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INTERMITTENT POSITIVE CONTROL--PHASE I. OPERATIONAL TEST AND EV--ETC(U)
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Report No. FAA-RD-77-125

INTERMITTENT POSITIVE CONTROL--PHASE I, OPERATIONAL TEST AND EVALUATION

John W. Goodwin

OCTOBER 1977

INTERIM REPORT

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FEDERAL AVIATION ADMINISTRATION
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NOTICE

METRIC CONVERSION FACTORS

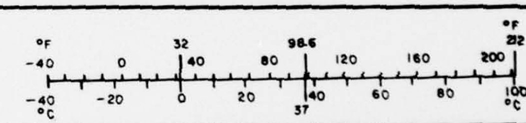
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



Technical Report Documentation Page

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16. Abstract

This report reflects the results of an effort at the National Aviation Facilities Experimental Center (NAFEC) to test and evaluate the interface between the intermittent positive control (IPC) system and the enroute air traffic controller. In testing this interface, the IPC algorithm was resident in the Digital Simulation Facility, which simulated the operation of a Discrete Address Beacon System (DABS). The test series was operationally oriented and did not consider such factors as program size, loading factors, or processing time. The results of the tests reveal that the IPC controller alerts, consistency of commands, readability of displayed information, and method of displaying information to the controllers were acceptable. The issuance of negative commands to aircraft presents a problem to the controllers, in that negative phraseology is not utilized in the air traffic control system. The alerting methods of IPC and conflict alert are similar, but because of the critical timing of the IPC alert, it was felt that a distinctly different alert for IPC should be utilized.

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Intermittent Positive Control Conflict Alert Conflict Alert/IPC List Voice Command List NAS Stage A Model 3d2.1	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151

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PREFACE

The Intermittent Positive Control (IPC) Phase I Operational Test and Evaluation effort was primarily concerned with the interface between the enroute air traffic controller and the IPC system. Consequently, in-depth testing of the IPC algorithm was not planned nor conducted. The number of flight situations included in the test data scenario to result in aircraft encounters was sufficient for test and evaluation of the aforementioned interface, but not of sufficient scope to result in a complete evaluation of the algorithm.

The results, conclusions, and recommendations referring to the algorithm, therefore, should be viewed in this light and not construed as a total evaluation of the algorithm. Nor, for that matter, should it be related in any way to the terminal area, since this test and evaluation effort was completely contained in the enroute airspace. Finally, as indicated in the title of this effort, additional development of the algorithm was already planned, and the scope of these tests, therefore, was designed to maximize results in the area of primary interest while providing some useful generalized feedback for future IPC development.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ABBREVIATIONS

A/C	-	Aircraft
ARTCC	-	Air Route Traffic Control Center
ATC	-	Air Traffic Control
ATCRBS	-	Air Traffic Control Radar Beacon System
ATCS	-	Air Traffic Control Specialist
CA	-	Conflict Alert
CDC	-	Computer Display Channel
DABS	-	Discrete Address Beacon System
DCC	-	Display Channel Complex
DSF	-	Digital Simulation Facility
DSS	-	Data Systems Specialist
FAA	-	Federal Aviation Administration
HSP	-	High-Speed Printer
IFR	-	Instrument Flight Rules
IOT	-	Input/Output Typewriter
IPC	-	Intermittent Positive Control
NAFEC	-	National Aviation Facilities Experimental Center
NAS	-	National Airspace System
PVD	-	Plan View Display
PWI	-	Proximity Warning Indicator
SAR	-	System Analysis Recording
SE	-	System Engineer
SSF	-	System Support Facility
UDS	-	Universal Data Set
VFR	-	Visual Flight Rules

INTRODUCTION

OBJECTIVE.

The objective of this activity was to evaluate the performance of the Intermittent Positive Control (IPC) function operating as part of the National Airspace System (NAS) Enroute A3d2 system. Specific attention was focused on four different areas: (1) IPC conflict detection/alert capability, (2) the interaction between the air traffic control (ATC) system and IPC, (3) the consistency of the IPC command, and (4) the quality and timeliness of the data displayed to the controller.

BACKGROUND.

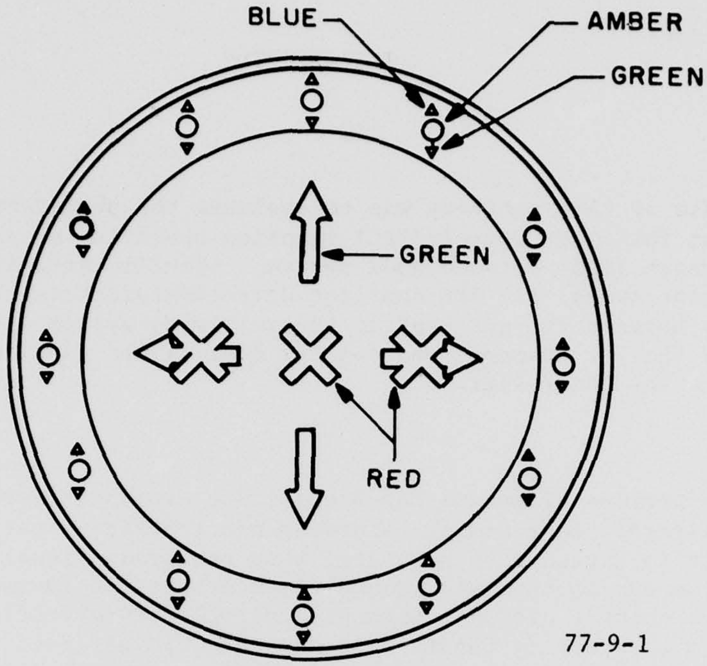
IPC is an experimental ground-based collision avoidance system which is intended to assist aircraft in avoiding hazardous air traffic situations. As a primary function, it is intended to separate, when required, visual flight rules (VFR) aircraft from one another via ground-computer-derived advisories or commands forwarded to cockpit displays without controller intervention. It is also intended, as a secondary function to separate VFR aircraft from instrument flight rules (IFR) aircraft without controller intervention; however, in this situation, the IFR aircraft will have an additional advantage of being under control of the ATC system. In the case of two IFR aircraft, IPC is intended to serve as a backup to the present-day conflict alert (CA) function which is contained in the NAS Enroute system. The conflict alert function provides flashing data blocks of conflicting IFR aircraft to the controller on his plan view display (PVD).

The IPC cockpit displays are presently undergoing testing (reference 1), and several types are currently available (figure 1). The cockpit displays are designed to show the relative azimuth and altitude of an intruder aircraft and, in addition, give command or maneuver instructions to the pilot.

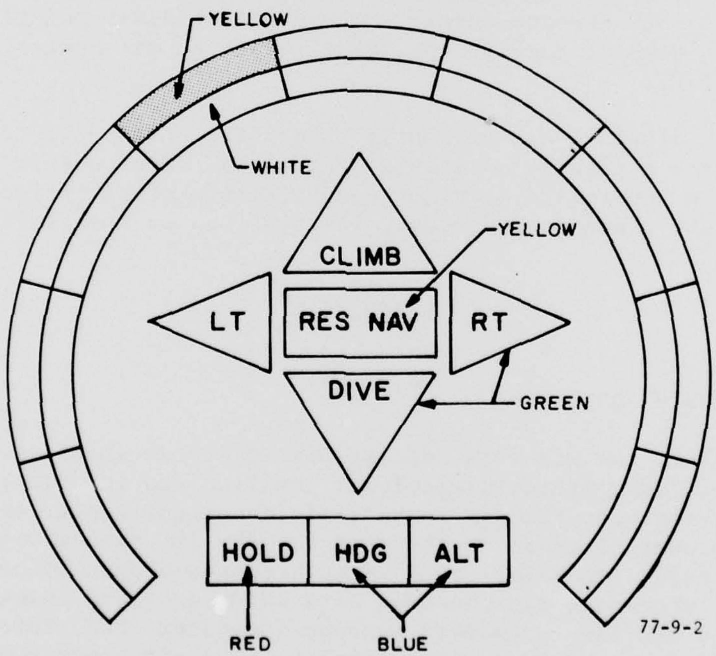
DISCUSSION

IPC SYSTEM DESCRIPTION.

In the IPC System, the Discrete Address Beacon System (DABS) provides the positive surveillance (three-dimensional position and identity) and the data link capability between the air route traffic control center (ARTCC) and all beacon/IPC-equipped aircraft in the sector. The IPC system monitors the DABS location, altitude, and velocity of these beacon-equipped aircraft. A ground-based computer processes the incoming data which projects three-dimensional flightpaths and provides proximity warning indicator (PWI) information to aircraft equipped with the IPC cockpit display. The air traffic controller is alerted when IFR aircraft under his control are involved. The ground-based



A. BADCOM DISPLAY



B. NAFEC-PROPOSED DISPLAY

FIGURE 1. TWO ALTERNATIVE IPC DISPLAYS

computer issues collision resolution commands, as required, to the IPC cockpit display. In addition, the command is displayed on the controller's PVD so that he is advised of what course of action the computer has instructed the pilot to perform. Also available for display to the controller are the aircraft response indicators which show whether or not the pilot will comply ("W" meaning will comply), if he will not comply ("N" meaning will not comply), if the message has been delivered but no response from aircraft ("D" means message delivered, no response), if unable to transmit to aircraft ("U" means unable to transmit message), and the instruction must be issued by the controller ("V" meaning voice contact is required (figure 2)). The type of messages and commands generated by the IPC system and routed to the aircraft and/or controller will vary, depending on the status and equipment of the aircraft; i.e., IFR or VFR, DABS equipment, air traffic control radar beacon system (ATCRBS) equipment, or not equipped. Reference 2 lists the operational aspects of the various other display symbologies presented on the plan view display in figure 2.

TEST CONDUCT.

The test series was conducted utilizing the IPC algorithm which resided in the Digital Simulation Facility (DSF) software. This simulated a DABS site operation with its data link between an ARTCC and the aircraft.

The DSF was simultaneously used to generate preplanned target movement data on specific routes with associated flight plans (taped inputs). Each test session was comprised of operational ATC situations in a sterile test environment; i.e., no code garbling, no radar noise, and no radar jitter. In addition to generating the targets, the DSF was utilized for simulating IPC pilot command acknowledgements.

ENVIRONMENT.

All controller test sessions were conducted in the System Support Facility (SSF), a laboratory model of an ARTCC developed at the National Aviation Facility Experimental Center (NAFEC) for enroute ATC system testing (figure 3).

The SSF is divided into two 12-sector laboratories, differing only in the type of equipment used to drive the displays. One laboratory uses the computer display channel (CDC), and the other, the 9020E display channel complex (DCC). Tests were conducted using either configuration.

The NAS A3d2.1, second update, system software (also containing the CA function) was used with the program data base varying, depending on the laboratory used for testing. For the CDC laboratory, CDC version 38E5 program was utilized. When the DCC laboratory was used, the DCC version 507 was utilized.

Sector configuration was identical in both laboratories and was based upon a hypothetical ARTCC geography known as the universal data set (UDS). Although 12 sectors were available, only 6 enroute sectors (low-altitude sectors 1, 2, 3, and 4 and high-altitude sectors 14 and 15/16) were utilized for test sessions.

Simulated radar inputs to the SSF were provided by the DSF using only one radar-site to simulate a DABS sensor.

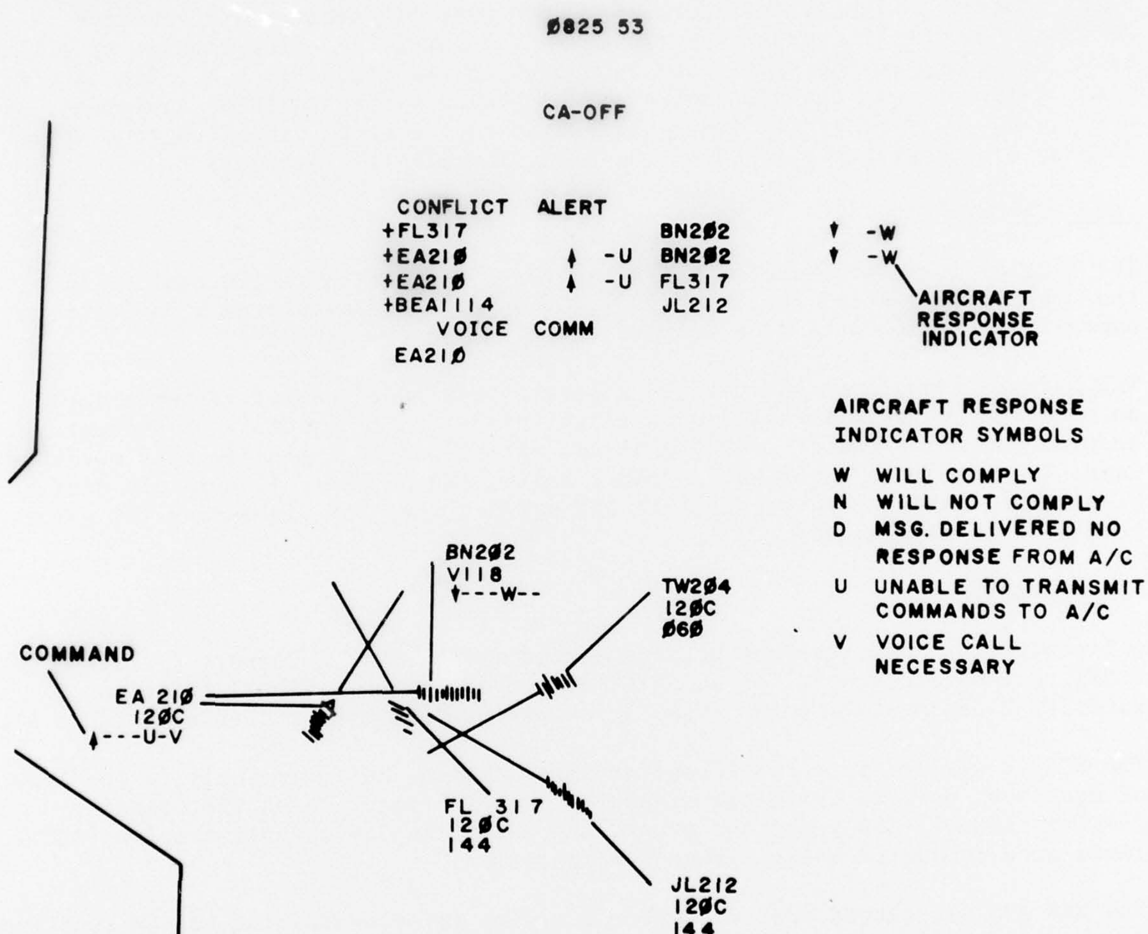


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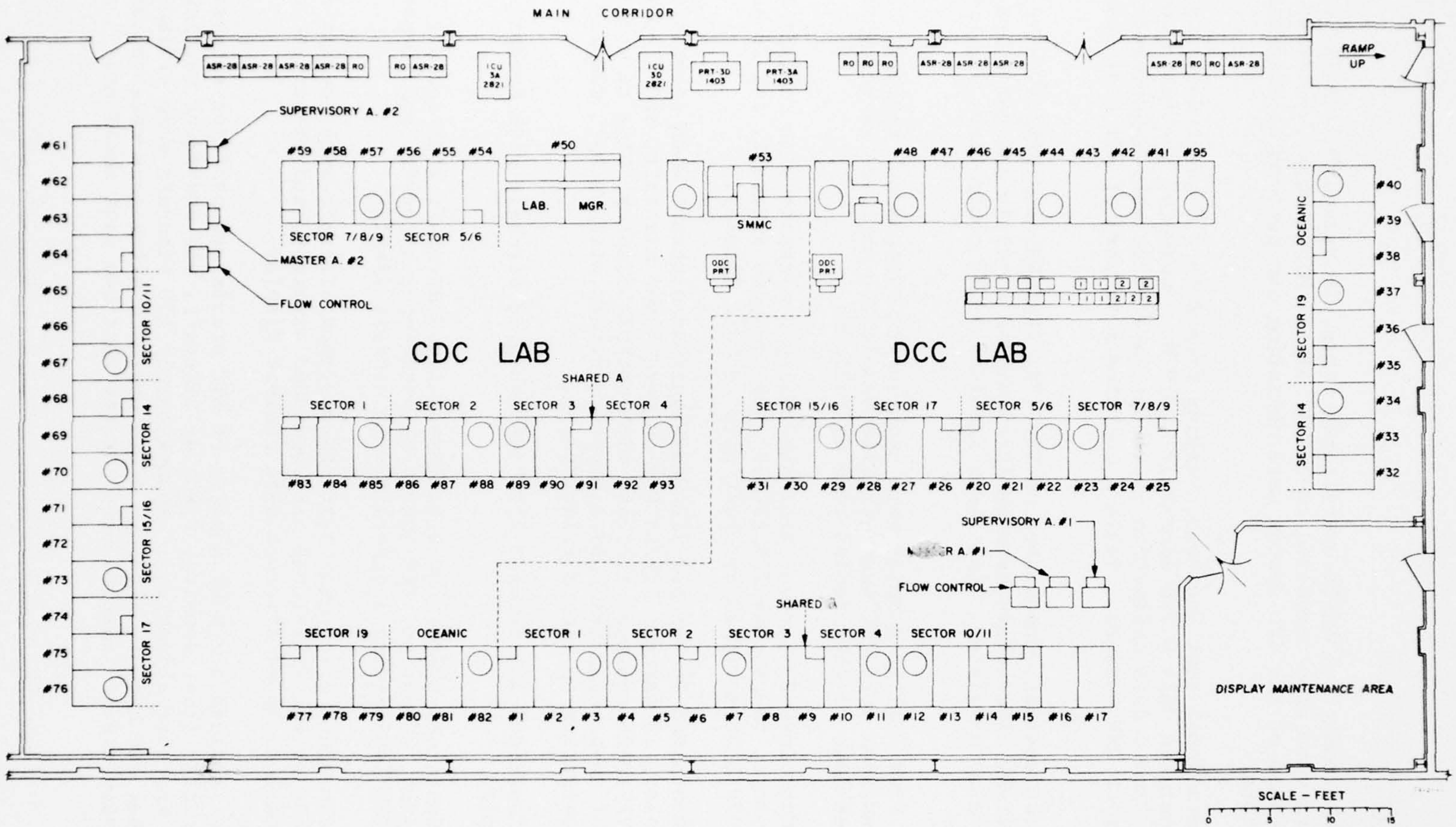
FIGURE 2. PVD DISPLAY OF IPC FUNCTIONS



F GURE 3. SYSTEM SUPPORT FACILITY (SSF)

METHODOLOGY.

Prior to the conduct of NAFEC operational tests, 20 successful design verification tests were also conducted on behalf of the MITRE Corp., to determine that all phases of the IPC system were operating and performing according to specifications.

Fifteen operational test sessions, varying from 2 to 2.5 hours duration, were conducted between July 6 and September 1, 1976. Twelve of the tests were successful from a data collection viewpoint, and three were unsuccessful, due to computer or DSF outages. Table 1 contains a summary of all test sessions conducted.

For each test session, encounters of IFR/IFR, IFR/VFR, and VFR/VFR aircraft were simulated. Encounters between IPC-equipped aircraft and nonequipped aircraft were also simulated. All tests involved NAFEC controllers and DSF personnel.

A total of five traffic samples were used during operational testing. Succeeding test sessions used different traffic samples to preclude learning effects. A brief breakdown of the samples were as follows:

IPC 014 Contained 25-percent IFR/DABS-equipped aircraft with cockpit displays, 50-percent IFR/ATCRBS-only-equipped aircraft, and 25-percent VFR/DABS-equipped aircraft with cockpit display.

IPC 030 Contained 56-percent IFR/DABS-equipped aircraft with cockpit display, 23-percent IFR/ATCRBS-only-equipped aircraft, and 21-percent VFR/DABS-equipped aircraft with cockpit display, plus an overload of 10-percent VFR/DABS-equipped aircraft with cockpit display, operating on random flight plans.

IPC 031 Contained 100-percent IFR/DABS-equipped aircraft with cockpit display.

IPC 032 Contained 60-percent IFR/DABS-equipped aircraft with cockpit display, 20-percent IFR/ATCRBS-only-equipped aircraft, and 20-percent VFR/DABS-equipped aircraft with cockpit display.

IPC 151 Contained 15-percent IFR/DABS-equipped aircraft with cockpit display, 60-percent IFR/ATCRBS-only-equipped aircraft, and 25-percent VFR/DABS-equipped aircraft with cockpit display.

Each sample provided a 2-hour session of ATC preplanned conflict situations with air traffic flow, density, types of aircraft, and equipment varying so as to meet the test objectives. Approximately 130 aircraft were tracked during crossover situations, although a few overtake situations were contained in the heavier traffic samples used for the last two test sessions.

TABLE 1. SUMMARY OF ALL TEST SESSIONS CONDUCTED

Test Number	Date Conducted	Type Test	Test Successful	Remarks
1	July 6, 1976	Familiarization for ATCS personnel with all Aircraft DABS-equipped.	Yes	Passive monitoring, controllers took no action to resolve conflicts.
2	July 8, 1976	Evaluation of consistency of command data displayed to the controller on his PVD.	Yes	Command data were adequate. Data on two aircraft were lost due to a problem with the modem controller located in the DSF.
3	July 13, 1976	IPC system was operated utilizing DABS, ATCRBS, and VFR-equipped aircraft.	No	Beacon code assignments were mismatched between the DSF and SSF, causing the failure.
4	July 15, 1976	IPC system was operated utilizing DABS, ATCRBS, and VFR-equipped aircraft.	Yes	Air traffic mix contained 50-percent ATCRBS-equipped aircraft, 25-percent DABS-equipped aircraft, and 25-percent VFR aircraft. Problems encountered during this test were directly related to an overload of the high-speed printer. The problem has been corrected in the NAS system.
5	July 27, 1976	IPC commands to VFR aircraft were evaluated to assure adequate separation between VFR/IFR aircraft.	Yes	Adequate separation was maintained between VFR/IFR aircraft.
6	July 28,1976	Noncomplying and nonwilcoing aircraft to IPC commands were evaluated.	Yes	These aircraft presented no problems to the ATCS personnel.
7	August 3, 1976	Voice commands were evaluated for timeliness.	Yes	Voice commands of a negative nature caused the controllers a problem in phraseology.
8	August 4, 1976	Interrelationship between IPC system and ATCS with the NAS conflict alert turned ON.	Yes	Air traffic controllers were instructed to use standard radar separation precedures. A high volume of VFR aircraft caused some data block cluttering in the NAS system.
9	August 10,1976	All aircraft in this traffic sample were DABS-equipped.	No	Power failure in Bldg. 149 caused the test to fail.
10	August 17, 1976	DABS-equipped VFR aircraft were maneuvered in close proximity to IFR aircraft.	Yes	100-percent DABS-equipped aircraft resulted in the heaviest concentration of maneuver commands tested. One IPC false alert was attributed to an improper controller entry into the NAS system.
11	August 18, 1976	DABS-equipped VFR aircraft were maneuvered in close proximity to IFR aircraft.	Yes	Descending aircraft from high altitude to low altitude causing a descending mix which the IPC system appeared to handle without problem.
12	August 24, 1976	Determine if the operational system (NAS) with conflict alert can function along with the IPC system.	No	Test was a failure due to RMC2 in the CDC.
13	August 25, 1976	Evaluate the impact on the ATC system and obtain controller reaction to continuing IPC maneuver commands to VFR aircraft.	Yes	Controllers expressed satisfaction with IPC system.

TABLE 1. SUMMARY OF ALL TEST SESSIONS CONDUCTED (Continued)

Test Number	Date Conducted	Type Test	Test Successful	Remarks
14	August 31, 1976	Evaluate the impact on the ATC system and obtain controller reaction to continuing IPC maneuver commands to VFR aircraft.	Yes	The traffic sample was extremely heavy with 60-percent DABS-equipped aircraft. 20-percent ATCRBS equipped aircraft, 20-percent DAB-equipped VFR aircraft plus 10-percent VFR (DABS-equipped) random flights. A speed reduction to 250 knots prior to handoff to approach control was in effect throughout the test.
15	September 1, 1976	Controller capacity was estimated while utilizing the IPC system.	Yes	A heavy traffic sample with conflict alert on was used with instruction to the ATCS not to induce any alerts but to respond immediately in the event of an alert. The traffic sample has a good mix of climbing and descending aircraft.

Throughout each test session, controllers and observers were asked to record any discrepancies of the IPC function, the A3d2.1 program, or the CA function. At times, specific sectors were selected to test certain situations that had not been included in the traffic sample or were causing problems of an unknown nature.

During the test sessions, data were collected or obtained via the following methods: (1) debriefing sessions that followed each test session, (2) test observer logs, (3) analysis of online printouts, (4) analysis of the data-reduction-and-analysis printouts obtained from the automatic data collected on the 9020 system analysis recordings, and (5) collected from the DSF recordings of pilot instructions of the 12 successful tests. The major emphasis of the first six tests (see table 1) was to make sure that the air traffic controllers understood the operation and applications of the IPC function in an enviroment with various percentages of aircraft responding to IPC commands, mixed with other aircraft that could not respond to IPC command, since they were not DABS-equipped and without cockpit display. The major emphasis of the second six tests (see table 1) was to obtain the controller's reaction to the use of the IPC system in an environment which included VFR and IFR aircraft, some of which were DABS-equipped, while others were not. VFR aircraft were not in contact with the controllers and hence could only receive automatic commands when DABS-equipped with associated cockpit display. The continued mixing of IFR/VFR DABS-equipped aircraft with non-DABS-equipped aircraft allowed for a thorough workout of the IPC algorithm and an interesting challenge to the air traffic controllers involved. Due to the fact that the DSF could only simulate one DABS site, only six sectors could be utilized; four low-altitude sectors and two high-altitude sectors which overlaid the low-sectors.

In order to exercise the IPC program with climbing and descending aircraft, the climb or descend instructions were distributed during the briefing immediately prior to testing. All descending aircraft were terminated upon reaching 6,000 feet and 250 knots.

To determine the compatibility of the IPC/CA functions during testing, the CA function was turned ON to uncover any unforeseeable problem areas and turned OFF to verify probable cause.

DATA COLLECTION.

Manually collected data, recorded by observers, controllers, and debriefing sessions, were used as the basis for analysis of test results. CA printouts, IPC printouts, and automatic data collected on the system analysis recordings (SAR) were utilized to verify and supplement the manually collected data.

RESULTS

DETECTION/ALERT CAPABILITY.

All conflicts in the traffic sample were presented as flashing alerts on the PVD. Hard copy verification was provided from data recorded at the high-speed printer (HSP), data recorded at the DSF site, and data reduction printouts of SAR tapes. No malfunctions or false alerts were noted or recorded by any of the test participants.

CONSISTENCY OF IPC COMMANDS.

Based on an analysis of the data collected, the commands were consistently accurate, pertaining to direction of maneuver, as a means for maintaining separation of conflicting aircraft. In previous IPC testing one of the main objections was the problem with climb/descent or left/right commands appearing in rapid succession. After all testing in this phase had been completed, it appeared this problem had been resolved.

A problem that was brought out during a debriefing session with the controllers concerned the IPC command that instructed VFR aircraft to climb or descend and resulted in producing a possible collision situation with IFR aircraft maintaining an assigned altitude. This happened on approximately 10 occasions and was considered a major problem. The IPC system has been programmed to issue VFR aircraft a climb or descent instruction as its first command in the event of a potential collision situation with other aircraft.

QUALITY OR READABILITY OF THE IPC-DISPLAYED INFORMATION.

No derogation in either the quality or readability of radar and forced IPC information on the PVD was experienced during testing. However, the similiarity of the IPC and CA function (flashing data blocks to signal an alert) was disconcerting to the controllers and could cause a serious IPC alert to be confused with a less serious CA. The addition of the aircraft response indicators (see figure 2) on the PVD were of great value in determining the status of a command. The command symbols in the data blocks were also fully utilized and easily read as reflected by the controller questionnaire.

IMPACT OF THE IPC FUNCTION UPON THE ENROUTE ATC SYSTEM.

The results of testing indicated that air traffic controllers generally accepted the IPC alerts and IPC commands for both VFR and IFR traffic. However, the generation of negative-type commands caused much concern among controller personnel. The use of negative commands is irrelevant and superfluous to the positive clearances issued by air traffic controllers, since only positive action has any meaning in the air traffic control system. This was emphasized in the response to controller questionnaires that were distributed among participating controllers. Eight out of 10 air traffic controllers favored elimination of the negative commands from the IPC voice function.

All controllers did agree it was acceptable to transmit the negative commands to the pilot via a data link system. This they felt would not present a problem to ATC. It was unanimously agreed that once there is a CA generated, the controllers would take the necessary action to resolve the situation and not wait for IPC. This was evident in situations where the controllers had a choice of action before an IPC command was generated. In all cases, the conflict was resolved prior to any IPC command. During the latter part of the test sessions a problem was encountered when descending aircraft would level off at a predetermined altitude until their airspeed was reduced to 250 knots, and then would continue their descent to a lower assigned altitude. This leveling off procedure had not been anticipated, which resulted in controllers being correctly alerted to potential hazardous situations either by the CA or IPC function.

During IPC testing at NAFEC, simulation introduced limitations which would not be duplicated in the real world. Positional information used in IPC testing was routed through the ATCRBS system, which is considered to be less accurate than DABS system is projected to be. Therefore, results conducive to the IPC system using ATCRBS should be even more conducive using the DABS.

CONCLUSIONS

Based upon the NAFEC simulation tests conducted in an enroute enviroment, it is concluded that:

1. Air Traffic Radar Controllers were able to adapt to the IPC system and resolve any resulting interface problems while considering its importance as a collision avoidance system.

2. Aircraft receiving IPC commands to climb or descend to avoid a second aircraft could become involved in another conflict situation with a third aircraft flying at another altitude.

3. IPC-generated commands "data linked" to the aircraft (DSF pilot displays), and displayed on the radar controller's PVD were consistent for all conflict situations tested.

4. Although adequate by itself, the similarity of the flashing full data block alert of the IPC program to that of the conflict alert program could cause difficulty to the controller in identifying an IPC alert.

5. The IPC/CA list (figure 2) displayed on the radar controller's PVD was considered adequate, after a period of familiarization, for both IFR/IFR and IFR/VRF conflict situations. The list information was meaningful to the controller and allowed accurate and timely responses.

RECOMMENDATIONS

Based on the results and conclusions of the IPC/controller interface tests, the following recommendations are offered:

1. Conduct further IPC testing of both the controller interface and enroute algorithm using the next development of the IPC system.

2. Develop an independent type of alert for IPC alerts, to distinguish them from those generated by the conflict alert function.

3. Refine the IPC resolution logic so that priority will be given to a change of direction (turns) rather than a change of altitude (climb or descent) in resolving potential collisions.

4. Eliminate all negative commands to IFR aircraft for voice delivery by the controller.

5. Procedures must be instituted whereby VFR aircraft will be required to respond to IPC-generated control commands, so as to avoid unnecessary impact on IFR aircraft in the ATC system.

REFERENCES

1. Eldredge, D., Simulation of the Original and NAFEC-Proposed IPC Displays, FAA-RD-77-73, August 1977.

2. Ranger, F., Preliminary Test and Evaluation of the Intermittent Positive Control/Air Traffic Control System Interface with the NAS Enroute System, FAA-Rd-74-163, January 1975.