVD CRD
Trans Comm.	Manual Auto	Yes No	Yes No	PVD CRD
EMSAW	Manual Auto	Yes No	Yes No	PVD CRD

Comments?____

____

8. Please rate how well each service would perform at your position if optimally configured.

SERVICE	VG	G	SG	F	SP	P	VP
Altitude Confirmation							
Transfer of Communication							
EMSAW							

Comments?____

____

9. Using the optimum services, what would be the projected effect of data link at your position on the following:

PROJECTED EFFECT ON	VG	G	SG	F	SP	P	VP
System capacity (a/c in sector)							
Keeping the Picture							
Weather handling							
R-D controller coordination							
Sector Interphone coordination							
Pilot-controller communications							
A/C conflicts (system errors)							
Flight strip marking/handling							
Status board info. handling							
Overall efficiency (speed)							
Overall safety							
Overall controller workload							

Comments?____

____

____

____

10. Using data link should leave no “gaps" in the system. Did you see any places where gaps in positive control could occur? Also, give any ideas as how to prevent them.

____

____

____

11. What about data link do you like best, and why?

12. What about data link do you like least, and why?

13. What future services would you like to see data link do?

APPENDIX E

ANALYSIS OF CONTROLLER WORKLOAD AND PREFERENCE DATA

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

The primary measures used during formal data collection in the Data Link test bed were controller ratings of the workload associated with each test option and of their preference for each option. Following every test condition, the controller subjects completed two rating forms. The first form required the subject to project the workload that would be associated with the option on a moderately busy work day for each of the three services. The method that was used to obtain these ratings is known as the Projective Subjective Workload Assessment Technique (PROSWAT). PROSWAT ratings were assigned by judging the test options on three, 3-point scales referring to time load, mental effort load, and psychological stress.

The second form required the subject to judge the test option as acceptable or unacceptable in terms of its effect on air traffic control (ATC) safety and efficiency. If judged acceptable, the subject rated the option on a 7-point rating scale ranging from "highly preferred" to "acceptable, but not preferred." Comments were solicited at the bottom of the form in order to determine the subject's rationale for his preference ratings. Samples of each of the rating forms as well as instructions for their use are contained in appendix B.

PROSWAT DATA

CARD SORT ANALYSES.

The quantitative interpretation of PROSWAT ratings is based on an analysis of a preliminary card sorting task which is used to determine the way in which subjects combine the three dimensions of the scale to produce an overall concept of workload. In the current study, this task was completed by all eight test controllers prior to training and testing in the Data Link test bed.

Computer analysis of the card sorts revealed only moderate agreement among card orderings (W=.74). In PROSWAT, such a result makes it undesirable to use single scale solution for all subjects in a sample. As a consequence, the SWAT prototyping algorithms were employed to identify subgroups of subjects who produced similar card sorts. This algorithm classified three subject sorts in the time prototype, two in the effort prototype and three in the stress prototype. Classification within a prototype group indicates that the subject weighed the associated factor more strongly than the others when performing the sort.

Analysis of the agreement among subjects within the prototype subgroups showed that all three were acceptable (time, r=.90; effort, r=.89; stress, r=.90). Therefore, separate scaling solutions were computed for the three prototype groups using the SWAT conjoint measurement and scaling programs. The resulting tables relating time, effort, and stress ratings to interval scale values were used to score the PROSWAT ratings of individual subjects classified in those groups. Table E-l presents the card orderings for each subject along with the mapping of scale values assigned to the prototype groups.

The statistical analyses which follow were performed on PROSWAT scores transformed from the ordinal ratings using the prototype scaling solution identified for each subject. In each case, one to three ratings on the three dimensions were interpreted by referring to the appropriate subgroup scale which ranged from 0 (low workload) to 100 (high workload).

TABLE E-l. PROSWAT CARD SORTS AND PROTOTYPE SCALE VALUES

Card			Subject Sort			Time Proto.	Subject Sort		Effort Proto.	Subject Sort			Stress Proto.
T	**E**	**S**	**1**	**2**	**3**		**2**	**8**		**5**	**6**	**7**	
1	1	1	1	1	1	0.0	1	1	0.0	1	1	1	0.0
1	1	2	2	2	4	8.7	4	2	11.9	8	7	2	28.2
1	1	3	11	3	5	23.4	13	3	26.6	17	16	5	51.8
1	2	1	5	4	2	11.3	7	10	29.4	3	5	6	14.8
1	2	2	7	5	10	19.9	10	11	41.2	14	14	14	43.1
1	2	3	8	7	11	34.6	22	12	55.9	22	18	15	66.6
1	3	1	6	5	6	21.7	16	19	58.8	5	6	7	23.1
1	3	2	9	8	12	30.4	19	20	70.6	16	17	16	51.3
1	3	3	14	9	22	45.1	25	21	85.3	25	20	17	74.8
2	1	1	3	10	3	23.7	2	4	7.3	2	2	3	13.9
2	1	2	4	11	9	32.4	5	5	19.2	9	12	4	42.2
2	1	3	16	14	14	47.1	14	6	33.9	18	13	12	65.7
2	2	1	12	12	7	35.0	8	13	36.7	4	3	8	28.8
2	2	2	15	15	13	43.7	11	14	48.6	10	15	21	57.0
2	2	3	19	16	23	58.4	23	15	63.3	23	26	24	80.6
2	3	1	13	13	8	45.5	17	22	66.1	12	8	19	37.0
2	3	2	10	17	21	54.1	20	23	78.0	20	24	20	65.2
2	3	3	25	18	25	68.8	26	24	92.7	26	21	25	88.8
3	1	1	20	19	15	54.9	3	7	14.7	6	4	10	25.2
3	1	2	21	20	18	63.6	6	8	26.6	11	11	9	53.4
3	1	3	22	21	20	78.3	15	9	41.2	19	25	23	76.9
3	2	1	17	22	16	66.1	9	16	44.0	7	10	13	40.0
3	2	2	24	23	19	74.8	12	17	55.9	15	22	18	68.2
3	2	3	23	24	26	89.5	24	18	70.6	24	23	26	91.8
3	3	1	18	25	17	76.6	18	25	73.4	13	9	11	48.2
3	3	2	26	26	24	85.3	21	26	85.3	21	19	22	76.5
3	3	3	27	27	27	100.0	27	27	100.0	27	27	27	100.0

OVERALL ANALYSES OF VARIANCE.

The PROSWAT scores contributed by each subject under each test option are shown in table E-2.

Because of the interval scale properties of the transformed PROSWAT ratings, these data were analyzed using standard parametric statistical techniques. In order to determine whether any of the test options produced significant variations in perceived workload, single factor, repeated measures analyses of variance were performed on the PROSWAT scores across the eight experimental conditions. Individual analyses were performed for the altitude confirmation, transfer of communications, and AIMS services.

Results of these analyses revealed that projected workload was significantly affected by the test options for each of the services (altitude confirmation, $F(7,49)=9.26$, $p<.0001$; transfer of communications, $F(7,49)=3.98$, $p<.o01$; EMSAW, $F(7,49)=5.12$, $p<.0003$). Based on the significance of these findings, individual post hoc analyses were performed using the Student's t statistic in order to assess the impact of the individual display and procedural factors on controller workload.

DATA LINK TRANSACTION DISPLAY LOCATION.

Mean PROSWAT scores derived from comparable procedural conditions in which the Plan View Display (PVD) list display and the Computer Readout Display (CRD) list display were used are presented in figure E-l. As shown in the figure, while no difference was obvious between the displays for AIMS, the PVD list received lower projected mean workload scores than the CRD list in the altitude confirmation and transfer of communications tasks. However, t test comparisons of these scores revealed no statistically significant differences in perceived workload between the PVD and CRD displays either for altitude confirmation ($t(7)=1.52$, $p=.17$) or for transfer of communications ($t(7)=.99$, $p=.35$).

MANUAL VS. AUTOMATIC CONTROL.

Unlike the statistically weak impact of display location, strong effects on PROSWAT workload were obtained for manual and automatic control options. Figure E-2 presents the mean workload scores obtained for the manual and automatic options in each of the tested services. The manual means were calculated by computing an average PROSWAT score for each subject across the three test conditions which required manual designation of the relevant data in the list display and an entry to release the uplink (manual/pilot response/PVD, manual/pilot response/CRD, and manual/no pilot response). The automatic means were calculated in the same way for the three conditions in which the uplink was achieved automatically following normal entry of the transfer of control data to the NAS, entry of an altitude amendment, or detection of an AIMS event (automatic/pilot response, automatic/no pilot response, and automatic/pilot response/no voice).

As shown in figure E-2, workload was higher in the manual conditions than in the automatic conditions for all three services. Statistical comparisons confirmed the significance of all three differences (altitude confirmation, t(7)=3.74, p<.0l; transfer of communications, t(7)=2.66, p<.015; EMSAW, t(7)=3.24, p<.0l).

TABLE E-2. PROSWAT SCORES AND PROTOTYPE SCALE VALUES

	Test Options						
Altitude Confirmation							
Subject	1	2	3	4	5	6	7
1	35.0	85.3	66.1	35.0	35.0	11.3	11.3
2	7.3	7.3	7.3	7.3	7.3	7.3	0.0
3	66.1	66.1	23.7	0.0	0.0	0.0	0.0
4	32.4	74.8	74.8	11.3	8.7	0.0	0.0
5	68.2	68.2	68.2	57.0	57.0	57.0	14.8
6	40.0	40.0	40.0	0.0	0.0	0.0	0 0
7	28.8	28.8	37.0	28.8	28.8	0.0	13.9
8	36.7	36.7	36.7	29.4	41.2	0.0	0.0
Transfer Of Communications							
1	23.7	23.7	35.0	35.0	35.0	23.7	0.0
2	7.3	7.3	7.3	7.3	7.3	7.3	0.0
3	66.1	66.1	23.7	0.0	0.0	0.0	0.0
4	0.0	66.1	66.1	0.0	0.0	0.0	19.9
5	68.2	68.2	40.0	13.9	68.2	57.0	0.0
6	25.2	25.2	25.2	13.9	13.9	0.0	0.0
7	28.8	28.8	28.8	28.8	14.8	13.9	13.9
8	7.3	7.3	41.2	0.0	0.0	0.0	0.0
EMSAW							
1	19.9	19.9	19.9	19.9	19.9	8.7	0.0
2	7.3	7.3	7.3	7.3	7.3	7.3	0.0
3	66.1	35.0	0.0	0.0	0.0	0.0	0.0
4	43.7	74.8	74.8	19.9	19.9	8.7	19.9
5	25.2	25.2	25.2	13.9	0.0	13.9	0.0
6	66.6	66.6	66.6	66.6	66.6	0.0	0.0
7	0.0	0.0	14.8	0.0	0.0	0.0	0.0
8	41.2	41.2	41.2	41.2	11.9	0.0	0.0

Test Option Key

1. Manual/Pilot Response/Voice PVD
2. Manual/Pilot Response/Voice/CRD
3. Manual/No Pilot Response/Voice
4. Automatic/Pilot Response/Voice

5. Automatic/No Pilot Response/Voice
6. Automatic/Pilot Response/no Voice
7. Modified System/Pilot Response/No Voice

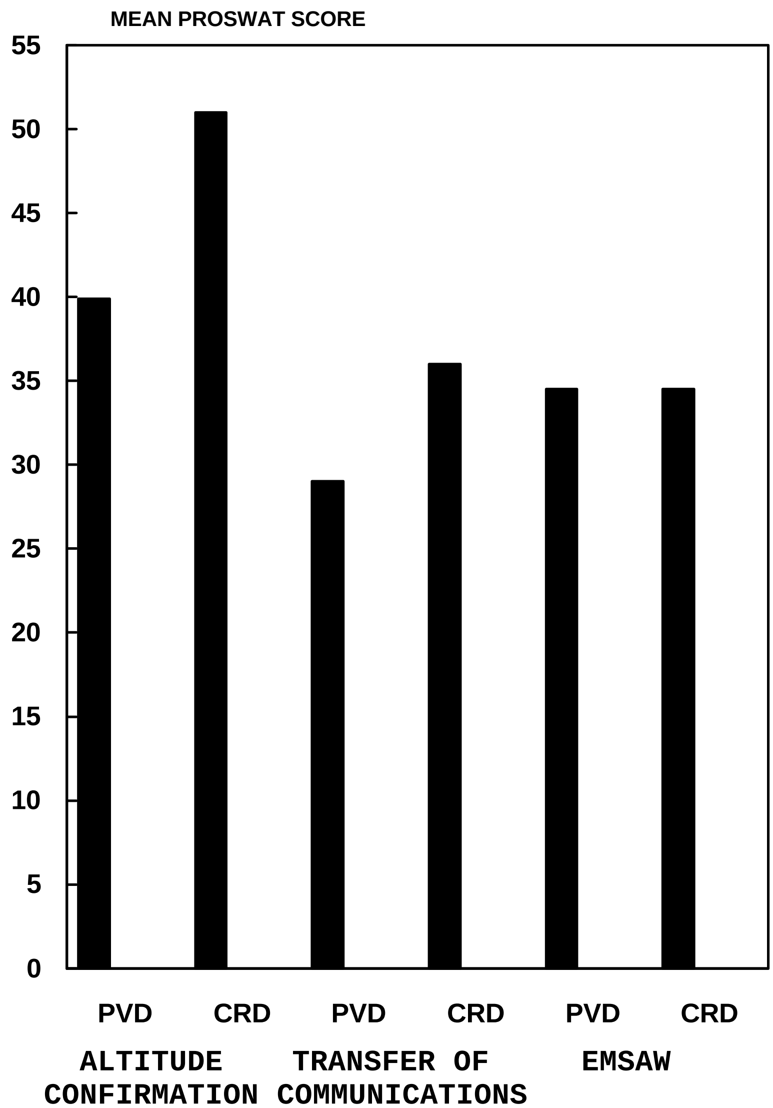

FIGURE E-1. DATA LINK CONTROLLER WORKLOAD, TRANSACTION DISPLAY LOCATION

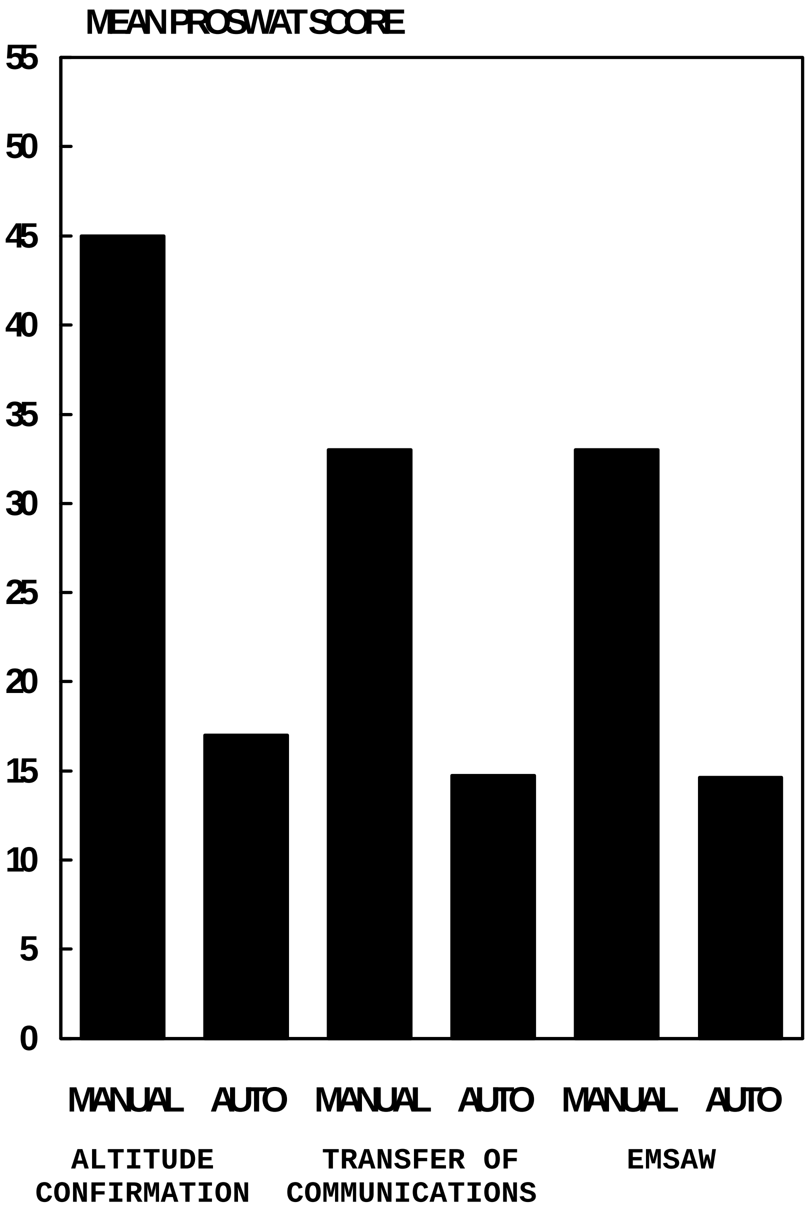

FIGURE E-2. DATA LINK CONTROLLER WORKLOAD, MANUAL VS. AUTOMATIC UPLINK

VOICE.

Figure E-3 presents the effect on workload of the presence or absence of voice communications between the controller and pilot which were redundant with a message delivered via Data Link. The PROSWAT scores for the voice condition were computed by calculating mean scores for the two automatic conditions in which redundant voice was included (with pilot response and without). The no voice means were based on the scores obtained in the automatic/pilot response/no voice condition and in the revised system tested on Day 2 without voice. As shown in figure E-3, mean workload scores were lower in the no voice condition than for the voice condition for all three services. Statistical tests of the significance of these differences revealed a significant effect for the altitude confirmation service (t(7)=3.16, p<.05) and marginally significant effects for transfer of communications and EMSAW (t(7)=1.77, [>.10 and t(7)=1.82, p<.l0, respectively).

PILOT RESPONSE.

A third combined comparison was performed to assess the effect of requiring the controller to monitor for a downlinked pilot confirmation of a received message. In all cases, these comparisons were made under voice conditions in which the data linked pilot response would be redundant with voice radio communications. The mean workload ratings for each service under both manual and automatic conditions are presented below:

		Pilot Response	No Response
Altitude Confirmation	Manual	39.31	44.22
	Auto	21.10	22.25
Transfer of Communications	Manual	28.33	33.39
	Auto	12.36	17.40
EMSAW	Manual	33.75	31.23
	Auto	21.10	15.70

As the illustration shows, no large or consistent differences in perceived workload were obtained as a function of the requirement for a pilot response either in the manual or the automatic conditions. The test comparisons between all pilot response and no response conditions detected no statistically significant differences between the means (p>.15 in all cases).

MODIFIED SYSTEM COMPARISONS.

A final group of statistical comparisons were performed to assess the significance of the reduction in workload produced by the modified system tested on Day 2 to the conditions evaluated on the first day of testing. The mean workload score obtained for the modified system was 5.00 for altitude confirmation, 4.23 for transfer of communications, and 2.49 for EMSAW. These scores were significantly lower than the manual options for all services

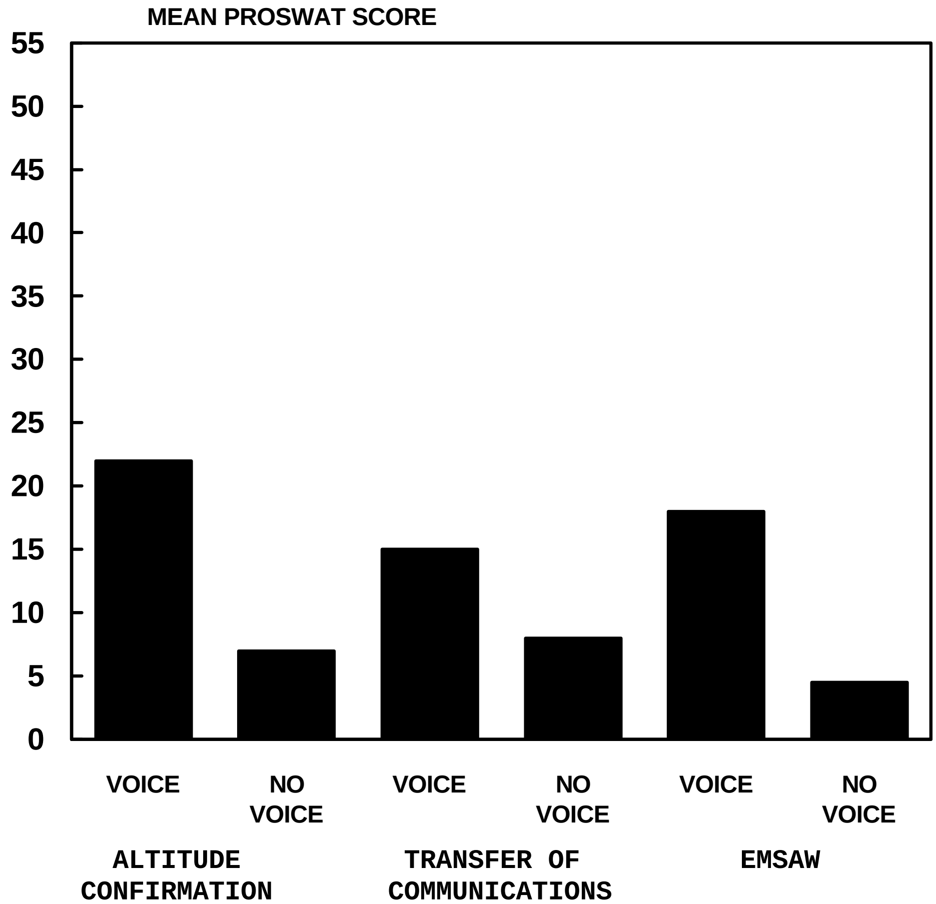

FIGURE E-3. DATA LINK CONTROLLER WORKLOAD, REDUNDANT VOICE COMMUNICATIONS (p<.05). In addition, projected workload on the modified system was significantly reduced in comparison to two of the three automatic options for altitude confirmation (p<.02). No statistically significant differences in workload were detected between the automatic/no voice options and the modified systems for any of the services.

PREFERENCE/ACCEPTABILITY DATA

The preference/acceptability ratings produced by all subjects under each test option are shown in table E-3.

OVERALL ANALYSES OF VARIANCE

Because of the ordinal characteristics of the ratings obtained on the preference/acceptability scale, the results were analyzed using nonparametric statistical tests of significance. Overall analyses to determine the significance of variations in preference produced by the test options were performed using the Friedman Two-Way Analysis of Variance by Ranks. Unacceptable ratings were assigned a value of "8" for these analyses in order to include scores from all subjects under each test option.

Significant variation in test option preferences were detected for altitude confirmation (chi square (6) = 26.03, p<.001), and EMSAW (chi square (6) = 24.18, p<.OOl). However, no significant differences in option preferences were detected for the transfer of communications task (chi square (6) = 7.0, p>.4).

The primary reason for the failure of the transfer of communications task preference ratings to reach statistical significance was the preponderance of unacceptable ratings obtained under these conditions. While the altitude confirmation and EMSAW test options each received only one unacceptable rating out of 56 ratings per service, the transfer of communications options were rated unacceptable in 11 cases. These ratings were produced by four different subjects and were not consistently associated with any particular procedural or display condition.

Evaluation of controller comments indicated that these unacceptable ratings were attributable to the fact that the original Day 1 test options all required the receiving controller to uplink the new radio frequency to the pilot. Since this is contrary to current ATC operational procedures, a number of controllers assigned low preference or unacceptable ratings to all of the options, disregarding the focal test parameters. This interpretation is supported by inspection of the transfer of communications preference ratings obtained for the modified system on Day 2 of testing. In this option, where the frequency change was under the control of the transferring controller, no unacceptable ratings were assigned and preference ratings were significantly lower than those for any of the other test options (p<.01, Wilcoxon test).

Based on the general significance of the overall analyses, individual nonparametric comparisons among test conditions were performed using Wilcoxon's Matched Pairs Signed Ranks test in order to evaluate the effects on controller preference of the individual display and procedural options.

TABLE E-3. PREFERENCE/ACCEPTABILITY RATINGS

	Test Options						
Altitude Confirmation							
Subject	1	2	3	4	5	6	7
1	5	5	2	2	1	2	2
2	7	7	6	5	5	3	2
3	7	7	5	3	5		
4	4	7	7	2	u	2	2
5	7	7	5	4	5	4	2
6	1	7	4	4	3	3	7
7	5	5	3	3	3		
8	5	6	6	3	6	2	2
Transfer of Communications							
1	5	4	3	2	1	2	
2	7	7	6	5	5	3	2
3	u	7	7	3	5		
4	2	7	7	2	u	2	3
5	u	u	u	6	6	4	2
6	u	u	u	u	u	u	
7	6	5	5	5	4	2	2
8	4	5	5	3	5	2	2
EMSAW							
1	6	5	3	2	3	3	
2	7	7	6	5	5	3	2
3	4	7	4	3	5		
4	4	7	7	1	u	1	7
5	7	7	7	5	7	6	5
6	1	4	4				
7	6	6	5	6	6	4	6
8	4	5	5	2	5	2	2

NOTE: Completely unacceptable ratings are indicated by "u." Preference ratings range from 1 "highly preferred" to 7 "acceptable but not preferred."

DATA LINK TRANSACTION DISPLAY LOCATION.

Figure E-4 shows the median preference ratings obtained for the comparable test conditions in which the PVD and CRD lists were used. In general agreement with the workload data, these preference ratings indicate that the PVD list was preferred over the CRD list for all three tested services. Statistical comparisons confirmed the significance of this preference for both altitude confirmation (T=0, p<.01) and EMSAW (T=4.5, p<.05). Put in p level for Transfer of Control.

MANUAL VS. AUTOMATIC CONTROL.

Controller workload and preference ratings were also closely correlated for the comparison between the manual and automatic control options. Figure E-5 presents the median preference ratings obtained for the three test options involving manual selection and initiation of uplinks and for those which include automatic uplinks. All three services were more highly preferred when conducted in the automatic modes than when performed manually (altitude confirmation, T=0, p<.0l; transfer of communications, T=0, (N=7), P<.02; EMSAW, T=0, (N=7), p<.02).

VOICE.

Figure E-6 presents the median preference ratings computed for the automatic mode conditions in which redundant voice communications were present and for those in which Data Link communications were the only form of data transfer between the controller and the pilot. As shown in the figure, controller preference ratings were consistently higher in the no voice options. This was confirmed in statistical comparisons for all three ATC services (altitude confirmation, T=3.5, p<.05; transfer of control, T=0, p<.01; EMSAW, T=0, p<.01; EMSAW, T=0 (N=7), p<.02).

PILOT RESPONSE.

A comparison of controller preferences for requiring a pilot confirmation downlink is presented in the following median ratings:

		Pilot Response	No Response
Altitude Confirmation	Manual	5	5
	Auto	3	4
Transfer of Communications	Manual	4.5	5.5
	Auto	3	5
EMSAW	Manual	5	5
	Auto	2.5	5

As shown above, the subject controllers appeared to have a slight preference for requiring a pilot response via Data Link in conditions where the response would be redundant with a voice communications. However HIGHLY PREFERRED tical comparisons

E-11

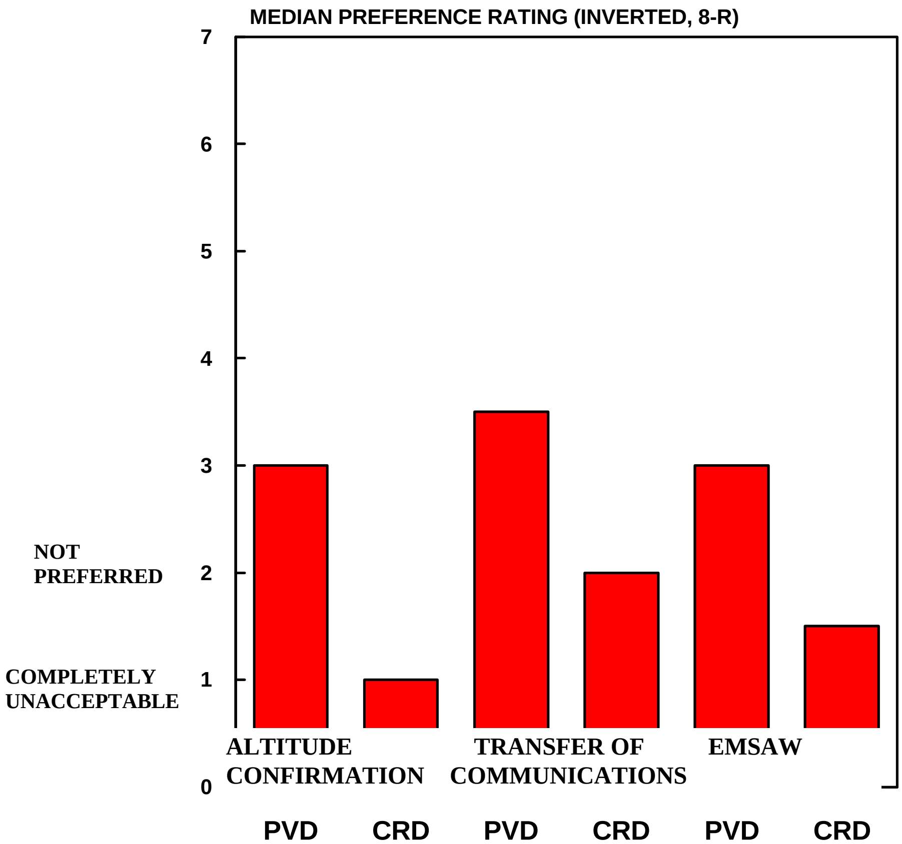

FIGURE E-4. DATA LINK CONTROLLER PREFERENCE, TRANSACTION DISPLAY LOCATION

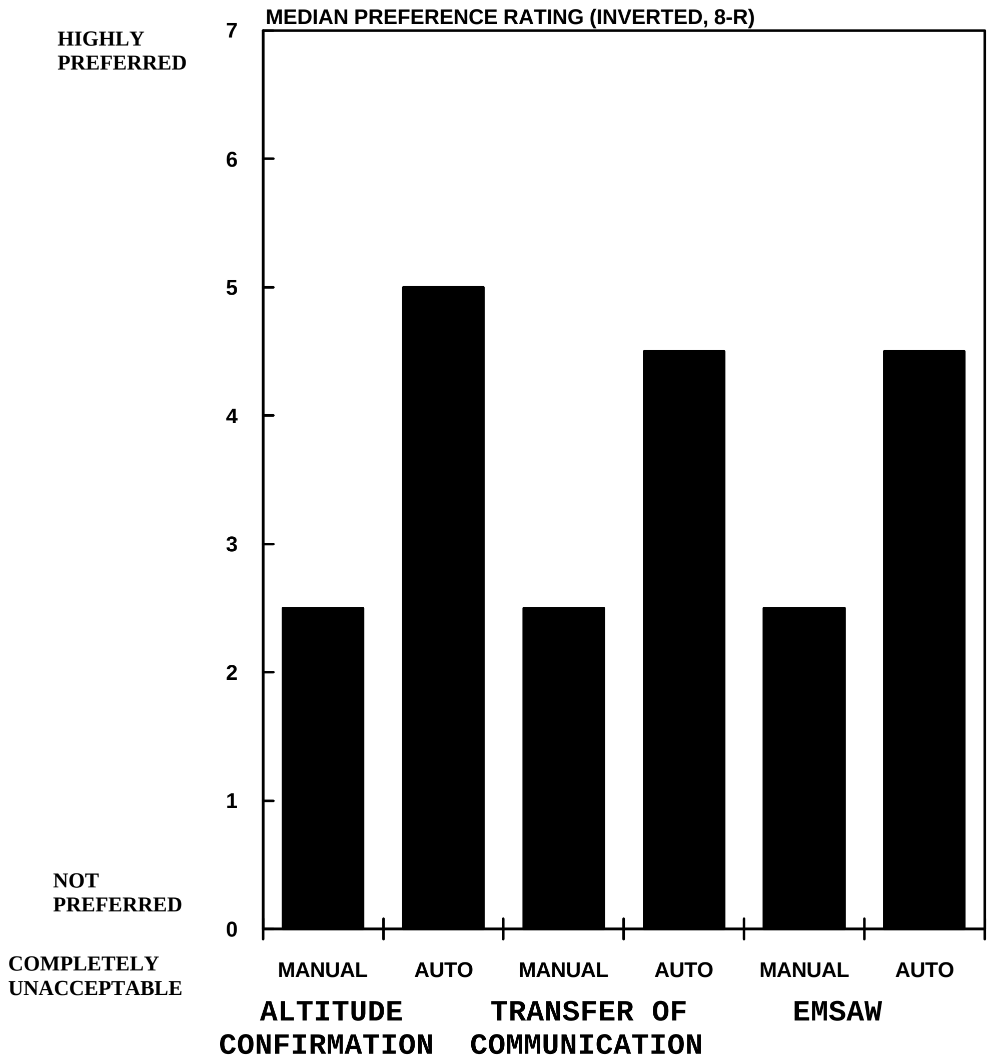

FIGURE E-5. DATA LINK CONTROLLER PREFERENCE, MANUAL VS. AUTOMATIC UPLINK

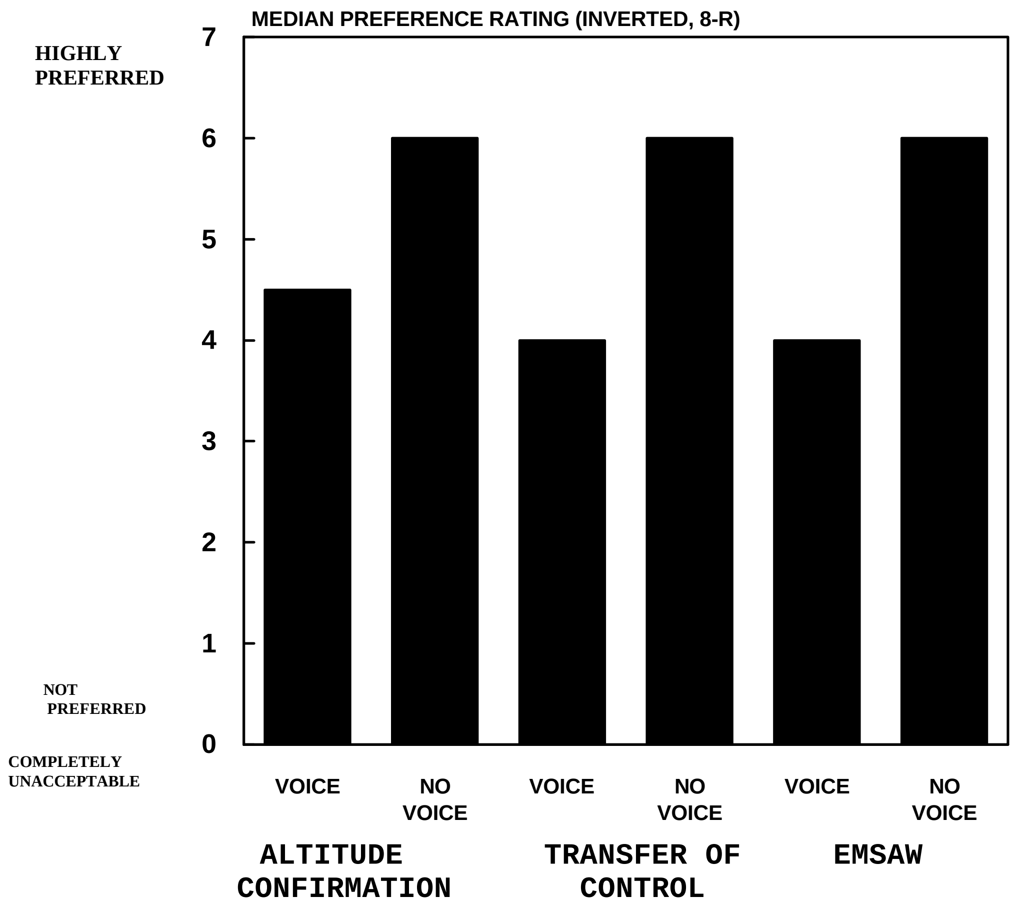

FIGURE E-6. DATA LINK CONTROLLER PREFERENCE, REDUNDANT VOICE COMMUNICATIONS revealed no significant differences between the conditions except for the automatic version of the EMSAW service (T=0, $p<.01$) which favored the pilot response.

Both the workload data and the preference data presented above for the pilot response factor yielded equivocal results. However, when viewed in light of the clearly superior preferences elicited for the no voice conditions, these data suggest that the positive impact of pilot confirmation via Data Link emerges most strongly when redundant voice radio calls are eliminated.

MODIFIED SYSTEM COMPARISONS.

The modified system tested on Day 2 was more highly preferred than any of the other options tested in the mini study. The median preference scores for all three services in this version was 2.0. In comparison, median preference scores for the manual options ranged from 4.5 to 7.0, and for the automatic options from 2.5 to 5.0. The only median preference rating which equaled those obtained for the modified system was that elicited under the automatic/no voice condition for altitude confirmation.

PREFERENCE/ACCEPTABILITY COMMENTS

Following each rating on the preference/acceptability scale, the controller subjects were asked to write brief comments explaining the rationale underlying their ratings. These comments are summarized below for each test option. Substantially similar comments obtained from different controller subjects were classified as a single comment. All cases are annotated to show the number of controllers contributing the comment.

OPTION 1 - MANUAL CONTROL/PILOT RESPONSE REQUIRED/PVD DISPLAY.

Five subjects indicated that the data entry requirements of this option were excessive.

Two controllers noted that the procedure used in the transfer of communications service was inappropriate. All transfer of communication tasks are the responsibility of the transferring controller. Thus, the receiving controller should not initiate the uplink of the frequency change.

Two subjects felt that the list display would be difficult to interpret when several Data Link services were displayed simultaneously.

One controller indicated that a list type display would distract the controller's attention from his observation of the central radar track data.

One controller was concerned about TIMEOUT and UNABLE responses. He felt that these were not valid pilot response options to a positive control uplink.

One controller noted that this option would permit inadvertent deletion of a status line from the list before the pilot response was received.

OPTION 2 - MANUAL CONTROL/PILOT RESPONSE REQUIRED/CRD DISPLAY.

All eight subjects indicated the PVD display was superior to the CRD option presented in this condition. The reasons given for this preference were that observing the CRD would distract the controller's attention from the primary PVD display (four subjects), and that use of the CRD would make it unavailable or too congested for display of beacon codes (two subjects).

No additional comments regarding the manual/pilot response option were elicited during this test condition.

Because of the unanimous agreement among subjects regarding the display option, all succeeding testing was conducted using the PVD for display of the Date Link transaction list.

OPTION 3 - MANUAL CONTROL/NO PILOT RESPONSE.
One controller indicated that data entries appeared to be reduced under this option in comparison to Option 2. However, two subjects noted that the data entries were still excessive.

One controller felt that this option was an improvement over the "pilot response required" options because it eliminated the need to monitor for a WILCO response. However, two controllers indicated a concern over a procedure which did not have a mandatory requirement for pilot acknowledgment.

OPTION 4 - AUTOMATIC CONTROL/PILOT RESPONSE REQUIRED.
Six controllers explicitly indicated that the automatic mode was better than the manual modes tested in the previous conditions. No subjects rejected the automatic mode. However, two subjects felt that it could be a safety hazard under some conditions and expressed a desire for a one-key message release input for uplink of an automatically prepared message.

Reasons given for preference of the automatic mode were the reduction in data entry requirements and the increased speed with which traffic would be worked.

Continued concern was also expressed over the assignment of controller responsibilities in the transfer of communications procedure (one subject).

One subject indicated that the message transaction status information should be displayed in the data block on the PVD.

OPTION 5 - AUTOMATIC CONTROL/NO PILOT RESPONSE.
Equivocal comments were elicited regarding this second test of a no pilot response mode. Of the four subjects who provided comments, two indicated that they would accept this mode and two argued that the lack of acknowledgment would create confusion and anxiety about the agreement between data transmitted and the pilot's awareness of the transmission. The absence of a strong opinion on this question was probably due to the fact that Options 1 through 5 were redundant with voice radio communications and verbal pilot acknowledgment.

A second subject indicated a preference for displaying Data Link transaction data in the aircraft data block (see Option 4).

OPTION 6 - AUTOMATIC/PILOT RESPONSE REQUIRED/NO VOICE.

Of the five controllers who commented on this option, all subjects agreed that the no voice condition was ideal with reservations. Two subjects noted that voice communications must remain available as a backup.

Other comments from individuals regarding the automatic mode and no voice options included the following:

1. Data entries for deleting list lines should be reduced.

2. Controller should retain control over when uplink is sent (inhibit function).

3. Data block display of Data Link transaction status is preferred.

4. Transfer of communications must be under control of transferring controller.

OPTION 7 - NEW SYSTEM (DAY 2)/NO VOICE.

The improved system, modified to specifications suggested by controllers during the Day 1 group debriefing, was preferred by all controllers who provided comments. Reasons for this preference included: (1) reduced key actions, (2) simplified message deletion from transaction list, and (3) improved transfer of communications procedure.

Suggested further improvements to increase preference included:

1. Eliminate problem of reading and monitoring long transaction list by presenting status of Data Link action in full data block.

2. Add capability to inhibit uplink of data. One subject described a more sophisticated version of this message send control function in which single character commands could be used to send data only to the NAS, send data entered earlier to the aircraft, or send data to both the NAS and the aircraft simultaneously.

APPENDIX F

ANALYSIS OF WRAP-UP QUESTIONNAIRE DATA

A Wrap-Up Questionnaire was given to the Dallas/Fort Worth controllers during the final debriefing on Day 2 of testing. A copy of the questionnaire is contained in appendix C. This appendix documents the statistical treatment and results. Computations were done using a spreadsheet on an IBM PC XT.

The questionnaire was comprised mainly of 7-level rating scales and free narrative comment questions. The numerical values and verbal labels attached to the 7-level rating scales questions were:

7 = Very Good,
6 = Good,
5 = Slightly Good,
4 = Fair (center scale),
3 = Slightly Poor,
2 = Poor, and
1 = Very Poor.

These values were used for the computation of the rating scale statistical results. Narrative comments for all questions were compiled and are attached herein. Also, a frequency count of controllers making similar written comments is attached.

RATING SCALE ANALYSIS.

Table F-l shows the resulting descriptive and inferential statistics for the 24 items rated using the 7-level rating scale. Items 1, 5a-c, 6a-e, 8a-b, and 9a-1 in this table are arranged in the same order as they appeared in the questionnaire. Means and variation about the means were computed for each of the items. A grand mean across subjects and items was computed for the entire questionnaire. Student's t scores were computed for the deviation of the means from center scale (4) and from the grand mean. Table F-2 shows the same results as table E-l, but with the items presented in order of the magnitude of the t score computed relative to the grand mean. A 95-percent confidence interval about each item mean was also computed. Notes at the bottom of the tables give a brief explanation of the meaning of the table headings.

The t score relative to center scale indicates whether that mean rating is significantly above or below fair. The t score relative to the grand mean indicates whether the mean rating is significantly above or below the mean of all scores, which was computed to be 5.77 (between slightly good and good). The grand mean thus falls approximately in the middle of the group of item means. Ranking of the t scores relative to each other, such as in table F-2, makes comparison easier. These ranks are given in the results below.

The following results, using a 95-percent probability criterion (p=.05) for significance, were obtained. The grand mean was significantly higher than center scale, indicating that the distribution of all judgments was significantly favorable to Data Link (i.e., to the good side of center scale). Of the 24 items rated, 18 were rated good (significantly higher than fair), 6 were rated fair (did not differ significantly from fair), and none were rated poor (significantly lower than fair). Considering the nature of the questionnaire items, this shows an overwhelming acceptance of the Data Link concept.

TABLE F-1. ANALYSIS OF WRAP UP QUESTIONNAIRE FOR DATALINK MINI STUDY IN QUESTION ORDER

Statistical Results Presented in Questionnaire Order

N	MEAN	t.05	VAR	SDn-1	SE	RANGE.05		tcs	tgm	Scs	Sgm	#	Questionnaire Item
9	5.78	2.31	0.84	0.97	0.32	5.03	6.52	5.49	0.03	0.05	NA	1.	Realism
7	5.71	2.45	1.63	1.38	0.52	4.44	6.99	3.29	-0.10	0.05	NA	5a.	SWAT separation of workloads
5	5.80	2.78	0.96	1.10	0.49	4.44	7.16	3.67	0.07	0.05	NA	5b.	Independence of SWAT dimensions
10	6.70	2.26	0.21	0.48	0.15	6.35	7.05	17.68	6.11	0.05	0.05	8a.	Using best altitude confirmation method
10	6.80	2.26	0.16	0.42	0.13	6.50	7.10	21.00	7.75	0.05	0.05	8b.	Using best transfer of control method
10	4.90	2.26	6.29	2.64	0.84	3.01	6.79	1.08	-1.04	NA	NA	8c.	Using best EMSAW method
10	6.60	2.26	0.24	0.52	0.16	6.23	6.97	15.92	5.10	0.05	0.05	9a.	Projected system capacity
10	6.20	2.26	0.96	1.03	0.33	5.46	6.94	6.74	1.33	0.05	NA	9b.	Projected ability to "keep the picture"
10	5.40	2.26	3.84	2.07	0.65	3.92	6.88	2.14	-0.56	NA	NA	9c.	Projected weather handling
10	5.80	2.26	1.36	1.23	0.39	4.92	6.68	4.63	0.09	0.05	NA	9d.	Projected R-D controller coordination
10	5.90	2.26	1.29	1.20	0.38	5.04	6.76	5.02	0.35	0.05	NA	9e.	Projected sector interphone coordination
9	6.56	2.31	0.47	0.73	0.24	6.00	7.11	10.55	3.26	0.05	0.05	9f.	Projected pilot-controller communications
10	4.90	2.26	2.09	1.52	0.48	3.81	5.99	1.87	-1.80	NA	NA	99.	Projected A/C conflicts
9	5 22	2.31	1.95	1.48	0.49	4.08	6.36	2.48	-1.10	0.05	NA	9h.	Projected flight strip marking/handling
8	5 50	2.37	1.50	1.31	0.46	4.41	6.59	3.24	-0.58	0.05	NA	9i.	Status board info handling
9	6.33	2.31	1.56	1.32	0.44	5.32	7.35	5.29	1.28	0.05	NA	9j.	Projected overall efficiency (speed)
10	6.40	2.26	0.84	0.97	0.31	5.71	7.09	7.86	2.07	0.05	NA	9k.	Projected overall safety
10	6.70	2.26	0.21	0.48	0.15	6.35	7.05	17.68	6.11	0.05	0.05	9l.	Projected overall controller workload
223	5.77	1.96	2.37	1.54	0.10	5.56	5.97	17.11	0.00	0.05	NA		GRAND MEAN

NOTES:
N = Number of controllers responding to the questionnaire item.
MEAN = The average item rating across all the responding controllers. General meanings of scale values are: 1 = VERY POOR, 4 = FAIR, 7 = VERY GOOD.
t.05 = 5% significance t score levels with degrees of freedom = N-1.
VAR = Variance of the controllers ratings about the item's MEAN rating.
SDn-1 = Corrected standard deviation computed from the variance.
SE = Standard Error of the MEAN; expected variability about the MEAN if the study were repeated several times under the same conditions.
RANGE .05 = 5% confidence interval centered about the MEAN within which, if the study were repeated several times, the new means should fall 95 X of the time.
RANGE .05 left column = Low limit of the range. Any lower value is significantly below the MEAN. RANGE .05 right column = High end of the range. Any higher value is significantly above the MEAN. tcs, tgm = Two-tailed Student's t tests to determine whether the MEAN deviates significantly from (falls above or below) a criterion value.
tcs = t test in which the criterion value is Center Scale (FAIR = 4.0).
tgm = t test in which the criterion value is the GRAND MEAN over all items.

Scs, Sgm = Significance levels ($p < .05$) for the items' t scores. .05 = "better than" the criterion value, -.05 = "worse than" the criterion value, NA = Not significantly different from the criterion value.

TABLE F-2. ANALYSIS OF WRAP UP QUESTIONNAIRE DATA LINK MINI-STUDY IN RANKED ORDER

Statistical Results Presented in Order Of t Score Relative to the Grand Mean (tgm)

N	MEAN	t.05	VAR	SDn-1	SE	RANGE.05		tcs	tgm	Scs	Sgm	# Questionnaire Item
10	6.80	2.26	0.16	0.42	0.13	6.50	7.10	21.00	7.75	0.05	0.05	8b. Using best transfer of control method
10	6.70	2.26	0.21	0.48	0.15	6.35	7.05	17.68	6.11	0.05	0.05	8a. Using best altitude confirmation method
10	6.70	2.26	0.21	0.48	0.15	6.35	7.05	17.68	6.11	0.05	0.05	9l. Projected overall controller workload
10	6.80	2.26	0.36	0.63	0.20	6.35	7.25	14.00	5.17	0.05	0.05	6a. Automatic mode for field use
10	6.60	2.26	0.24	0.52	0.16	6.23	6.97	15.92	5.10	0.05	0.05	9a. Projected system capacity
10	6.50	2.26	0.45	0.71	0.22	5.99	7.01	11.18	3.28	0.05	0.05	6d. PVD display for field use
9	6.56	2.31	0.47	0.73	0.24	6.00	7.11	10.55	3.26	0.05	0.05	9f. Projected pilot-controller communications
10	6.40	2.26	0.84	0.97	0.31	5.71	7.09	7.86	2.07	0.05	NA	9k. Projected overall safety
10	6.20	2.26	0.96	1.03	0.33	5.46	6.94	6.74	1.33	0.05	NA	9b. Projected ability to "keep the picture"
9	6.33	2.31	1.56	1.32	0.44	5.32	7.35	5.29	1.28	0.05	NA	9j. Projected overall efficiency (speed)
10	5.90	2.26	1.29	1.20	0.38	5.04	6.76	5.02	0.35	0.05	NA	9e. Projected sector interphone coordination
10	5.80	2.26	1.36	1.23	0.39	4.92	6.68	4.63	0.09	0.05	NA	9d. Projected R-D controller coordination
5	5.80	2.78	0.96	1.10	0.49	4.44	7.16	3.67	0.07	0.05	NA	5b. Independence of SWAT dimensions
9	5.78	2.31	0.84	0.97	0.32	5.03	6.52	5.49	0.03	0.05	NA	1. Realism
223	5.77	1.96	2.37	1.54	0.10	5.56	5.97	17.11	0.00	0.05	NA	GRAND MEAN
7	5.71	2.45	1.63	1.38	0.52	4.44	6.99	3.29	-0.10	0.05	NA	5a. SWAT separation of workloads
10	5 40	2.26	3.84	2.07	0.65	3.92	6.88	2.14	-0.56	NA	NA	9c. Projected weather handling
8	5 50	2.37	1.50	1.31	0.46	4.41	6.59	3.24	-0.58	0.05	NA	9i. Status board info handling
10	4.90	2.26	6.29	2.64	0.84	3.01	6.79	1.08	-1.04	NA	NA	8c. Using best EMSAW method
9	5.22	2.31	1.95	1.48	0.49	4.08	6.36	2.48	-1.10	0.05	NA	9h. Projected flight strip marking/handling
7	5.14	2.45	0.98	1.07	0.40	4.15	6.13	2.83	-1.54	0.05	NA	5c. Effectiveness as ATC Workload measure
10	4.90	2.26	2.09	1.52	0.48	3.81	5.99	1.87	-1.80	NA	NA	6e. Response time for field use
10	4.90	2.26	2.09	1.52	0.48	3.81	5.99	1.87	-1.80	NA	NA	9g. Projected A/C conflicts
10	4.60	2.26	2.64	1.71	0.54	3.37	5.83	1.11	-2.15	NA	NA	6b. Manual mode for field use
10	3.10	2.26	3.89	2.08	0.66	1.61	4.5	-1.37	-4.06	NA	-0.05	6c. RCRD display for field use

NOTES:

N = Number of controllers responding to the questionnaire item.

MEAN = The average item rating across all the responding controllers. General meanings of scale values are: 1 = VERY POOR, 4 = FAIR, 7 = VERY GOOD.

t.O5 = 5% significance t score levels with degrees of freedom = N-1.

VAR = Variance of the controllers ratings about the item's MEAN rating.

SDn-1 = Corrected standard deviation computed from the variance.

SE = Standard Error of the MEAN; expected variability about the MEAN if the study were repeated several times under the same conditions.

RANGE .05 = 5% confidence interval centered about the MEAN within which, if the study were repeated several times, the new means should fall 95 % of the time.

RANGE .05 left column = Low limit of the range. Any lower value is significantly below the MEAN. RANGE .05 right column = High end of the range. Any higher value is significantly above the MEAN. tcs, tgm = Two-tailed Student's t tests to determine whether the MEAN deviates significantly from (falls above or below) a criterion value.

tcs = t test in which the criterion value is Center Scale (FAIR = 4.0). tgm = t test in which the criterion value is the Grand Mean over all items.

Scs, Sgm = Significance levels (p < .05) for the items' t scores. .05 = "better than" the criterion value, -.05 = “worse than" the criterion value, NA = Not significantly different from the criterion value.

Relating the item means to the grand mean in table F-2 finds seven items rated significantly higher than the grand mean, with one so close to the cutoff that it's also included. These eight items are ranked according to the magnitude of the t score relative to the grand mean (tgm) score (first item is highest rated). they are:

Rank	No.	Item (Paraphrased)
1	8b	Projected performance using best transfer of communication method.
2	8a	Projected performance using best altitude confirmation method.
3	91	Projected overall controller workload, 4-6a. Automatic mode for field use, 5-9a. Projected system capacity, 6-6d. PVD display for field use.
7	9f	Projected pilot-controller communications.
8	9k	Projected overall safety.

One of the items is rated significantly below the grand mean and one is so close to cutoff that it is included below (the last is the worst):

Rank	No.	Item (Paraphrased)
23	6b	Manual mode for field use.
24	6c	RCRD display for field use.

The use of a ranking based on the tgm makes possible determination of which items are so much above or so much below the grand mean as to be notable. Above are shown the 10 notable items out of the total of 24 items analyzed.

QUESTION BY QUESTION RESULTS.

Question 1 asked for a rating of the simulation realism. The resultant mean rating is significantly better than fair. Thus, realism is judged good. It is not significantly different from the grand mean, with a rank = 14.

Question 2 shows suggested improvements for realism. Five suggestions are made. These are in the narrative comments section attached.

Question 3 asks for documentation of system malfunctions. Three are mentioned. These are in the narrative comments section attached.

Question 4 asks for training suggestions. Three are listed. These are found in the narrative comments section.

Question 5 asked for an evaluation of SWAT. All three items on SWAT were rated significantly higher than center scale, meaning they were judged good. None was significantly different from the grand mean. The highest SWAT aspect was independence of SWAT dimensions (rank = 13), and the lowest was effectiveness as ATC workload measure (rank = 20). It should be noted that vertical lines were omitted from the scale inadvertently, leading to several misinterpretations and entry omissions.

Question 6 asked for ratings of the various configurations in which Data Link could be operated. Two were highly rated for field use: automatic mode

rank = 4) and PVD display (rank = 6). The two lowest rated for field use were: manual mode (rank = 23) and RCRD display (rank = 24).

Question 7 required designing the optimum features for each service. The breakdown is given below. The asterisk (*) shows significance at the 95 percent level.

					Control Pilot			
	Mode		Voice		Voice		Display	
	Manual	Auto	Yes	No	Yes	No	PVC	CRD
Altitude Confirmation	1	8*	1	9*	2	8	10*	0
Transfer of Communication	1-l-	7*	1	9*	1	9*	10*	0
EMSAW	1	5	5	4	5	4	10*	0

Question 8 rated the three services envisioning usage of the optimum Data Link configuration. Of the three services, transfer of communication and altitude confirmation were rated so good they were the first and second most highly rated of all items rated. The EMSAW rating fell below the grand mean (rank = 17 from the top), but not significantly so. Nevertheless, this indicates a relatively low opinion of the EMSAW service compared to the other two.

Question 9 asked for ratings of various aspects of the ATC operation if optimized Data Link were used in the field environment. Results indicated that all projected Data Link effects, except for weather and conflicts, were significantly good. This includes controller workload (rank = 3), system capacity (rank = 5), pilot-controller communications (rank = 7), and overall safety (rank = 8).

Question 10 inquired about locating gaps in the Data Link system. Narrative responses indicated no gaps that voice couldn't fill.

Question 11 asked what was liked best about Data Link. Narrative answers found in a latter section of this report indicate that many features were liked. Table C-3 (appendix C) gives the frequency of controller response to popular comments.

Question 12 asked what was liked best about Data Link. The answers are in the narrative comments section.

Question 13 asked for projected future uses of Data Link. There are many comments listed in the narrative section. The projected uses seem unlimited.

SUMMARY

POSITIVE FINDINGS.

The Dallas/Fort Worth controllers reported that the Data Link mini study had good realism, training was adequate, and malfunctions minimal. They judged that a Data Link system using the automatic mode and PVD list display would work well in providing transfer of communication and altitude confirmation for en route control. Without the need for controller or pilot voice for these function, they judged that Data Link would reduce voice congestion. It was considered that projected use of such a Data Link system would have good effects on controller workload, pilot-controller communications, and overall ATC safety and efficiency.

NEGATIVE FINDINGS.

The Dallas Fort Worth (D/FW) controllers rated use of manual mode and the RCRD display no worse than fair; but they were the two lowest rated configurations of all the items in the questionnaire. They rated the EMSAW function much less favorably than transfer of communication and altitude confirmation. However, problems with EMSAW appear to be carried over from its NAS implementation in the flat lands of Dallas/Fort 'Worth. This may have affected its specific Data Link implementation as used in the mini study. EMSAW needs further review regarding manual versus automatic implementation and the necessity of controller/pilot voice.

NARRATIVE RESPONSES.

The total set of narrative responses is listed below for the 13 questions of the Wrap-Up Questionnaire. Arbitrary numbers from 1 to l0 were assigned to the l0 controller subjects and are listed on the left margin beside their responses. Table F-3 shows a summary.

Question 1. (No Narrative Responses)

Question 2. How can we enhance realism?

2. Not without speeding up the process.

4. Use realistic altitudes (FL300?), better trained pilots.

6. Realism is good. It would be difficult to improve.

7. Increase the number of actions.

9. Design a more realistic map and have the aircraft actually cross the boundaries.

10. It looked pretty real to me.

Question 3. Please document any system malfunctions that if worked as designed would have helped you make a better evaluation.

2. In some areas we received two indications, data block and list. Only one indication is needed.

3. None.

4. None.

6. A small problem surfaced whereas when a TC was accepted, data would appear in the list as HELD. This was later resolved.

7. Initial services had too many keypunches.

10. None.

Question 4. Looking back at training, any new ideas as to what training would have aided testing?

2. Do away with script.

3. Initial briefing and notebook handout were helpful training aids. The ability to use en route lab was extremely helpful.

4. No.

5. Train remotes or pilots longer on the techniques of ATC, where a script is not needed to follow along. More action-reaction type training. More realistic.

6. Training was good.

7. No.

9. Excellent training and back group information were provided.

10. None.

Question 5. Comments on SWAT.

3. Interesting - but not fully

4. Good tool.

6. It is difficult to evaluate SWAT because I am not familiar with the rating process, however, I readily understand how I was supposed to provide information and was able to determine or define the different categories of workload. It seems very effective.

9. Different controllers - different workload.

10. Good.

Question 6. Please rate these Data Link aspects regarding possibility of utilization in the field. Comments.

1. The display mode will, over time, require both RCRD and PVD, based on type and volume service.

3. Strong preference for auto mode. Manual mode keystroke entries are excessive and time consuming.

4. Message response times need to be increased (decreased?) for control functions. For noncontrol functions, time is OK.

7. This may need a combination of PVD and CRD in final form.

8. Need visual indication in the data block, with the PVD list available also.

Question 7. Please select the optimum methods for the three services. Comments.

3. Both control/pilot voice will be required until we have a proven system. Even long-term voice mode will be required in certain situations. I don't believe d/l can totally replace voice.

4. Voice ability still needs to be there, available for clarification/negotiation on transfer of control and altitude confirm.

7. EMSAW does not lend itself to this program.

8. As before - visual indication somehow in the aircraft's data block to avoid extensive lists that may make it difficult to locate in a timely manner certain aircraft.

9. Voice control must be available for emergency situation.

10. Under present configuration, manual altitudes would be required unless options were available in which the controller controlled who the message went to.

Question 8. Please rate how well each service would perform at your position if optimally configured.

1. MSPN is a questionable program.

3. Still need some "fine-tuning" but principles are sound.

9. Response time faster.

10. As long as control is had on where the altitude is sent. Alt Change
-None Key P (Pilot and NAS)
None Key U (Uplink info that is entered under none key only)
None Key (NAS only).

Question 9. Using the optimum services, what would be the projected effect of Data Link at your position on the following.

1. The system must reduce comm. and increase the capacity.

4. Those items marked good (instead of very good) were marked that way because of slow speed. There are instances where voice is faster. An altitude on turn is needed quickly for safety.

7. Flight strip marking/handling does not appear to be affected by Data Link under today's conditions. This also applies to status board info.

8. There are certain areas, like strips, etc., where little impact would happen from current procedures. There are areas like frequency changes, altitudes, etc., where the Mode S would be extremely useful, efficient, and timely.

10. I believe that workload will not be impacted if the system is implemented with minimum extra entries as discussed previously.

Question 10. Using Data Link should leave no "gaps" in the system. Did you see any places where gaps in positive control could occur? Also, give any ideas as how to prevent them.

1. No gaps is the primary concern, however, just as important is not increasing workload or add layers of duplicate commands.

2. Data Link is tied into information swap by radar. This 10-second sweep makes Data Link too slow for control instructions. Control instruction are given in priority order and need to be carried out in that order. It can, however, be used as an aid in non-time-critical clearances.

3. The matter of pilot confirmation method still needs to be fine-tuned.

4. Yes - when a pilot has a no reply - voice is then needed to find out why.

5. Slow response to and from pilot.

6. Yes, during adverse weather conditions voice communications would become necessary, thus, there is no benefit derived from Data Link in this area. However, Data Link utilized in the other areas during these periods would significantly enhance (reduce?) controller workload.

7. None are apparent at this time.

8. No gaps, just a "weaning" period for test purposes to get controllers/pilots used to having certain procedures done visually now, rather than verbally.

9. If the controller/pilot voice link is always maintained, the gaps could be filled the "old way" with direct communication. I feel that gaps would be the exception rather than the rule.

l0. No.

Question 11. What about Data Link do you like best and why?

1. The ability to reduce the voice comm and increase system capacity while reducing workload.

2. Ability to transfer data that is repeated several times by the controller.

3. The ability to reduce frequency congestion. Provides a backup/alternate method of communication with pilot.

4. Automatic function, prevents frequency congestion, hard copy confirmation of control action.

5. The possibly of the unlimited uses that can be added to the Data Link. Relief of frequency congestion.

6. Speed and reduction of controller workload (during the automatic mode).

7. Reduces radio congestion. This is our greatest problem in any effort to increase volume.

8. Ease of transferring data back and forth without utilizing so much frequency time. Very nice tool with lots of potential.

9. In automatic mode with no pilot voice, I feel this would increase the system capacity. If coded routes and altitudes were able to be data linked, things would improve. Each controller should be able to handle more aircraft.

10. Reduced phraseology - more time to plan, to project, to eliminate unnecessary chit-chat. A fail-safe system, a confirmation of verbal communications at first followed by the ultimate, which is a safe, orderly, and expeditious flow of traffic with not much more effort by the controller or the Pilot.

QUESTION 12. What about Data Link do you list least and why?

2. Time process.

4. Speed of response.

5. EMSAW alerts being automatic.

6. The data being displayed in a list. I feel that information should be displayed in the "data block" since this is primarily what the controller is concentrating on.

7. EMSAW does not appear compatible to this program in its present form.

8. Currently - no visual indicator in the actual data block. Ideally, if info is in data block, than I see no area to dislike.

9. Response time, especially on EMSAW. Messages must be reduced.

10. The fact that we cannot have it now, tomorrow. This is a shame, but it is not anyone's fault, I suppose.

QUESTION 13. What future services would you like to see data link do?

1. Any service that will reduce the workload on the controller: Primarily in the area of added services WX, CA, MSAW, etc. Separation and control of aircraft and the volume of aircraft on the PVD must be the primary concern.

2. Data Link should first be used to give sigmets, chop or turb, information, ATIS, and other general information. Also, Data Link could be used to downlink information like airspeed, mach #, heading, rate of climb or descent from the cockpit to controller. All this would cut controller workload and frequency time considerably. Not until we go to an automatic system should it be used for control instructions.

3. Provide field 10 amendments (route). Uplink speed info (IAS, Mach).

4. Weather/Sigmets. Turns. Speed Control. Altimeters. Data Link A/C speed and heading to controllers PVD. This would prevent controller from asking pilot for speed and heading.

5. A constant readout of the cockpit data, ground speed, or mach speed, heading.

6. All aspects of ATC, primarily to eliminate voice communication, thus reducing workload (controller and pilot) and frequency congestion.

7. Every radio transmission that can be eliminated by data link the better.

8. Headings, speeds, etc. Would require lots of input on specific headings, specific degree turns, mach speeds, indicated speeds, ground speeds, etc. and how do you indicate all this in current data block information.

9. Coded routes and altitude assignments. Automatic frequency assignment tied to certain sectors. Inhibit message capability.

10. Provide controller with aircraft's heading, indicated airspeed, mach speed (these items on request by manual entry at the control position). Issue radar vectors, revised route, clearance to deviate, holding instructions, and approach clearances.

TABLE F-3. COUNT OF WRITTEN CONTROLLER RESPONSES
TO WRAP-UP QUESTIONNAIRE

This section shows the frequency of controller comments for Wrap-Up questions 6 - 13. It shows the number of controllers that made similar comments over the course of the questionnaire. In the left margin is the number of controllers making a particular comment.

9 Using Data Link should reduce frequency congestion.
6 Possible future service - up/downlink indicated airspeed.
5 Possible future service - up/downlink mach number.
5 Possible future service - downlink heading.
5 Speed of Data Link response is sometimes too slow.
4 Voice is a necessary backup.
3 Possible future service - weather info (Sigmets, turbulence, ATIS). 3
Data Link should reduce workload.
3 EMSAW is not optimized.
3 Possible future service - turns (vectors).
2 Possible future service - field 10 (route)amendments.
2 Possible future service - downlink groundspeed.
2 Possible future service - coded altitude assignments.
2 Possible future service - automatic frequency assignments.
2 Use data block not list for Data Link display.
2 Data link can increase capacity.
2 Data Link provides backup communications (failsafe).
2 Many foreseen data link uses.
2 There is little impact on flight strip handling.
2 Data Link display will need to use both PVD and CRD.
2 Speed is OK for noncontrol but not for control functions.
1 Possible future service - collision alert.
1 Possible future service - MSAW.
1 Possible future service - general information
1 Possible future service - altimeter.
1 Possible future service - all aspects of ATC.
1 Possible future service - coded routes.
1 Possible future service - inhibit message capability.
1 Possible future service - clearance to deviate.
1 Possible future service - holding instructions.
1 Possible future service - approach clearances.
1 Data Link increases controller speed.
1 Pilot confirmation method needs to be fine tuned.

APPENDIX G

FINAL CONTROLLER NARRATIVE COMMENTS

Following completion of the Wrap-Up Questionnaire during the Day 2 debriefing session, the eight subject controllers and the two observer controllers were asked to write a narrative description of their preferred design for the three services under evaluation. The purpose of this exercise was to obtain unstructured, individual commentaries from the controllers that may not have been elicited during the group discussions that took place during the Day 1 debriefing sessions.

The responses that were collected during this session ranged from specific design suggestions to general views on the utility of Data Link. In order to summarize these data, sentences and paragraphs from the individual responses were categorized by topic area and paraphrased to form brief opinion statements. Each of the statements listed under the topics below represents an opinion extracted from a single controller's narrative.

1. General Opinions About Data Link.

I support the introduction of Data Link in small, fail-safe elements. The three services tested here are a good start.

I like the Data Link program. It will increase the number of aircraft that can be efficiently controlled.

I am concerned about Data Link assuming primary ATC functions of controlling aircraft heading, speed, and altitude. These must be done in a timely fashion and without forcing the controller to monitor displays for delayed pilot response. Data Link is good, but functions should concentrate on general information to pilots and on providing cockpit information to controllers. Data Link must reduce workload.

Data Link will improve the ATC system. Reduction of voice radio is the only way to handle increased traffic volume.

Overall, Data Link appears to be a tremendous enhancement to the system we have today. Its future uses seem limitless. The project is very good and holds much potential.

This will be our method of operation in the near future. It will be safer and we will be able to do our job better.

2. Data Link Displays.

The PVD should present the Data Link display, this is where the controller keeps his attention focused.

PVD is best.

Any Data Link display belongs on the PVD with location selectable.

List belongs on the PVD for easy access by trackball.

Use a PVD display.

Transaction list lines should be alphabetically labeled for addressing by D-controller from his keyboard.

3. Use of the Data Block.

The controllers unanimously preferred the PVD over the CRD as a location for the Data Link transaction list. However, a number of comments were directed toward a preference for providing information on the current status of any transaction in the data block rather than in a list. Comments and suggestions related to this concept are listed below:

The list is hard to scan and interpret when lengthy. In addition, scrolling of a long list could be problematic. Put primary Data Link information in the data block where the controller is focused. Suggests a single character denoting send (s), WILCO (w), etc., alternating with altitude change arrows in data block.

Two displays are needed. A list on the PVD to act as a menu for Data Link functions available, and a data block display for visual tracking of the Data Link transaction. A PVD or CRD list could be used for other noncritical downlinks from aircraft.

A data block display would be best with single characters for pilot acknowledgment, etc. Color coding could also be used when it becomes available.

Put as much information in the data block as possible. The data block should show that the aircraft is on frequency and ready to receive Data Link messages.

The ultimate would be a data block display timesharing with present information. Data block should show pilot responses to uplinks.

Menu function might be useful as a PVD list.

4. Controller Data Entry.

Minimize keyboard entries.

Automatic deletion of list lines when WILCO received is great. It reduces extra keyboard inputs.

Keep key entries to a minimum.

5. Automatic and Manual Modes.

The controllers expressed a general preference for automatic operations in their narratives. However, in most cases they preferred a design in which it was possible to use a single key input either to inhibit/delay an automatic uplink or to control the routing of the computer input to aircraft and the NAS by some other means. The following comments were relevant to this issue:

Automatic mode is more preferable except in cases where the controller must hold off transfer of communications after the hand-off. Need an optional inhibit input preceding message to achieve this. Inhibit should be possible by sector and aircraft.

Automatic mode preferred with inhibit.

Want automatic with inhibit capability.

Must have "inhibit auto uplink function".

Automatic uplink on all services with inhibit for transfer of communications.

Services can be automatically initiated.

6. Voice with Data Link.

Primary benefit of Data Link will be elimination of voice.

Voice should be available to resolve questions.

Voice not needed in most cases.

Data Link can replace voice, but voice must always be available to back-up Data Link.

Do not duplicate commands. Data Link should not be redundant with voice.

7. Altitude Confirmation - Specific.

This service will require more care than the others, it must be flexible and 100% reliable.

Altitude confirmation display should use single character codes in the second line of the data block to indicate sent, received, WILCO etc.

It is essential that the controller has the latitude to determine routing of messages when entered. A single character prefix to entry would send altitude to NAS, or NAS and pilot, or pilot only. This would permit assignment of temporary altitudes.

The system must be failsafe, no false or erroneous uplinks.

Altitude assignments should be adaptable by sector to permit standard, automatic altitudes.

Altitude assignment/confirmation should be a first step in Data Link. It should be automatic with an inhibit function for cases where the controller wants only a data block update. Voice should be available to deal with unables or questions.

Use PVD display. Delete status line after receipt of pilot response. Automatic mode acceptable with voice backup. Don't use Data Link for interim altitude assignment.

8. Transfer of Communications - Specific.

This service is best for early implementation. Could be very good in automatic mode with no voice.

Transfer of communications will require the inhibit uplink function.

Third line of data block could be used to display transfer of communications transaction status alternating with "H" symbol for hand-off. Both transferring and receiving controllers should have a display.

Make this automatic with inhibit function. No voice needed.

Can be automatic with time out on pilot response. Accepting controller should get a message showing aircraft is on frequency. No initial pilot voice check-in needed.

An alternative would be to have Data Link set up a PVD list of aircraft that have been handed off. Using a single key entry, controller would transfer communications. Once wilcoed, the aircraft would drop off the list.

9. EMSAW - Specific.

Fix the reliability of EMSAW and Data Link can serve this function, if it is as fast, or faster than controller's response.

EMSAW OK if refined and uplink message "informs" passively of a potential problem. Should not be a positive control emergency message.

Controllers from mountainous areas should be consulted.

See mountain area controllers.

EMSAW should be an automatic uplink.

Don't connect EMSAW to Data Link.

10. General Comments.

One controller offered alternative services for early implementation on Data Link. These are outlined below:

Data Link should be used to provide the controller with cockpit information. Automatic downlinks of airspeed, heading, etc., should be available and selected by controller for a time shared display in the data block.

Other general information such as ATIS, altitude settings, SIGMETS, and expected delays should be automatically uplinked to cut frequency time and reduce controller workload.