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UNCLASSIFIED 1343-01-3-2058-VOL-2 FAA/RD-79-124-2 NL

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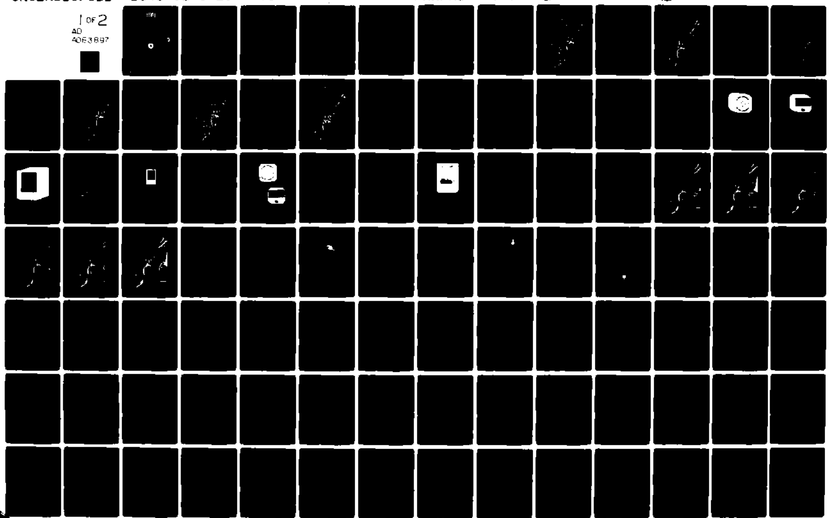

Report No. FAA-RD-79-124-2

LEVEL II

AN EVALUATION OF AIRCRAFT SEPARATION ASSURANCE CONCEPTS USING AIRLINE FLIGHT SIMULATORS

VOLUME II: APPENDIXES

Bruce Morgenstern
Thomas P. Berry

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a Subsidiary of Aeronautical Radio, Inc.
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Annapolis, Maryland 21401

NOVEMBER 1979

FINAL REPORT

Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

Prepared for
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

80 5 5 108

NOTICE

Technical Report Documentation Page

1. Report No. FAA-RD-79-124-2	2. Government Accession No. AD-A083 897	3. Recipient's Catalog No.
4. Title and Subtitle An Evaluation of Aircraft Separation Assurance Concepts Using Airline Flight Simulators. Volume II. Appendixes.		5. Report Date Nov[redacted]79
		6. Performing Organization Code
7. Author(s) Bruce Morgenstern, Thomas P. Berry		8. Performing Organization Report No. 1343-01-3-2058
9. Performing Organization Name and Address ARINC Research Corporation, 2551 Riva Road, Annapolis, Maryland 21401		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DOT-FA78[redacted]
12. Sponsoring Agency Name and Address Department of Transportation, Federal Aviation Administration, Washington, D.C. 20590		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code ARD-253

15. Supplementary Notes

Supplements FAA-RD-79-124-1

16. Abstract

This report supplements the main study report of a cockpit evaluation of ASA concepts. It contains a description of the flight scenarios used, a copy of the pilot advance briefing and pre-briefing copies of the flight crew questionnaire and supplemental questionnaire with all comments, data analysis formulas, and test bed description details.

17. Key Words	18. Distribution Statement
Aircraft Separation Assurance; ASA; Collision Avoidance; Cockpit Displays; Airline Simulators; Air Traffic Control	Document may be released to the National Technical Information Service, Springfield, Virginia 22151, for sale to public

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	171	

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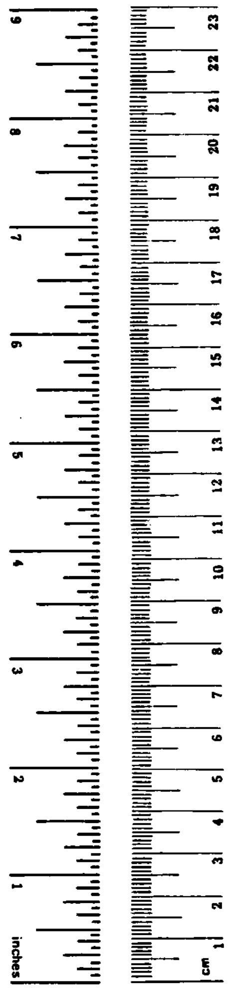
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

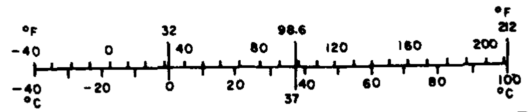
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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



CONTENTS

APPENDIX A

FLIGHT SCENARIOS

This appendix presents the six flight scenarios and conflicts that were used in the simulator cockpit evaluation. Each scenario consists of a nominal flight path expected for a flight that originates at the Los Angeles International Airport (LAX), follows a standard departure, establishes itself at a cruise altitude, changes course, and returns for an approach and landing at LAX.

Before the start of the simulation session, the crew was briefed on the entire flight route, including the point where they would be given clearance to return to LAX. The locations and types of conflicts were not presented to the crew before the start of the experiment.

The crew was in constant communication with an air traffic controller. Control was "passed" from clearance delivery to the tower, to departure control, to center, to approach control, and finally to the tower. The nominal clearances given to the pilots during each scenario are presented in this appendix. Clearances sometimes varied due to differences in the way that the simulator was flown.

The weather was kept constant for the departure, en route, and approach phases of flight for all scenarios: clear, visibility 9 miles, altimeter 30.00. Landing conditions varied by scenario.

The six flight scenarios are tabulated in Tables A-1 through A-6 and shown graphically in Figures A-1 through A-6. The conflict geometries are illustrated in Figure A-7 and their assignments to the specific scenarios are listed in Table A-7.

Table A-1. SCENARIO 1: LOS ANGELES TO LAS VEGAS

CLEARANCE: United 704 Cleared as Filed, Daggett 6 Departure, Las Vegas Transition, Maintain Flight Level 190, Departure Frequency 125.2, Squawk 6112, Departure Runway 24R

SEQUENCE NUMBER	EVENT	"CLEARANCE"/ACTION
1	Crew Calls for Takeoff	"Cleared for Takeoff, Maintain 6000"
2	Simulator at Shore Line	"Turn Right to 270 Contact Departure 125.2"
3	Conflict A: Intruder on V299, Heading 093, Speed 180 KIAS, Descending through Simulator Level at 6000; Turn Simulator to Create Conflict	"Turn Right to 060"
4	Simulator 5 Miles Prior to Crossing V23	"Maintain 11000"
5	Conflict B: Intruder on V201 Heading 189°, Speed 250 KIAS, Level at 11000; Simulator Climbing to 11000.	
6	Simulator Midway Between V201 and V197	Change to Active Mode
7	Simulator 12 Miles Prior to Crossing V197	"Maintain FL190"
8	Conflict C: Intruder on V197 Heading 142°, Speed 320 KIAS, Descending through 19000 Simulator Climbing to 19000.	
9	Simulator Prior to Crossing 6° Radial POM	"Cleared to LAX Airport, Present Heading, Maintain FL190, Los Angeles Weather: Clear, 9 Miles, Wind 230 at 11, Altimeter 30.00" "This will be an ILS Approach to Runway 24R" "Reduce Speed to 250 Knots"
10	Conflict D: Intruder on 180° Heading Vector, Speed 190 KIAS Level at 14000; Simulator Descending to 14000, Turn Simulator to Create Conflict.	"Turn Right to 180 Descend and Maintain 14000"
11	Simulator Crossing V264	"Turn Right to 220 Descend and Maintain 10000"
12	Simulator Intercepts ILS Runway 24R	Restore Full Mode
13	Conflict E: Intruder on ILS Runway 24R, Speed 250 KIAS, Descending through 10000; Simulator Level at 10000.	
14	Conflict E Resolved	"Descend and Maintain 7000"
15	Simulator 25 Miles from Touchdown	"Reduce Speed to 210 Knots Cleared ILS Runway 24R Approach Contact Tower 120.3 at the Outer Marker"
16	Conflict F: Intruder on Intercept to ILS Runway 24R Heading 220° Speed 210 KIAS, Descending through 7000, Simulator Level at 7000	
17	Simulator at Outer Marker	"Cleared to Land, Runway 24R Wind 230 at 11"

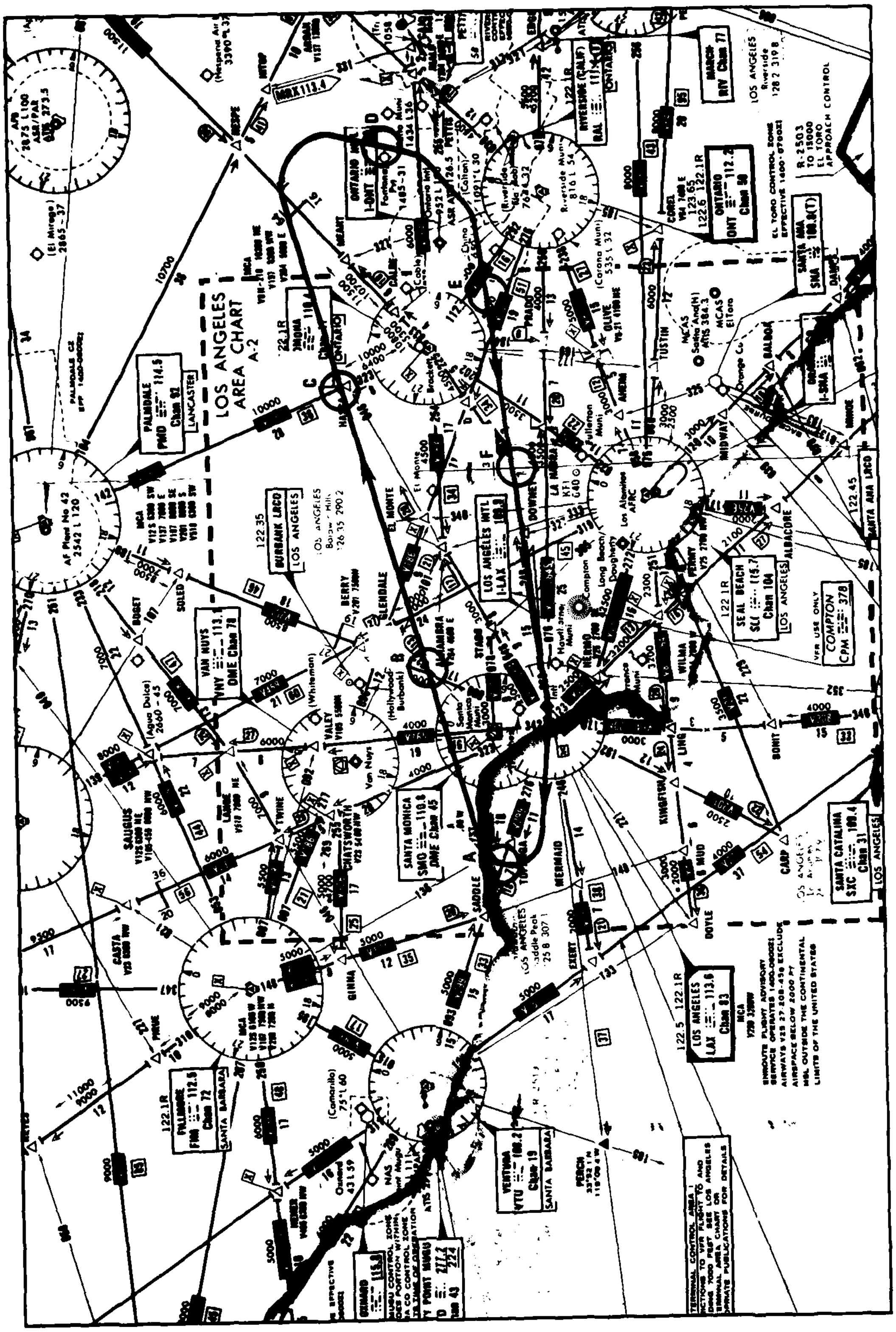


Figure A-1. SCENARIO 1

Table A-2. SCENARIO 2: LOS ANGELES TO SAN DIEGO

CLEARANCE: United 704 Cleared as Filed, Maintain 4000, Maintain Runway Heading, Expect 16000 10 Miles South of SLI, Departure Frequency 125.2, Squawk 6127, Departure Runway 6L

SEQUENCE NUMBER	EVENT	"CLEARANCE"/ACTION
1	Crew Calls for Takeoff	"Cleared for Takeoff. Runway 6L, Maintain Runway Heading, Maintain 4000"
2	Simulator Airborne	"Contact Departure"
3	Conflict A: Intruder on ILS Course Heading Toward Simulator, Speed 230 KIAS, Level at 4000; Simulator Climbing to 4000	
4	Conflict A Resolved	"Turn Right, Direct SLI, Depart SLI on 148° Radial to Intercept V25, Climb and Maintain 13000, Maintain 250 Knots in Climb"
5	Conflict B: Intruder on V-8-21 Heading 238°, Speed 250 KIAS, Descending through 13000; Simulator Climbing to 13000	
6	Simulator 5 Miles on SLI 148° Radial	Change to Active Mode
7	Simulator 10 Miles on SLI 148° Radial	"Climb and Maintain 16000"
8	Conflict C: Intruder on V25 Heading 123°, Speed 340 KIAS, Descending through 16000; Simulator Climbing to 16000	
9	Simulator 45 Miles on LAX 123° Radial	"Cleared LAX Airport, Maintain 16000, Present Heading for Radar Vectors to ILS Runway 24R, LAX Weather Clear, 9 Miles, Wind 220 at 15, Altimeter 30.00"
10	Simulator 50 miles on LAX 123° Radial	"Turn Left to 360; Intercept V23 to SLI, Reduce Speed to 250 Knots"
11	Conflict D: Intruder on V23 Heading 300°, Speed 250 KIAS, Descending through 16000; Simulator Level at 16000	
12	Conflict D Resolved	"Descend and Maintain 7000" Restore Full Mode
13	Conflict E: Intruder on V23 Programmed to Turn to 320 at SLI. Speed 160 KIAS, Level at 7000; Simulator Descending to 7000	
14	Simulator at SLI	"Depart SLI, Heading 320, Descend to 3000, Reduce Speed to 180 Knots"
15	Simulator 1 Mile from ILS Localizer Runway 24R	"Turn Left to 290, Maintain 3000 Until Localizer, Cleared ILS 24R Approach. Contact Tower 120.8 at Outer Marker
16	Conflict F: Intruder on Intercept to ILS Runway 24R. Heading 200. Speed 160 Knots. Descending Along Glide Slope; Simulator Descending Along Glide Slope	
17	Simulator at Outer Marker	"Cleared to Land, Runway 24R, Wind 220 at 15

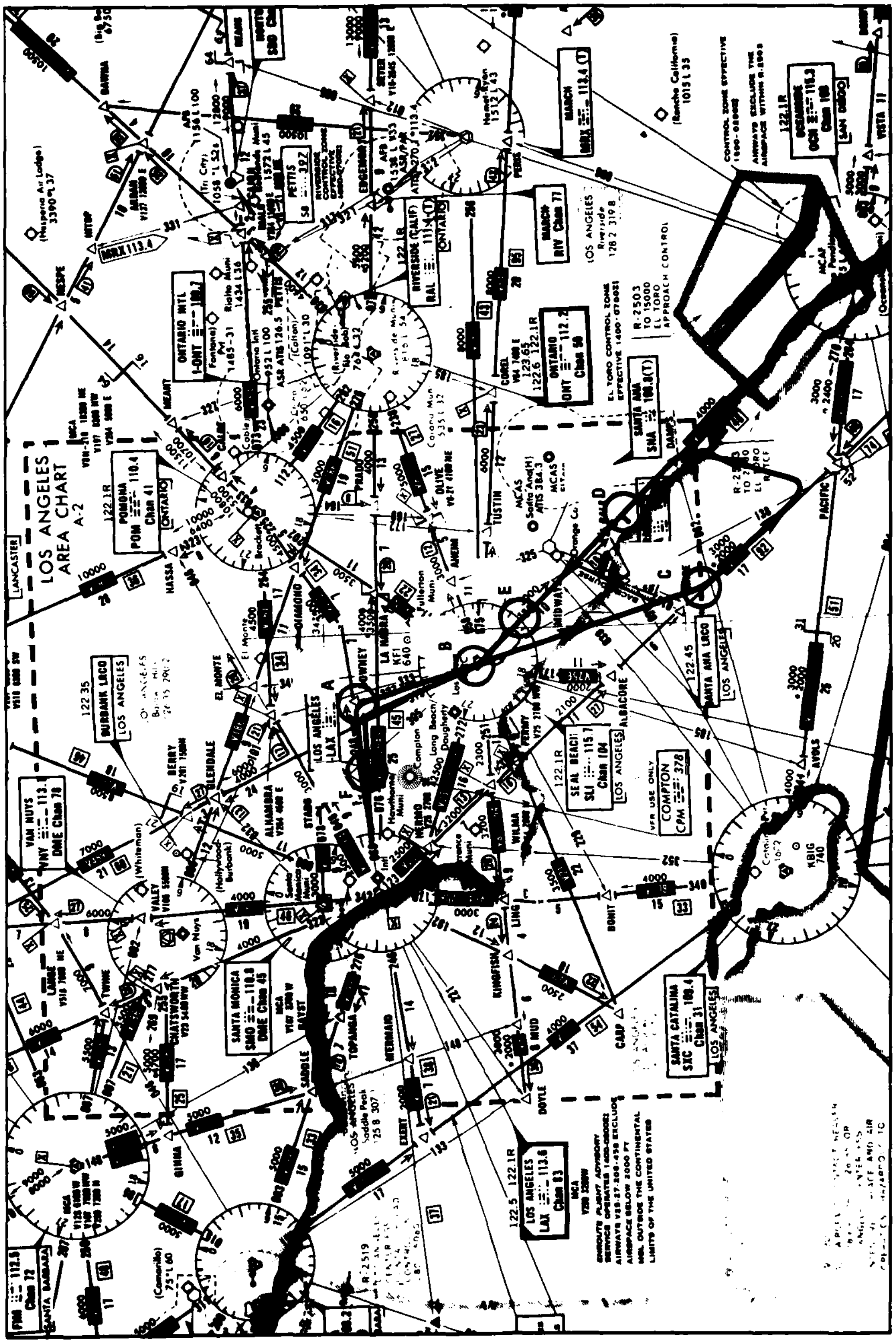


Figure A-2. SCENARIO 2

Table A-3. SCENARIO 3: LOS ANGELES TO BAKERSFIELD

CLEARANCE: United 704 Cleared as Filed, Gorman 4 Departure, Bakersfield Transition, Maintain Flight Level 180, Departure Frequency 125.2, Squawk 6134, Departure Runway 25L

SEQUENCE NUMBER	EVENT	"CLEARANCE"/ACTION
1	Crew Calls for Takeoff	"Runway 25L, Cleared for Take-off, Crossing the Shore Line, Fly Heading 270"
2	Simulator Airborne	"Contact Departure Control"
3	Conflict A: Intruder South of LAX Heading 360°, Speed 200 KIAS, Descending through 8000; simulator is climbing to 18000.	
4	Conflict A Resolved	"Maintain 8000, Turn Right to 060"
5	Simulator Established on 060	"Maintain 10000"
6	Simulator 2 Miles Prior to Crossing V23	"Turn Left to 350 Intercepting V23 on Course, Climb and Maintain FL180"
7	Conflict B: Intruder on V518 Heading 087, Speed 340 KIAS, Intruder Level at 15000; Simulator Climbing to 18000.	
8	Conflict B Resolved	Change to Active Mode
9	Conflict C: Intruder on V23 Heading 143°, Speed 370 KIAS, Descending through 18000; Simulator Level at 18000.	"Turn Left to 290 for Clearance to LAX Airport"
10	Conflict C Resolved	"Cleared to LAX Airport, Maintain FL180, Radar Vectors to GMN, Intercept V299, Los Angeles, Weather: Clear, 9 miles, wind 080 at 11, Altimeter 30.00, ILS Runway 6L"
11	Simulator at GMN	"Reduce Speed to 250 Knots"
12	Conflict D: Intruder on V299, Heading 167°, Speed 250 KIAS, Descending through 18000; Simulator Level at 18000.	
13	Conflict D Resolved	"Descend and Maintain 12000, Depart FIM on the FIM 158° Radial"
14	Simulator at FIM	"Descend and Maintain 5000" Restore Full Mode
15	Conflict E: Intruder on FIM 158° Radial, Speed 160 KIAS, Level at 9000; Simulator Descending to 5000.	
16	Conflict E Resolved	"Reduce Speed to 180 Knots"
17	Simulator 3 Miles Prior to Localizer Runway 6L	"Turn Left to 090 Intercept Localizer, Maintain 5000 to Glide Slope, Cleared ILS Runway 6L Approach, Contact Tower at SUPPI, 120.8
18	Conflict F: Intruder on Intercept to Runway 6L, Heading 043, Speed 130 KIAS, Descending Along Glide Slope; Simulator Descending Along Glide Slope	
19	Simulator at Suppi	"Cleared to Land, Runway 6L, Wind 080 at 11"

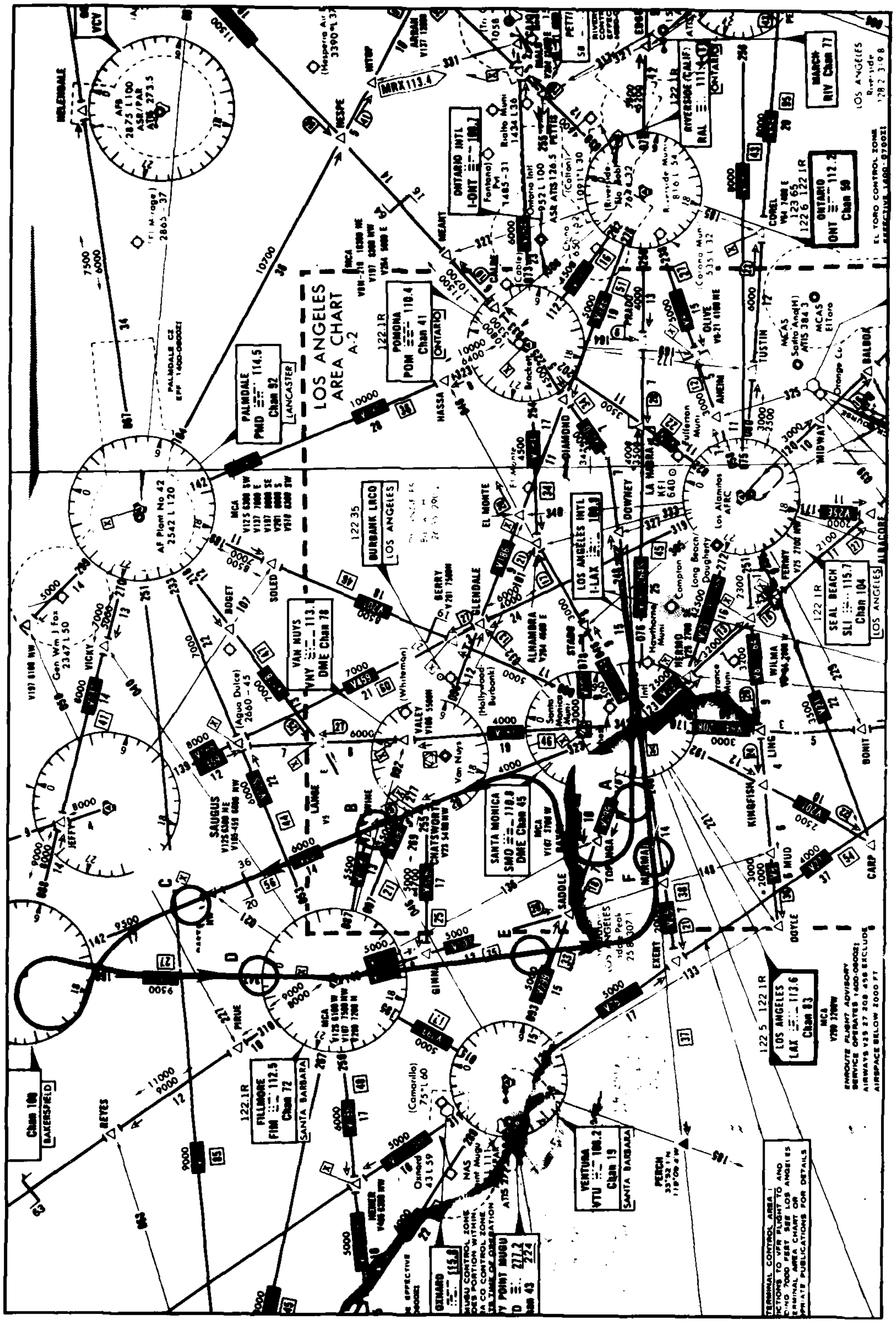


Figure A-3. SCENARIO 3

Table A-4. SCENARIO 4: LOS ANGELES TO LAS VEGAS

CLEARANCE: United 704 Cleared as Filed, Maintain Flight Level 180, Departure Frequency 125.2, Squawk 6144, Departure Runway 7R

SEQUENCE NUMBER	EVENT	"CLEARANCE"/ACTION
1	Crew Calls for Takeoff	"Cleared for Takeoff Runway 7R Maintain Runway Heading"
2	Simulator Airborne	"Contact Departure Control"
3	Simulator 6 Miles from LAX VOR	"Turn Left to 300"
4	Simulator Established on 300 Heading	"Intercept V165 on Course"
5	Conflict A: Intruder on V201, Heading 189°, Speed 120 KIAS, Descending to 5000 from 11000; Simulator Climbing to FL180.	
6	Conflict B: Intruder Crossing V165, Heading 072, Speed 250 KIAS, Level at 18000; Simulator Climbing to 18000	
7	Conflict B Resolved	"Intercept V518 on Course", Change to Active Mode
8	Simulator 10 Miles SW of PMD	"Depart PMD on the 040 Radial for Radar Vectors to LAX".
9	Conflict C: Intruder Intercepting V201 at PMD, Heading 189°, Speed 360 KIAS, Descending through 18000; Simulator Level at 18000	
10	Conflict C Resolved, Simulator Heading Past PMD for Vectors Back to LAX	"Cleared to LAX Airport, PMD, V197, POM, Depart POM Heading 190°, Radar Vectors to ILS Runway 25L, Maintain FL180, Reduce Speed to 250 Knots"
11	Conflict D: Intruder on V197, Heading 148°, Speed 340 KIAS, Descending through 18000; Simulator Level at 18000	
12	Conflict D Resolved	"Descend and Maintain 10000" Restore Full Mode
13	Conflict E: Intruder on V197 Heading 148°, Speed 110 KIAS, Level at 10000; Simulator Descending to 10000	
14	Conflict E Resolved	"Descend and Maintain 6000, Cross POM at 7000"
15	Simulator 1 Mile NW POM	"Reduce Speed to 180 Knots. Depart POM Heading 190°"
16	Simulator 1 Mile SW POM	"Turn Right to 220, Intercept Localizer, Maintain 6000 to Glide Slope, Cleared ILS Runway 25L Approach, Contact Tower at Outer Marker, 120.9
17	Conflict F: Intruder to Intercept 25R, Heading 220 to Localizer Speed 180 KIAS Simulator Descending Along Glide Scope	
18	Simulator at Outer Marker	"Cleared to Land, Runway 25L Wind 250 at 3"

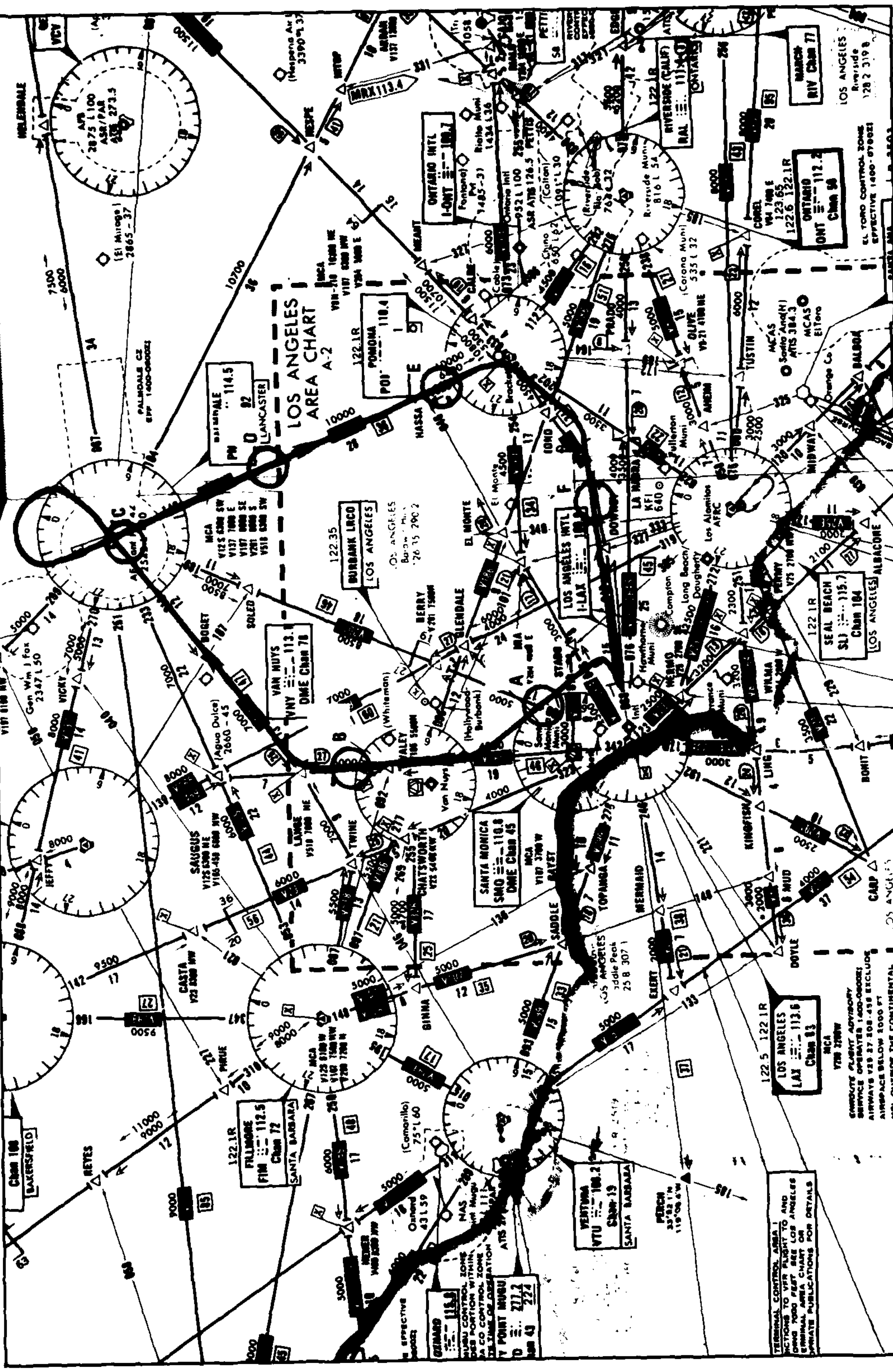


Figure A-4. SCENARIO 4

Table A-5. SCENARIO 5: LOS ANGELES TO SANTA BARBARA

CLEARANCE: United 704 Cleared as Filed, Ventura 3 Departure, Santa Barbara Transition, Maintain 14000, Departure Frequency 125.2, Squawk 6152, Departure Runway 7R

SEQUENCE NUMBER	EVENT	"CLEARANCE"/ACTION ON
1	Crew calls for takeoff	"Cleared for Takeoff, Runway 7R, Maintain 4000
2	Simulator Airborne	"Contact Departure Control"
3	Simulator 5 Miles NE of Airport	"Turn Right to 240"
4	Conflict A: Intruder on V201, Heading 012°, Speed 250 KIAS, Descending through 4000; Simulator Level at 4000	
5	Simulator 3 Miles Past V201	"Climb and Maintain 14000, Turn Right to 265, Intercept V25 on Course"
6	Conflict B: Intruder Perpendicular to Simulator Course, Heading 175° Speed 250 KIAS, Level at 9000; Simulator climbing to 14000	
7	Simulator 10 Miles SE of Kwang Intersection	"Continue Present Heading, Maintain 14000, Radar Vectors to ILS Runway, 6L Los Angeles Weather: Clear, 9 Mile Visibility Wind 060 at 9, Altimeter 30.00" Change to Active Mode
8	Conflict C: Intruder on 109° Heading Between V12S and V25, Speed 300 KIAS, Descending through 14000; Simulator Level at 14000. Turn Simulator to Create Conflict	"Turn Right to 040"
9	Conflict C Resolved	"Turn Right to Intercept V12S on Course to FIM"
10	Conflict D: Intruder on V12S, Heading 087°, Speed 340 KIAS, Descending through 14000; Simulator Level at 14000	
11	Conflict D Resolved	"Depart FIM on the FIM 158° Radial"
12	Simulator 15 Miles SE of FIM	"Descend and Maintain 3000" Restore Full Mode
13	Conflict E: Intruder on FIM 158° Radial, Speed 100 KIAS, Level at 5000; Simulator Descending to 3000	
14	Simulator 3 Miles From ILS Localizer Runway 6L	"Turn Left to 090, Intercept Localizer, Maintain 3000 to Glide Slope, Cleared ILS Runway 6L Approach, Contact Tower at Guppi, 120.8
15	Conflict F: Intruder Intercepting Localizer for 6R, Heading 128°, Speed 160 KIAS, Descending Along Glide Slope; Simulator Descending Along Glide Slope	
16	Simulator at Guppi	"Cleared to Land, Runway 6L Wind 060 at 8"

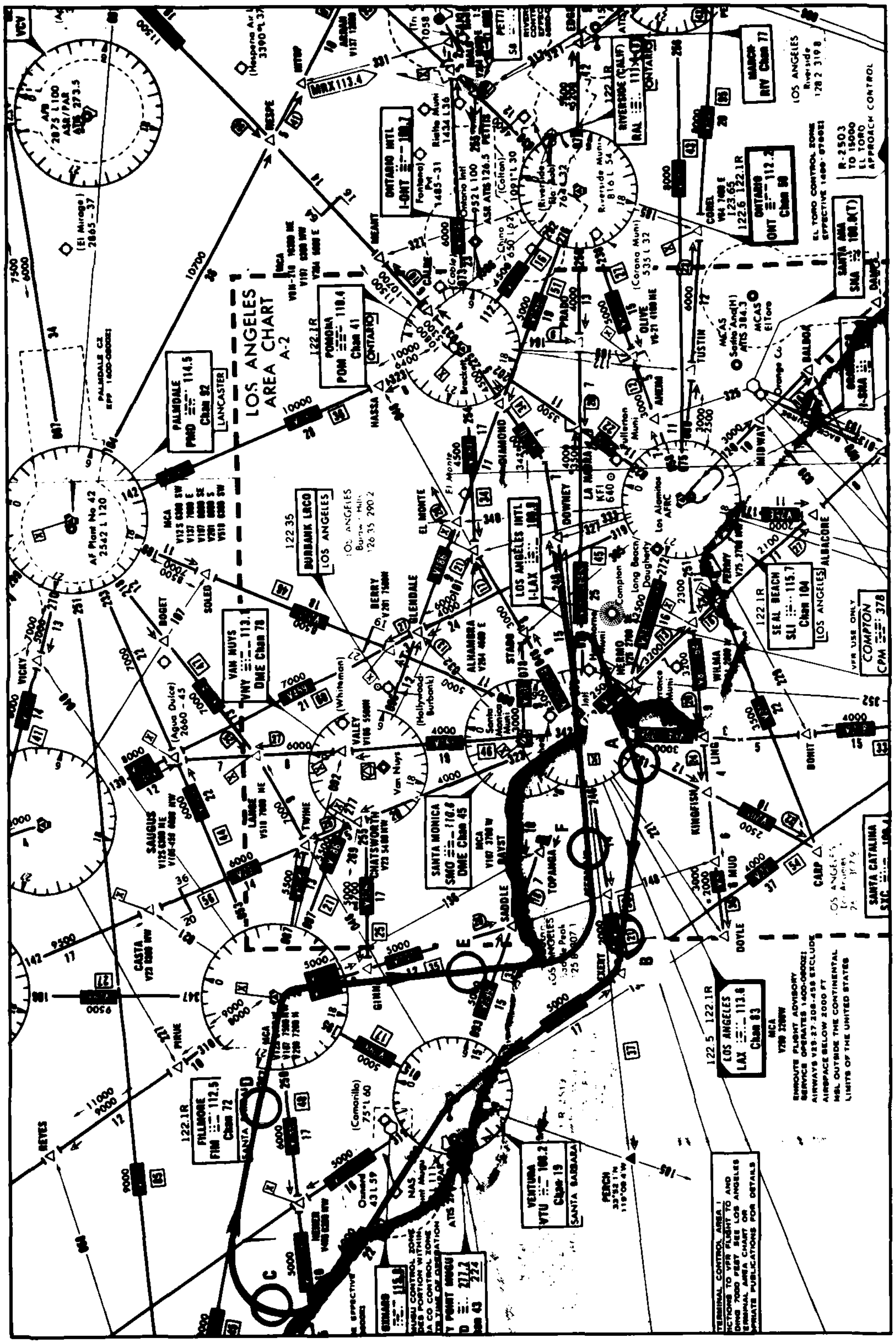


Figure A-5. SCENARIO 5

Table A-6. **SCENARIO 6: LOS ANGELES TO SAN DIEGO**

CLEARANCE: United 704 Cleared as Filed, Maintain 14000.
Maintain Runway Heading, Departure Frequency 125.2
Squawk 6165, Departure Runway 25L.

SEQUENCE NUMBER	EVENT	"CLEARANCE"/ACTION
1	Crew Calls for Takeoff	"Cleared for Takeoff Runway 25L Maintain 4000"
2	Simulator Airborne	"Contact Departure Control"
3	Conflict A: Intruder on V201 Heading 012, Speed 160 KIAS, Level at 5000; Simulator Level at 4000, Climb and Turn to Hit	"Turn Left to 090, Climb and Maintain 14000"
4	Conflict A Resolved	"Intrecept V25 on Course, Do Not Exceed 340 Knots"
5	Simulator Intercepts V25	Change to Active Mode
6	Conflict B: Intruder on V25, Heading 123°, Speed 380 KIAS, Descending through 14000; Simulator Level at 14000	
7	Conflict B Resolved	"Reduce Speed to 250 Knots, This will be Radar Vectors to LAX Airport for ILS Runway 6L. Cleared LAX Airport, Maintain 14000, Radar Vectors, SLI 120° Radial Direct SLI, SLI 251° Radial, Radar Vectors to ILS Runway 6L".
8	Simulator 25 Miles SE SLI	"Turn Left to 360"
9	Simulator 2 Miles Prior to Crossing V23	"Turn Left to 330, Intercept SLI 120° Radial, Direct SLI
10	Conflict C: Intruder Perpendicular to V23, Heading 030, Speed 250 KIAS, Descending through 14000; Simulator Level at 14000	
11	Conflict C Resolved	Restore Full Mode "Descend and Maintain 8000"
12	Conflict D: Intruder on V8-64, Heading 251°, Speed 130 KIAS, Level at 12000; Simulator Descending to 8000	
13	Conflict E: Intruder on V8-64, Heading 071°, Speed 250 KIAS, Descending to 8000, Simulator Descending to 8000	
14	Conflict E Resolved	"Turn Right to 320, Reduce Speed to 180 Knots, Descend and Maintain 4000
15	Conflict F: Intruder on ILS Localizer 6L, Speed 160 KIAS, Descending Along Glide Slope; Simulator Level at 4000	"Turn Right to 030° Maintain 4000 to Localizer, Cleared ILS Runway 6L Approach. Contact Tower 120.8 at Supp1
16	Simulator at Supp1	"Cleared to Land Runway 6L Wind 063 at 3"

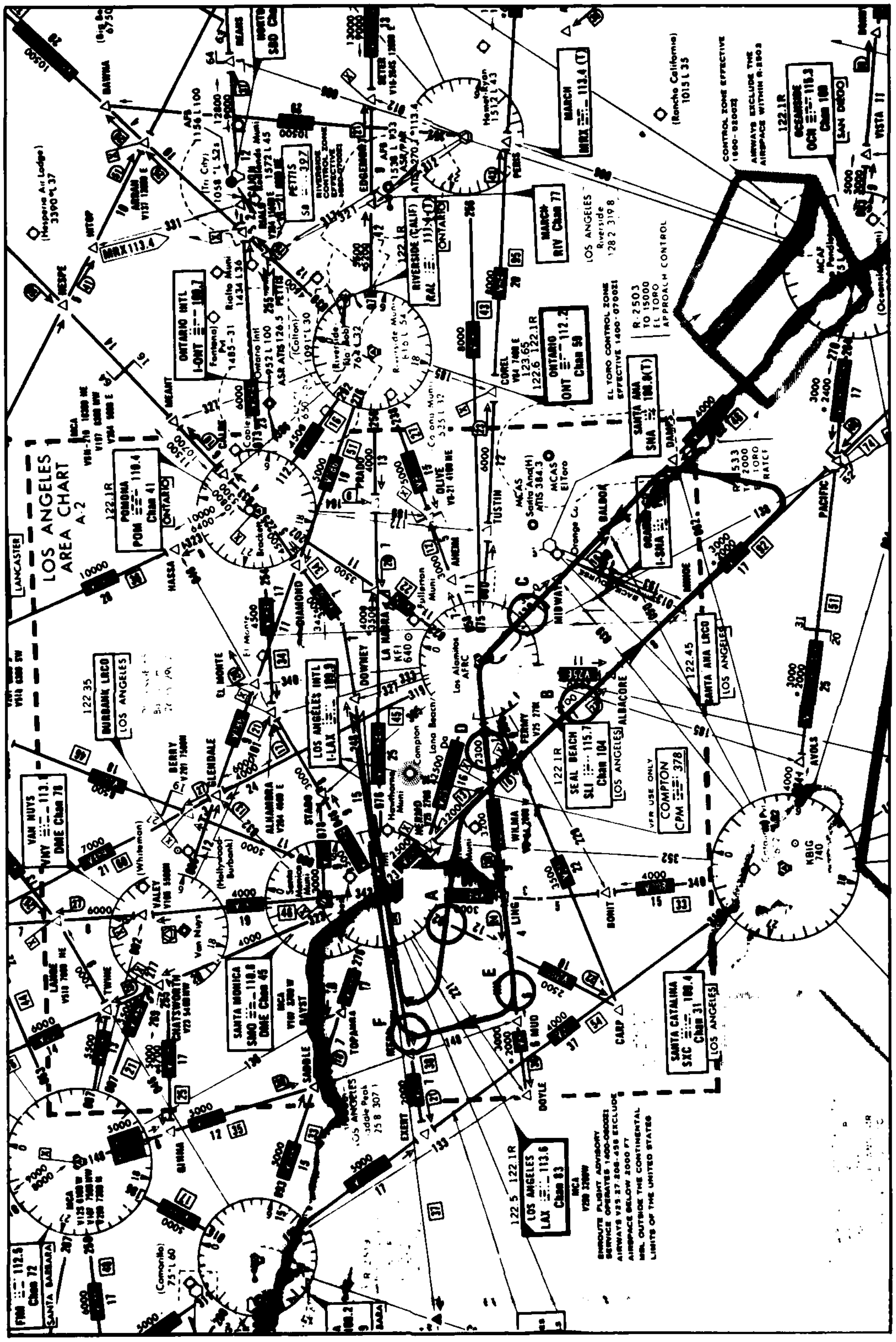
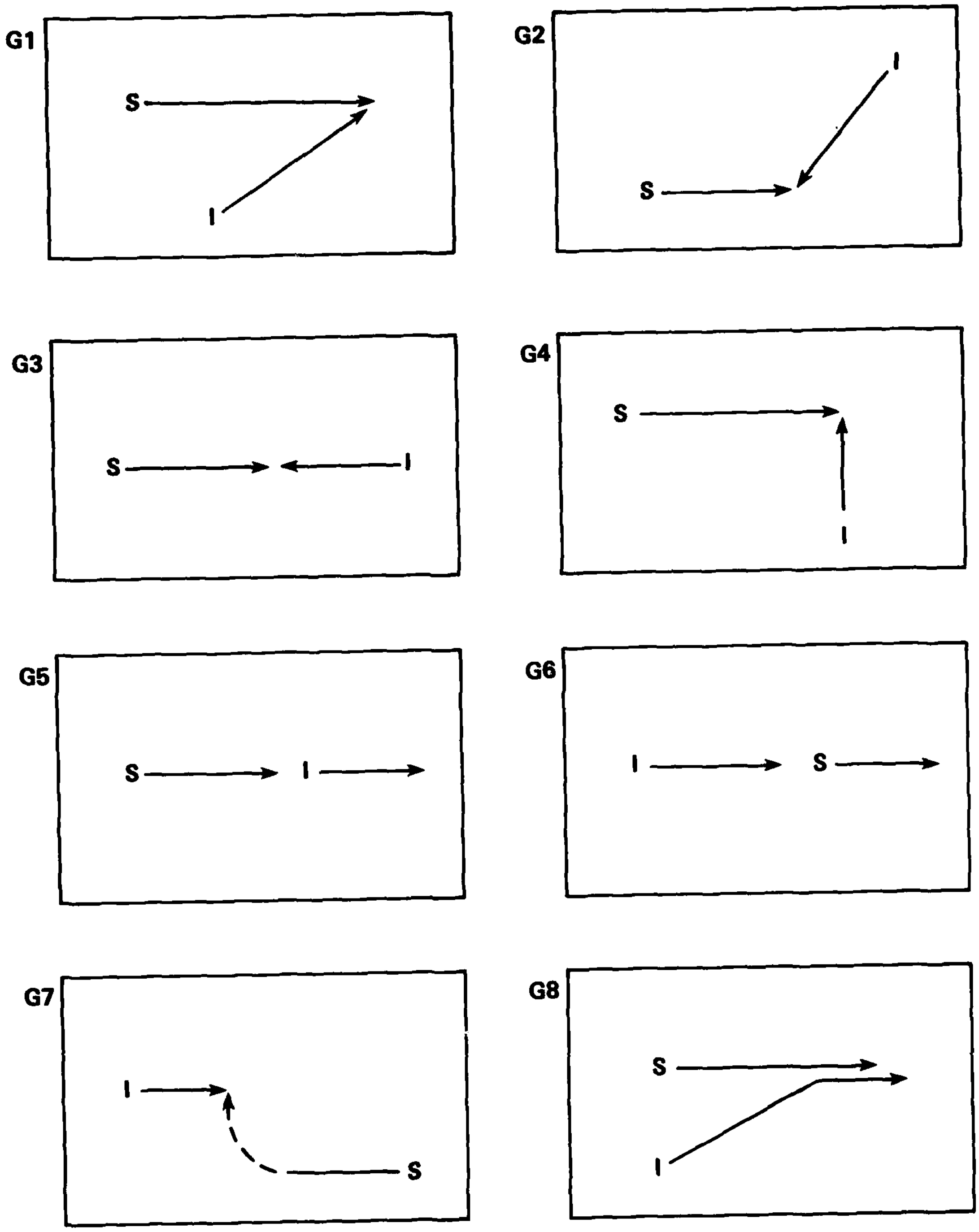


Figure A-6. SCENARIO 6



S = Simulator
I = Intruder

Figure A-7. CONFLICT GEOMETRIES (HORIZONTAL PLANE)

Table A-7. CONFLICT GEOMETRY ASSIGNMENTS						
Conflict	Scenario Number					
	1	2	3	4	5	6
A	G7 S → I ↓	G3 S ↑ I →	G4 S ↑ I ↓	G2 S ↑ I ↓	G2 S → I ↓	G1 S ↑ I →
B	G2 S ↑ I →	G4 S ↑ I ↓	G2 S ↑ I →	G4 S ↑ I →	G4 S ↑ I →	G6 S → I ↓
C	G4 S ↑ I ↓	G1 S ↑ I ↓	G3 S → I ↓	G3 S → I ↓	G7 S → I ↓	G4 S → I ↓
D	G5 S ↓ I →	G6 S → I ↓	G6 S → I ↓	G6 S → I ↓	G6 S → I ↓	G5 S ↓ I →
E	G6 S → I ↓	G5 S ↓ I →	G5 S ↓ I →	G5 S ↓ I →	G5 S ↓ I →	G3 S ↓ I ↓
F	G8 S → I ↓	G8 S ↓ I ↓	G8 S ↓ I ↓	G8 S ↓ I ↓	G8 S ↓ I ↓	G8 S → I ↓

G = Conflict geometry (from Figure A-7).
S = Simulator attitude (↑ = climbing, → = level, and ↓ = descending.
I = Intruder attitude.

APPENDIX B

SUBJECT PILOT ADVANCE BRIEFING

This appendix consists of the briefing material and cover letter which were mailed to the subject pilots several weeks before the testing. The briefing includes information on the Aircraft Separation Assurance (ASA) concepts, program objectives, test bed set-up, ASA displays and testing procedures. A Federal Aviation Administration (FAA) review cycle took place after this mailing and resulted in minor changes to the program. These changes were provided to the subject pilots during the pre-briefing held before each simulator session (see Appendix C).

November 22, 1978
S&ASP/G&CSD-78-163
W. O. 1343-01

Dear Sir:

The attached Aircraft Separation Assurance System Participation Briefing Sheet is provided to assist you in preparation for your upcoming participation in the ASA system evaluation. The briefing sheet is designed to provide more information on the ASA displays and experiment than was given in my original letter.

The experiment times have been changed for the better. Simulation periods will start at 8 p.m. each day and the last period will be completed at about midnight.

When you arrive in Denver, please contact the ARINC Research Corporation office at 398-5300. This phone will be manned after 1 p.m. each week day. Upon contact you will be assigned a reporting time of either 7 p.m. or 9 p.m. There is approximately a one hour briefing prior to starting the simulation run and there will be about a 45 minute debriefing at the conclusion of the period.

Directions to the briefing room will be posted in the crew lounge on the first floor of the main building at the United Flight Training Center.

We appreciate your participation in this program. If you have any problems with the scheduled date already assigned to you, please advise me as soon as possible.

Sincerely,

Loretta Albert/for

Thomas P. Berry
Project Engineer

Enc
TPB:la

ASA COCKPIT EVALUATION

PARTICIPANT BRIEFING SHEET

BACKGROUND

The aviation industry and the FAA have been deeply involved in the development of airborne collision avoidance systems since the late 1950's. The major thrust of these efforts has been directed toward solution of the technical problems inherent in complex electronic systems. Considerable effort has also been directed toward defining the operational problems that may arise with the implementation of a collision avoidance system. These operational problems affect both the users of the airspace (aircraft) and those responsible for maintaining an orderly and safe flow of traffic (The Air Traffic Control (ATC) System). The concept that incorporates these components; Aircraft, ATC System, and Collision Avoidance System, is generally called Aircraft Separation Assurance (ASA).

The Aircraft Separation Assurance concept incorporates the following basic principles:

- The Air Traffic Control System is responsible for the separation of controlled traffic within controlled airspace.
- The pilot is responsible for the safety of his aircraft.
- The Collision Avoidance System is responsible for providing safety benefits to each user who installs the equipment, i.e., the system should provide the user immediate protection against other aircraft even if they are not carrying the system.

The currently envisioned ASA system will monitor the interrogations and replies of the secondary radar (transponders) to determine the relative position and closure rate between the aircraft in which it is installed and other aircraft.

Because the ASA concept involves both hardware (Collision Avoidance Displays and Logic) and procedures, it is necessary to gather information on the system's acceptability by the users during development. The Federal Aviation Administration is conducting a series of studies and experiments to gather the reactions to the ASA concept by controllers, general aviation pilots and air carrier pilots. This phase of the project is dedicated to gathering the opinions and reactions of air carrier pilots to the ASA concept.

OBJECTIVES OF THE PROGRAM

The primary objective of the cockpit evaluation of Aircraft Separation Assurance concepts is to evaluate the operational impact of the introduction of ASA systems in commercial air carrier aircraft.

To meet this objective, an airline cockpit simulator, modified by the addition of ASA display devices, will be flown by air carrier line crews through realistic flight sequences. In addition to the events that normally occur during a routine flight, a number of traffic conflicts, undetected by ATC, will be introduced. The flight crew responses to these conflicts will be observed and measured.

Each flight crew will fly three short flights during a two hour simulation session. Each flight will use a different ASA display concept for presentation of information on conflicting aircraft.

TEST EQUIPMENT AND SETUP

The simulator cockpit represents a United Airlines Boeing 727-222 aircraft. The simulator, built by Singer-Link, is a high-fidelity system that includes a motion base and is similar to most 727 cockpit simulators. The cockpit visual system is a computer-generated two-window night scene. For this test, the visual system will be programmed to depict the Los Angeles area and the departure and arrival airport will be the Los Angeles International Airport. The visual system reproduces a night scene with a high degree of fidelity, however, only the forward view is available. The visual system also has the capability to depict other aircraft in flight.

The simulator cockpit will be modified by installation of three ASA displays. One display is an Instantaneous Vertical Speed Indicator (IVSI), modified to allow presentation of ASA commands. This instrument, shown in Figure 1, provides normal rate of climb information and indicates ASA commands by illuminating portions of the dial face. The second display, shown in Figure 2, is an alphanumeric display that uses a matrix of light emitting diodes (LEDs) to present ASA advisories and commands in a combined alphanumeric and symbolic format. The display provides traffic position information for as many as four aircraft. When an aircraft poses a collision threat, the position of that aircraft is shown along with an appropriate command which will assist the pilot in avoiding the collision.

The third display, shown in Figure 3, is a cathode ray tube (CRT) that symbolically displays the relative location track and MSL altitude of other aircraft, indicates which of the displayed aircraft is in conflict with your aircraft, and displays appropriate commands for resolution of the conflict.

Figures 4, 5 and 6 show the location of the displays on the Captain's, First Officer's and center console panels. Each crew member will have an IVSI and LED display. The CRT display is located on the center console in the space normally occupied by the weather radar indicator.

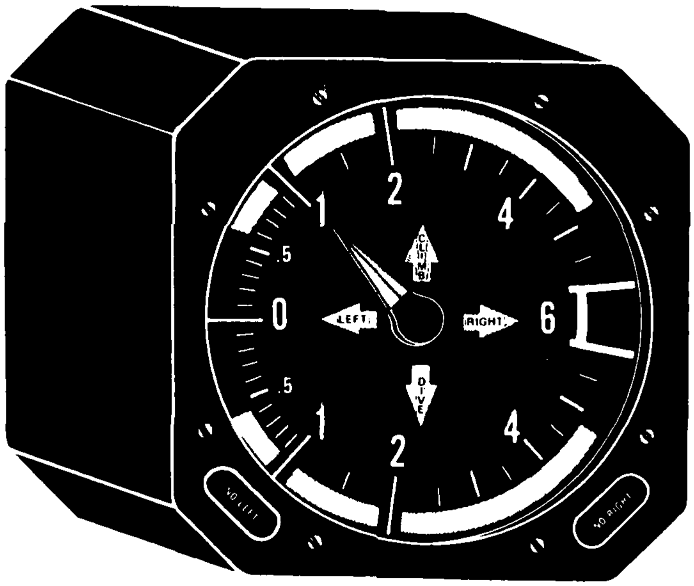


FIGURE 1

ASA MODIFIED INSTANTANEOUS VERTICAL SPEED INDICATOR (IVSI)

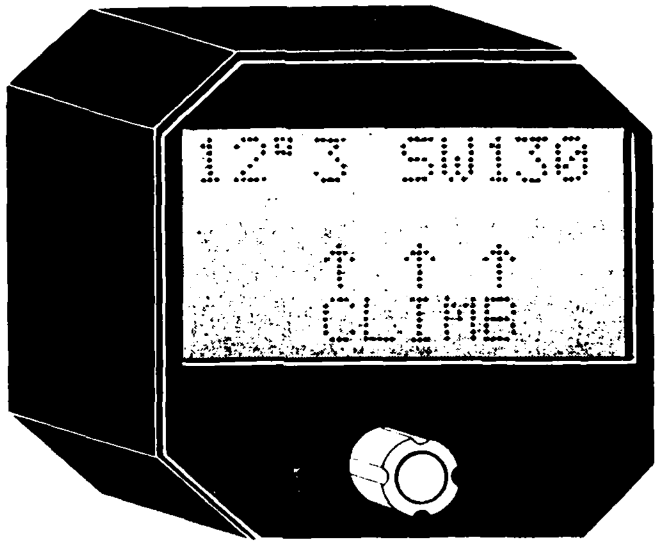


FIGURE 2

LED DISPLAY

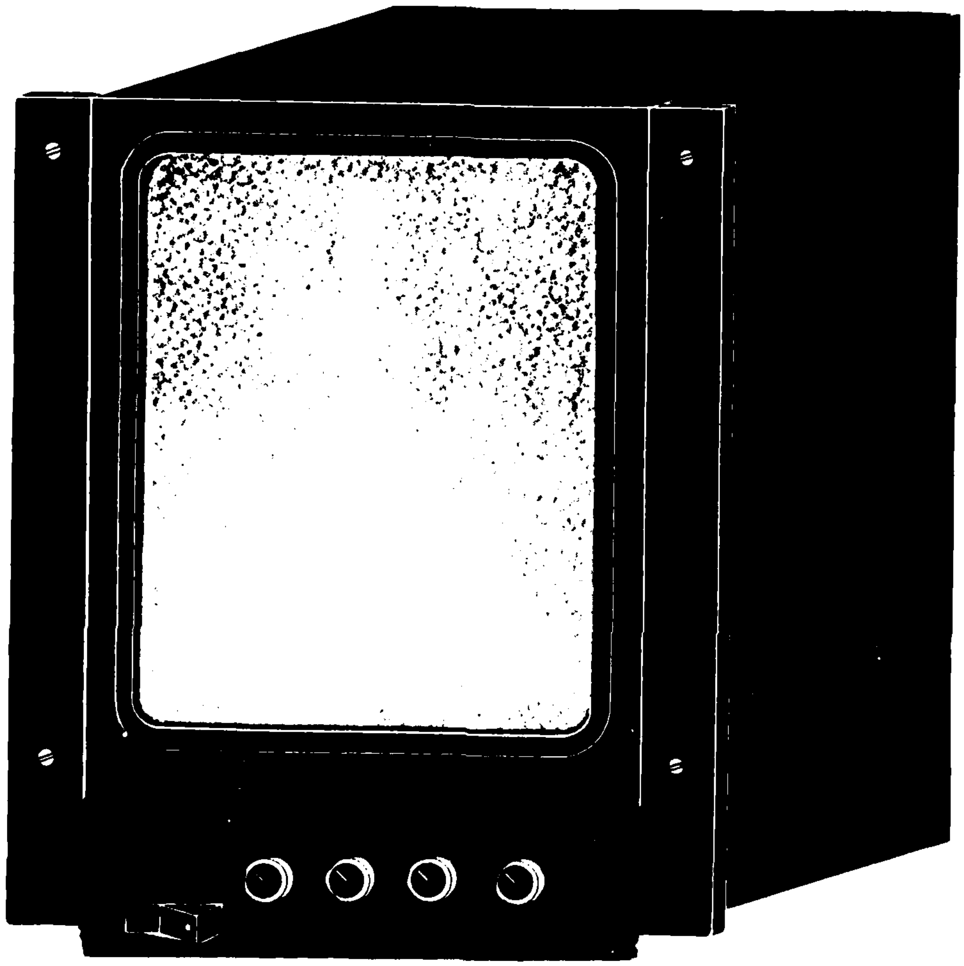


FIGURE 3

CATHODE RAY TUBE (CRT) DISPLAY

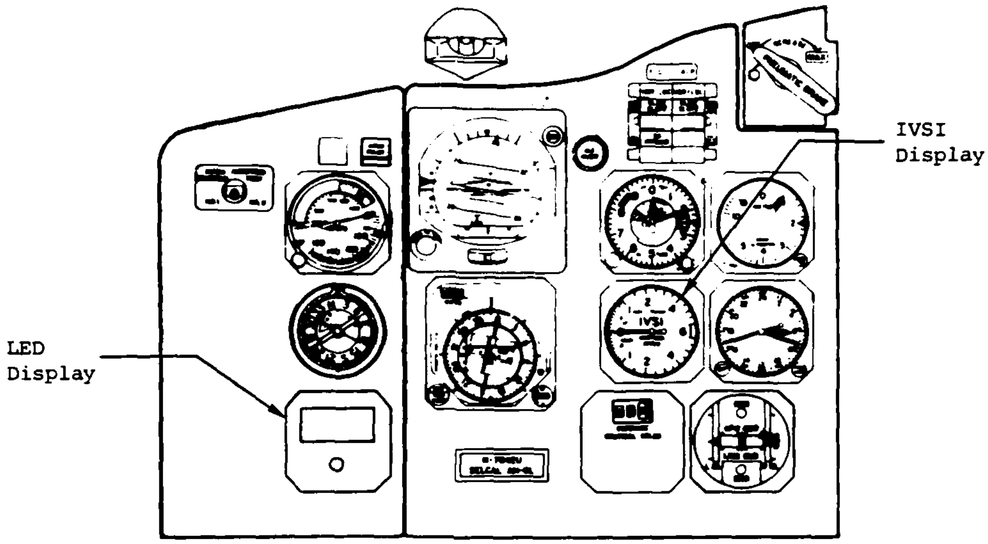


Figure 4. CAPTAIN'S PANEL

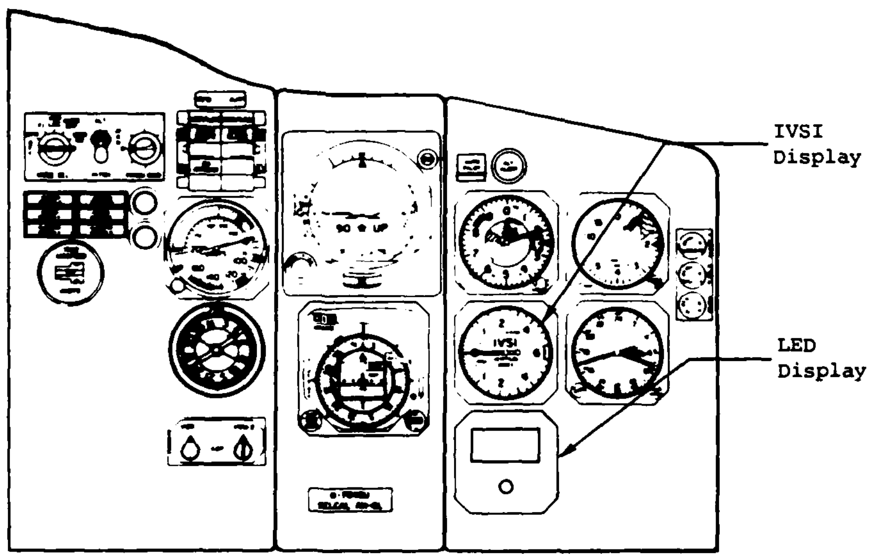
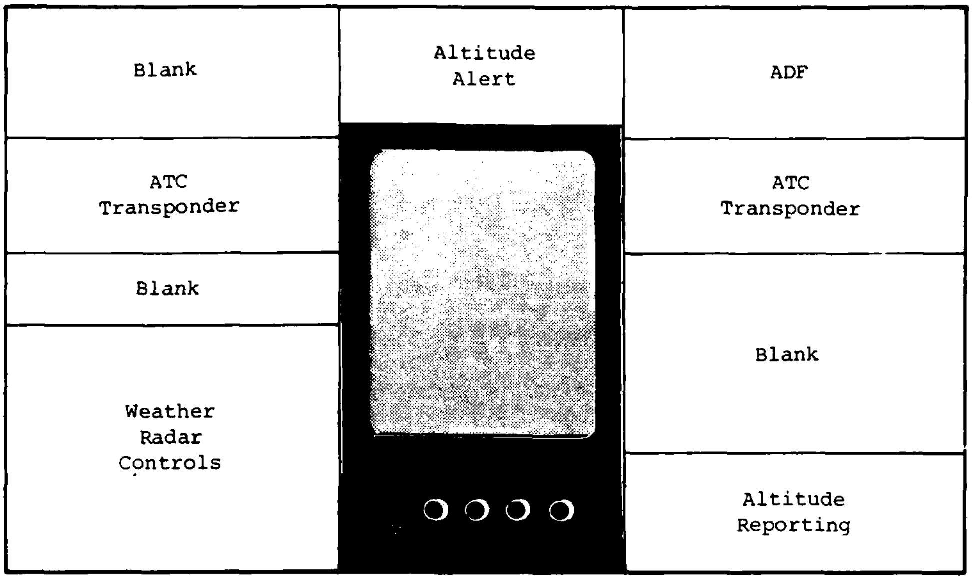


Figure 5. FIRST OFFICER'S PANEL



CRT DISPLAY

Figure 6. B-727 FORWARD PEDESTAL

ASA COMMANDS

The ASA commands fall into three categories; Limited Vertical, Negative and Positive. Limted vertical commands are the least restrictive and attempt to limit vertical maneuvers (CLIMB or DESCENT) to 2ØØØ, 1ØØØ, or 5ØØ FPM as the situation permits. Negative commands restrict the aircraft from performing specific horizontal or vertical maneuvers (DON'T CLIMB, DON'T DESCEND, DON'T TURN RIGHT, DON'T TURN LEFT). Positive commands are issued as a last resort and indicate that the pilot must maneuver to avoid a collision (CLIMB, DESCEND, TURN RIGHT, TURN LEFT). These commands are presented sufficiently early so that the pilot can respond with standard rate turns or standard climb/descent rates. Maneuvers should be executed until the command is deleted from the ASA display. If significant deviations from the nominal flight path occur, ATC should be notified.

DISPLAYS

The modified Instantaneous Vertical Speed Indicator (IVSI) combines two functions. It operates identically to a standard IVSI and also displays ASA commands. The instrument, shown in Figure 7, has no additional controls. The only adjustment available is that of the panel light control, located on the overhead panel, which varies the intensity of the light on the face of the instrument. The intensity of the ASA command lights are fixed. The limited vertical commands are displayed as yellow lighted arc segments outside the numbers, adjacent to the outside edge of the instrument face. When a limited vertical command is presented, either one, two, or three of these arc segments will be lighted to indicate the maximum climb or dive rate. To avoid a conflict, the rate of climb needle should not enter a lighted arc segment.

All other commands are easily understood. "No left" and "no right" turn commands are shown by lighting the appropriate indicator at the lower corners of the instrument case. Commands to "climb", "dive", turn "left" or "right" are shown by lighting the appropriate red arrow in the center of the instrument face. These commands are lighted only when the system senses an imminent collision.

The Light Emitting Diode (LED) display, is a special display constructed by Litton Aero Products for this test. The display panel consists of more than 2200 light points that can be lighted red, green or a combination of both colors (orange). Messages are formed by turning on the appropriate LEDs to form the desired letter, number or symbol. Traffic advisories and ASA commands are shown as messages of one or more lines. Traffic advisories are displayed in green, limited vertical and negative commands are displayed in orange, and positive commands are displayed in red. The format for traffic advisories is identical to current ATC voice traffic advisories. An example of the display format is shown in Figure 8.

Limited vertical and negative commands are displayed as alphanumeric messages in orange. These commands are shown in Figure 9. Each command occupies two lines at the bottom of the display. Whenever either of these types are displayed, a traffic advisory of the aircraft generating the command will be given on the top line.

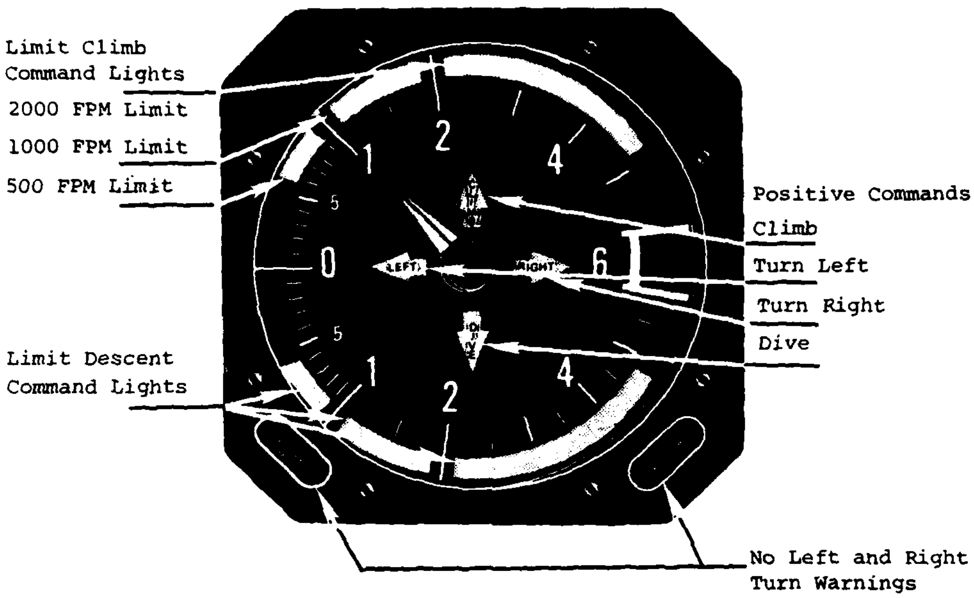


Figure 7. INSTANTANEOUS VERTICAL SPEED INDICATOR (IVSI) DISPLAY

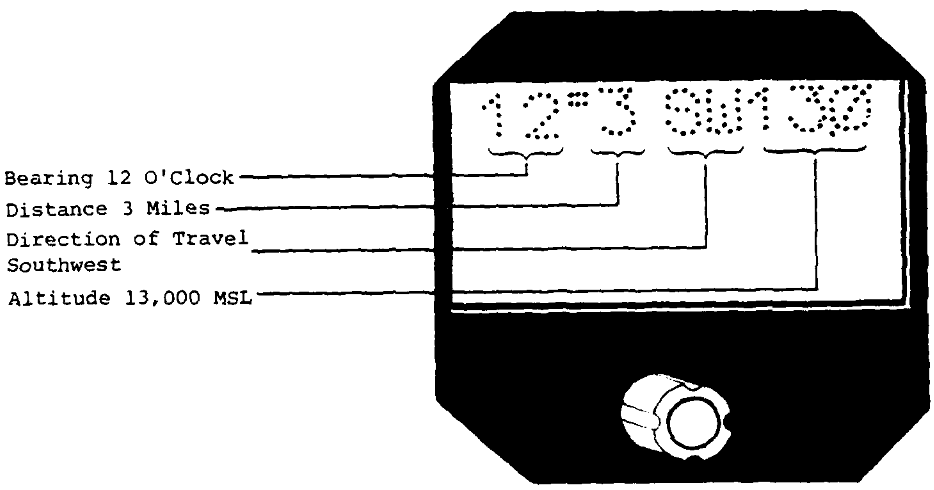


Figure 8. LIGHT EMITTING DIODE (LED) DISPLAY
WITH EXAMPLE TRAFFIC ADVISORY

COMMAND	MEANING	COMMAND	MEANING
DON'T TURN RIGHT	Self Explanatory	MX DESCENT 500	Do not descend More than 500 FPM
DON'T TURN LEFT	Self Explanatory	MX CLIMB 1000	Do not climb More than 1000 FPM
DON'T CLIMB	Self Explanatory	MX DESCENT 1000	Do not descend More than 1000 FPM
DON'T DESCEND	Self Explanatory	MX CLIMB 2000	Do not climb More than 2000 FPM
MX CLIMB 500	Do not climb More than 500 FPM	MX DESCENT 2000	Do not descend More than 2000 FPM

FIGURE 9

LED Negative and Limited Vertical Commands

(ORANGE LETTERS)

Positive commands are displayed as a combined alphabetic and symbolic command. Each of these commands, illustrated in Figure 10 occupies two lines at the bottom of the display. Whenever a positive commands is displayed, a traffic advisory of the aircraft generating the command will be given on the top line.

COMMAND	MEANING	COMMAND	MEANING
↑ ↑ ↑ CLIMB	CLIMB	←————	TURN LEFT
		←————LEFT	
DESCEND ↓ ↓ ↓	DESCEND	————→	TURN RIGHT
		RIGHT————→	

FIGURE 10

LED Positive

(RED)

The Cathode Ray Tube (CRT) display, shown in Figure 3, is a standard type CRT display adopted for use in this experiment. It displays the position of other traffic in relation to your own aircraft, which is always in the center of the display. The display is oriented with your aircraft heading up. Symbology used on the CRT display is shown in Figure 11.

ASA commands are displayed at the bottom of the display. Limited vertical and negative commands are displayed in the same form as shown in Figure 9. Collision avoidance commands, "Turn Left", "Turn Right", "Climb" and "Dive" are self-explanatory.

The CRT display is overlayed with two range rings. The inner range ring represents a distance of three (3) miles from your own aircraft, the second ring is six (6) miles from your own aircraft, and the top of the display is approximately nine (9) miles from your own aircraft.

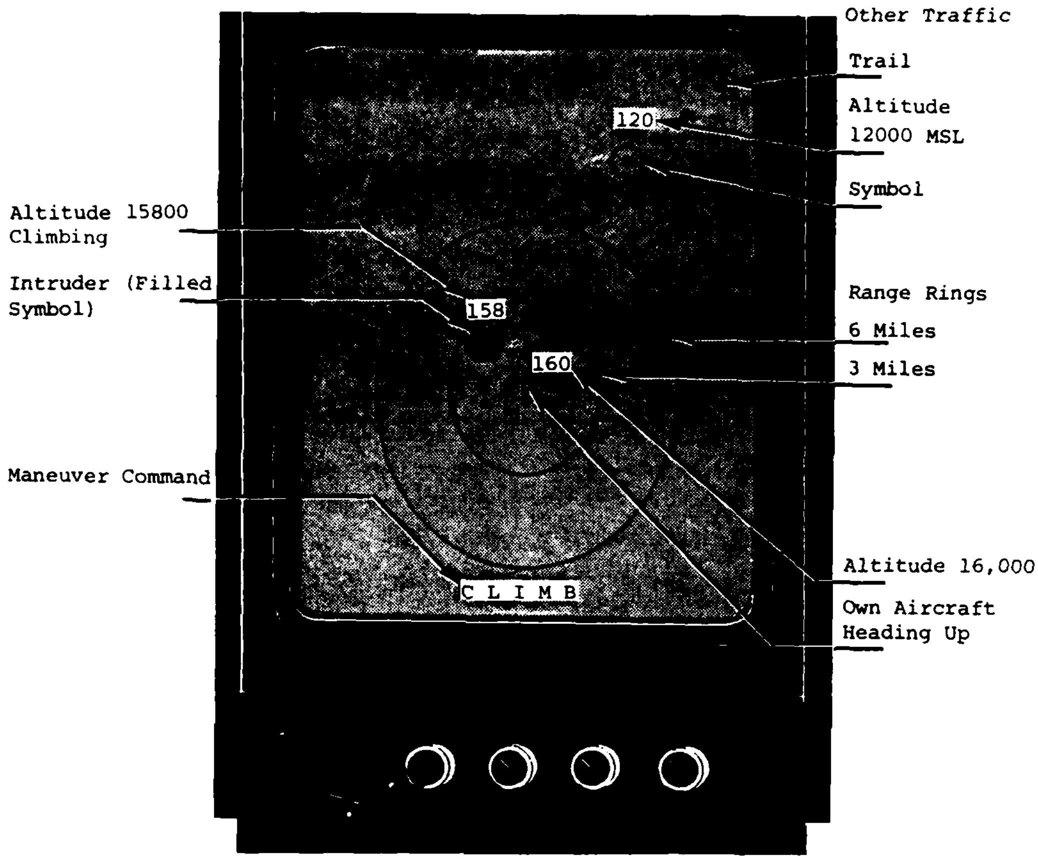


Figure 11. CATHODE RAY TUBE (CRT) DISPLAY

Active Mode Displays

During those periods when flying outside coverage by a modified radar, the ASA system operates in a so-called "Active" mode, as explained in the logic section below. When in "Active" mode, the display formats are slightly altered, however, the system provides the same degree of protection as the full feature system. When operating in "Active" mode, the ASA System periodically transmits a signal that causes the transponders of nearby Aircraft to transmit a reply. Based on the measured round-trip time of the signals, the ASA system determines the range and closure rate to nearby aircraft. Because the system operates on distance only, no bearing information is derived. Consequently, only vertical maneuver commands are given when the system is operating in the "Active" mode. "Active" mode is designed for protection in oceanic, foreign and low traffic density enroute and terminal areas.

On the IVSI display there is no change in the method of presenting maneuver commands or limit commands. No method is provided to alert the pilot when the system is operating in "Active" mode, and the pilot's reaction to commands should be the same as with the full system.

The LED display does not specifically notify the pilot when operating in "Active" mode either; however, "Active" mode operation can be detected by the absence of relative position and direction of movement from traffic advisory messages. All maneuver limit and command message formats are identical to those shown in Figures 9 and 10. Traffic advisories are in the format shown in Figure 12 as compared to Figure 8.

When operating in the "Active" mode, the CRT display format is completely changed. An example of this format is shown in Figure 13. No symbology is used for "Active" mode CRT display. The display provides range and altitude of intruder aircraft and alphanumeric limit and maneuver commands.

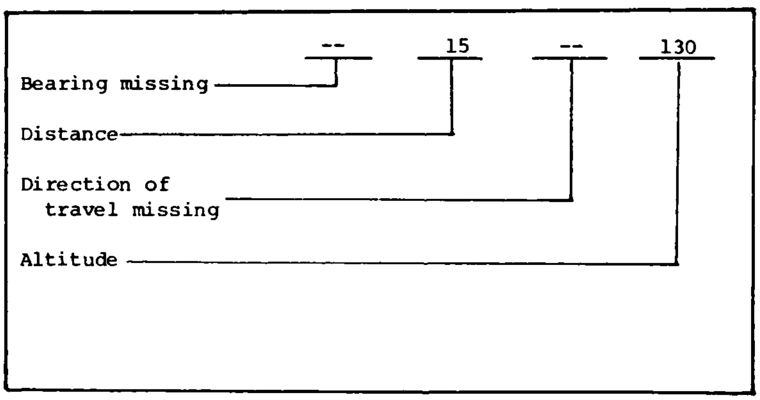


Figure 12. LED TRAFFIC ADVISORY FORMAT "ACTIVE" MODE

(Green letters)

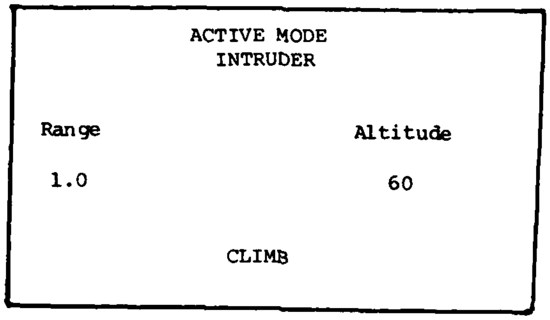


FIGURE 13. CRT "ACTIVE" MODE DISPLAY
WITH EXAMPLE COMMAND

<u>Logic</u>

The ASA system uses the electronic signals associated with the ATCRBS (transponder) system to determine the relative position of other aircraft. While the ASA system can utilize the signals from current transponders, it is a new and completely separate system, not merely an add-on to your present transponder. Full-service ASA will require modification of the ground radars in the FAA system to provide timing signals for use in determining the bearing to other aircraft.

The ASA system, using only the replies from existing transponders, determines the range to another aircraft. The altitude of other aircraft is also determined from the transponder reply. After performing a quality check to eliminate random signals, the ASA logic starts to track replies from other aircraft that are within a specified distance (horizontally and vertically) from your own aircraft. By making a series of range measurements, the system determines whether the two aircraft are closing or separating, and if closing, the rate of closure. When the projected minimum distance between the aircraft reaches a preset value, or the closure rate reaches a preset value, the system logic will select either a maneuver limit command, e.g., "Don't turn left," "Maximum climb 1000 fpm," or a positive command, e.g., "Climb," or "Turn right." The maneuver selection logic is designed to provide separation between two aircraft, even if only one is equipped and follows the commands. When ground radar timing signals are not available, the ASA system sends out a signal that causes the transponder of near by aircraft to send a reply. The system measures the round trip travel time of the signal to find the distance to the other aircraft. The closure rates are computed in the same manner as explained above and appropriate vertical command are generated to provide separation between aircraft.

Scenarios

Each flight crew that participates in this experiment will fly three flights within a two-hour block. The three flights will be selected from six flight scenarios, all starting from Los Angeles International Airport (LAX) and involving a departure, short enroute segment during which the flight will change course so as to make an approach, and landing back at LAX. A series of traffic conflicts will be created during the flight to exercise the ASA system.

The six flight scenarios, with nominal flight paths, are shown in Figures 14 through 19. The departures are consistent with flights to Las Vegas, San Diego, Santa Barbara, or Bakersfield. Arrivals back at LAX are similar to arrivals from these same cities.

Simulation Sessions

The simulation sessions will normally be conducted after 8 p.m. MST. A crew briefing will be conducted before each simulation session, where the crew will be assigned the specific flights, the operation of the display will be reviewed, and procedural questions will be answered.

Procedures

During the pre-simulation briefing session you will meet the other member of the test crew. He may or may not represent the same company as you, so it will be appropriate for you to discuss crew coordination. You should decide who will act as captain for the session. It is important that each subject participate by flying the simulator, therefore, you should reach an agreement on how you wish to divide the flying time.

During the simulation, an observer will be present in the cockpit to observe crew actions. In addition, an audio recording will be made to use in analysis of the crew's actions.

During the simulation, you should plan to follow all FAA rules and regulations as pertains to adherence to clearances, etc. In the event an ASA conflict causes you to deviate from your clearance, you should take the same actions that you now take when you make an emergency deviation.

After the simulation period, the crew will be asked to complete a questionnaire and comment sheet. In addition, a debriefing will be conducted to further explore crew member reactions.

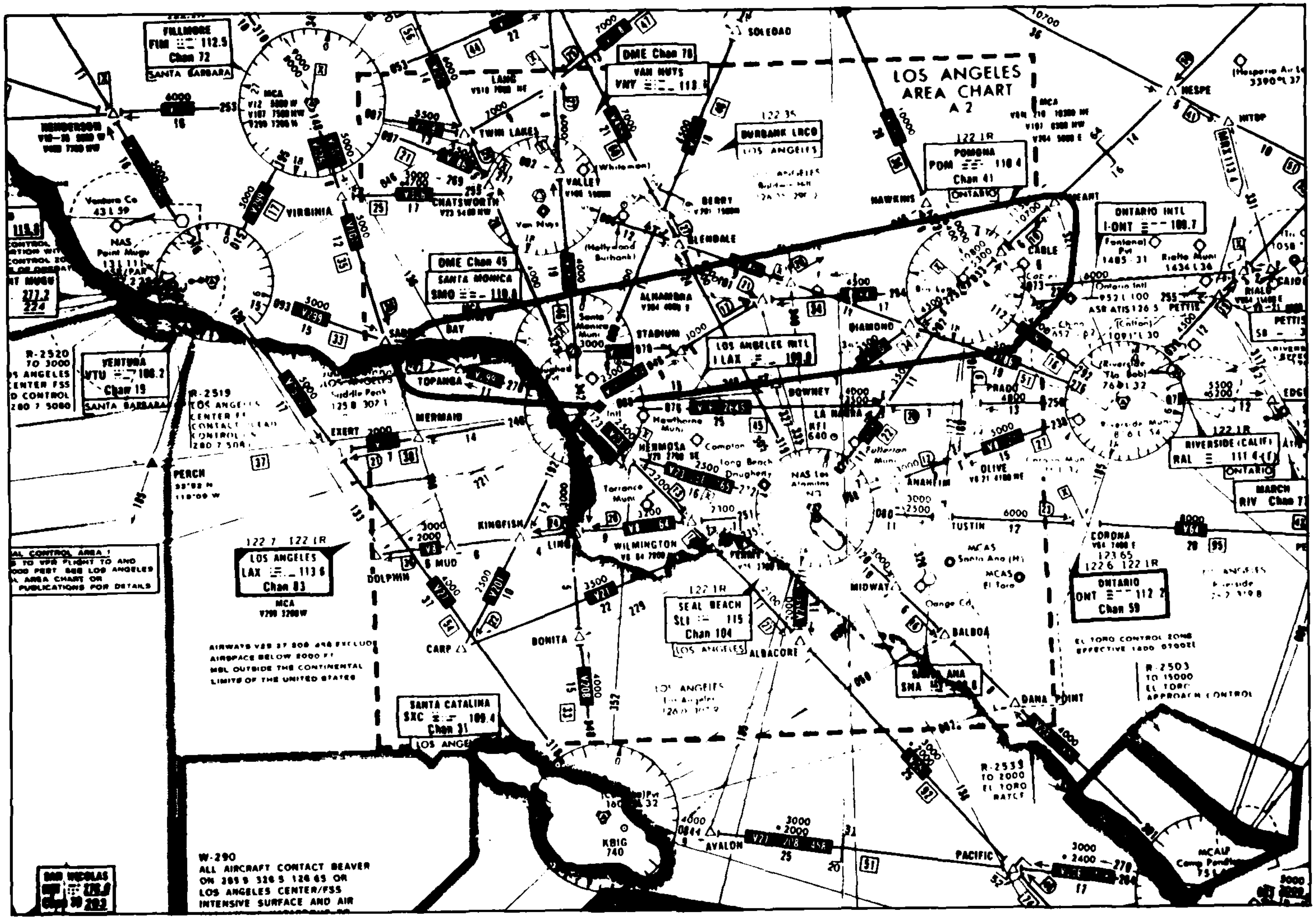


Figure 14. APPROXIMATE FLIGHT PATH, SCENARIO 1

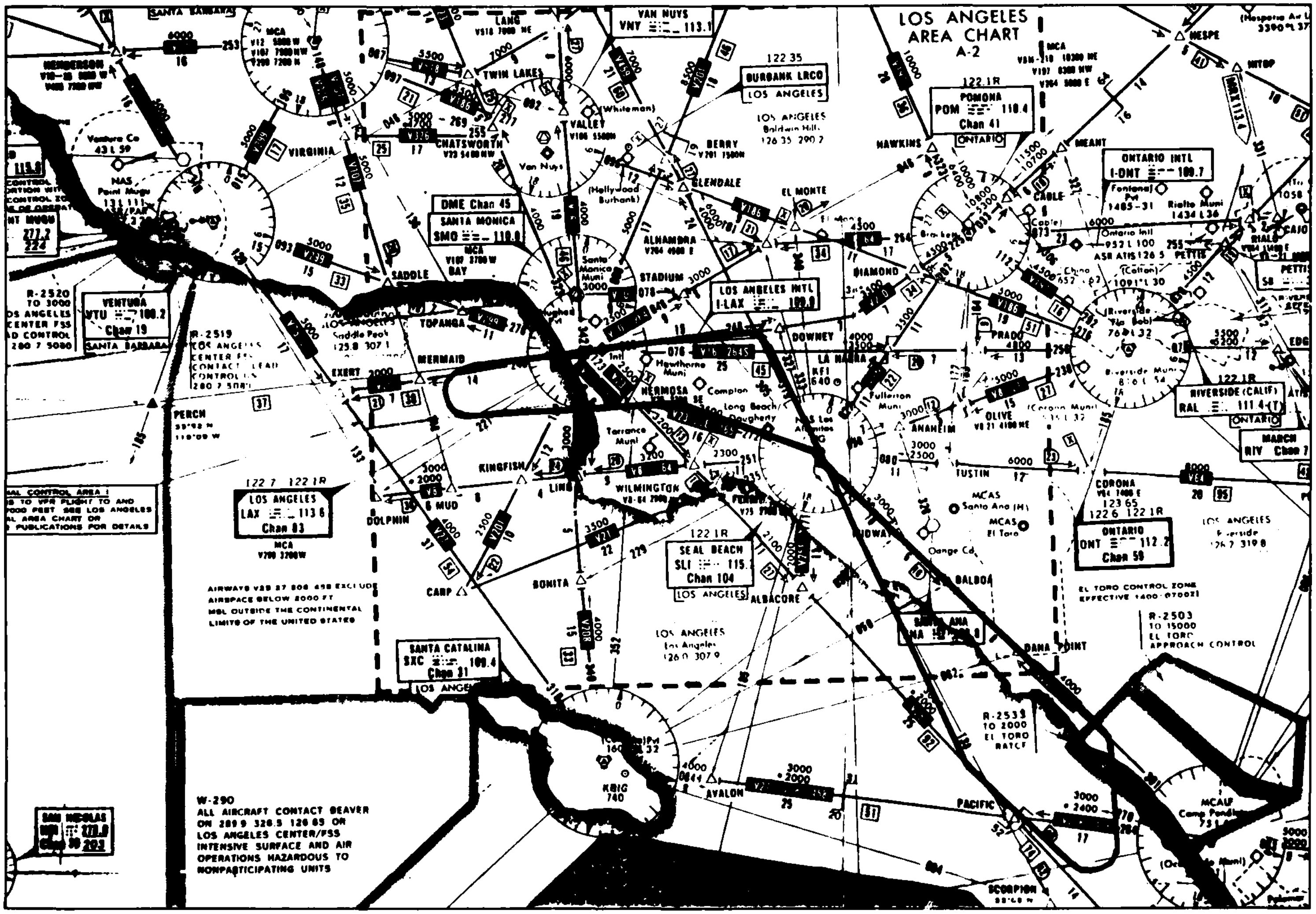


Figure 15. APPROXIMATE FLIGHT PATH, SCENARIO 2

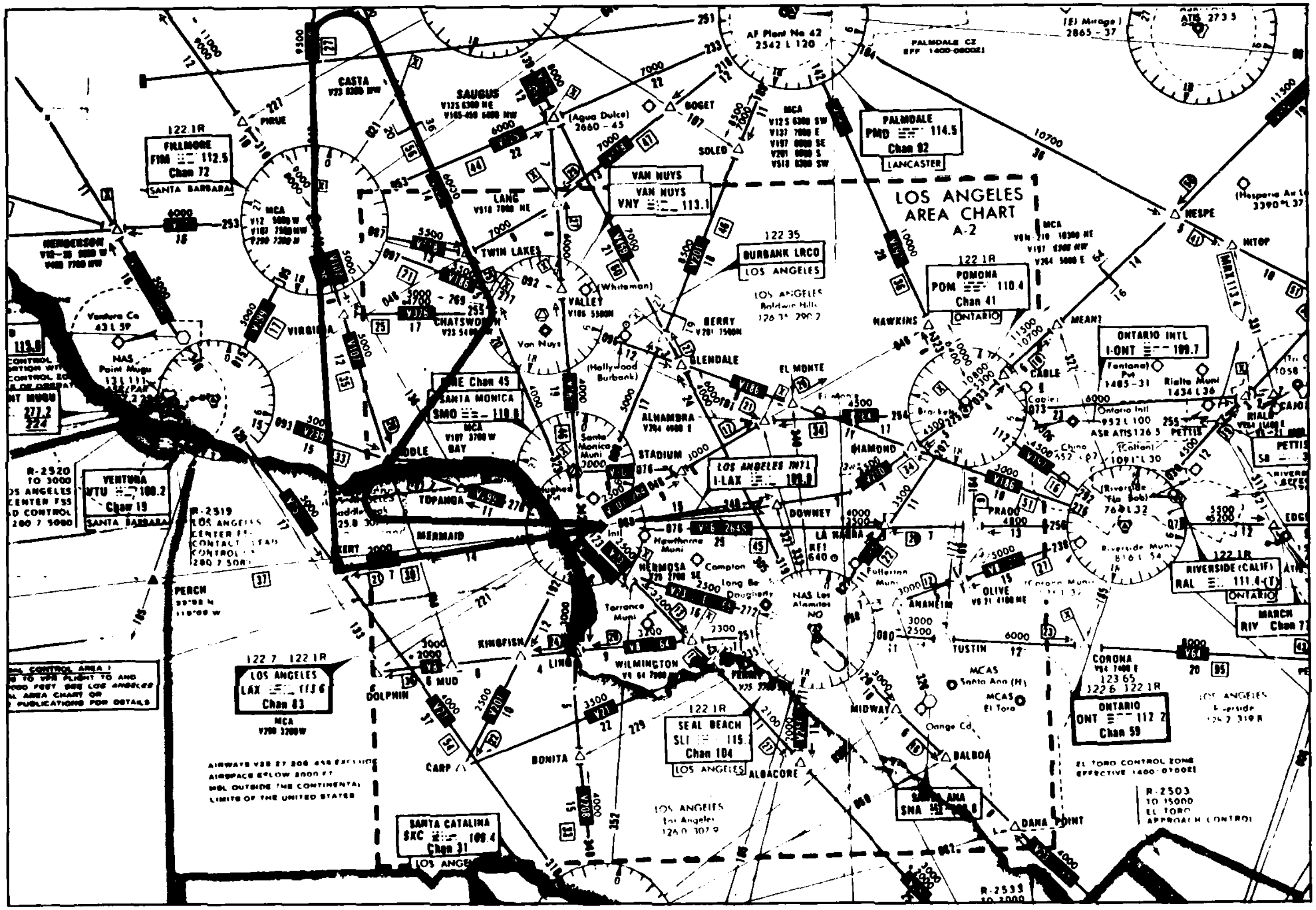


Figure 16. APPROXIMATE FLIGHT PATH, SCENARIO 3

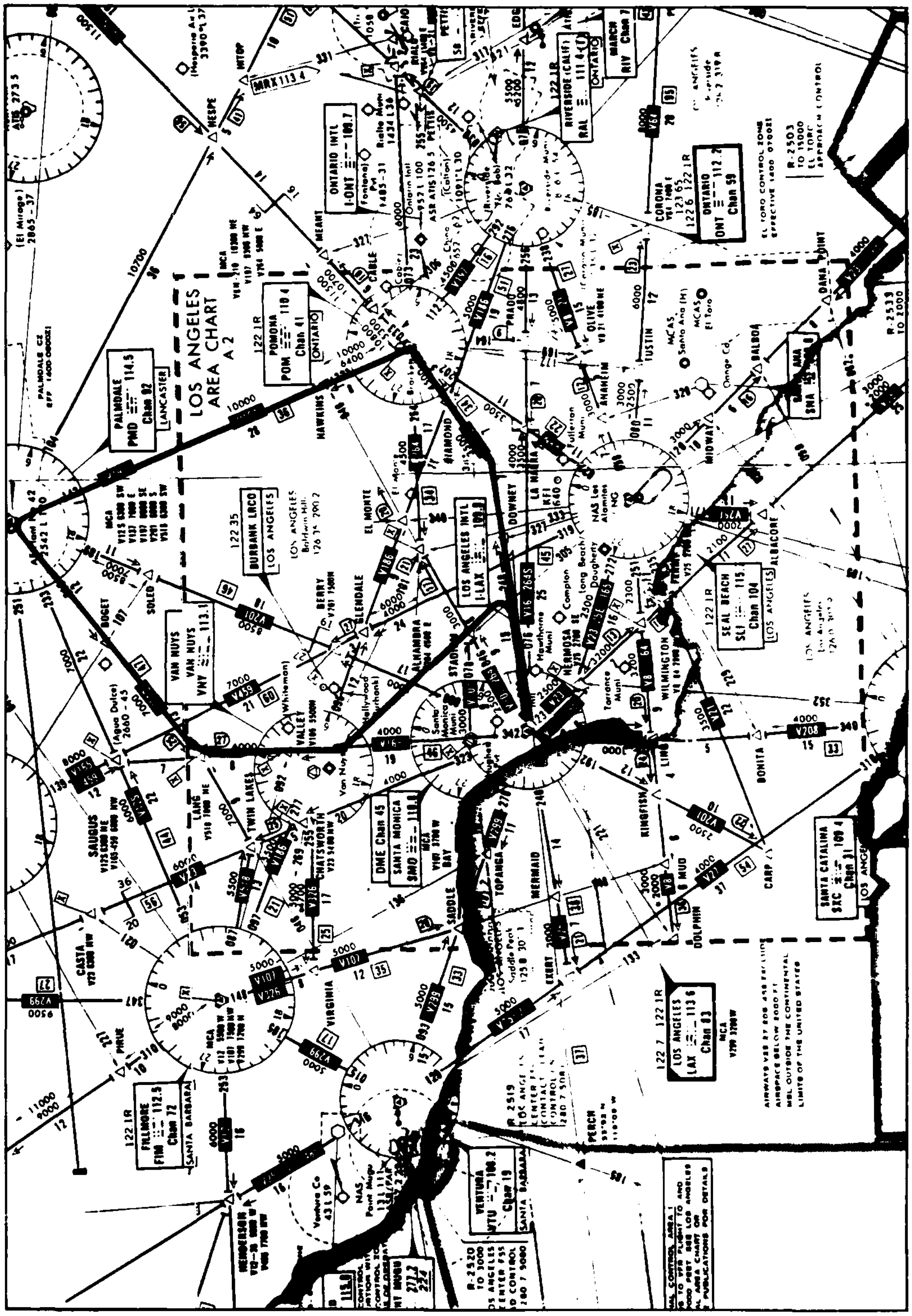


Figure 17. APPROXIMATE FLIGHT PATH, SCENARIO 4

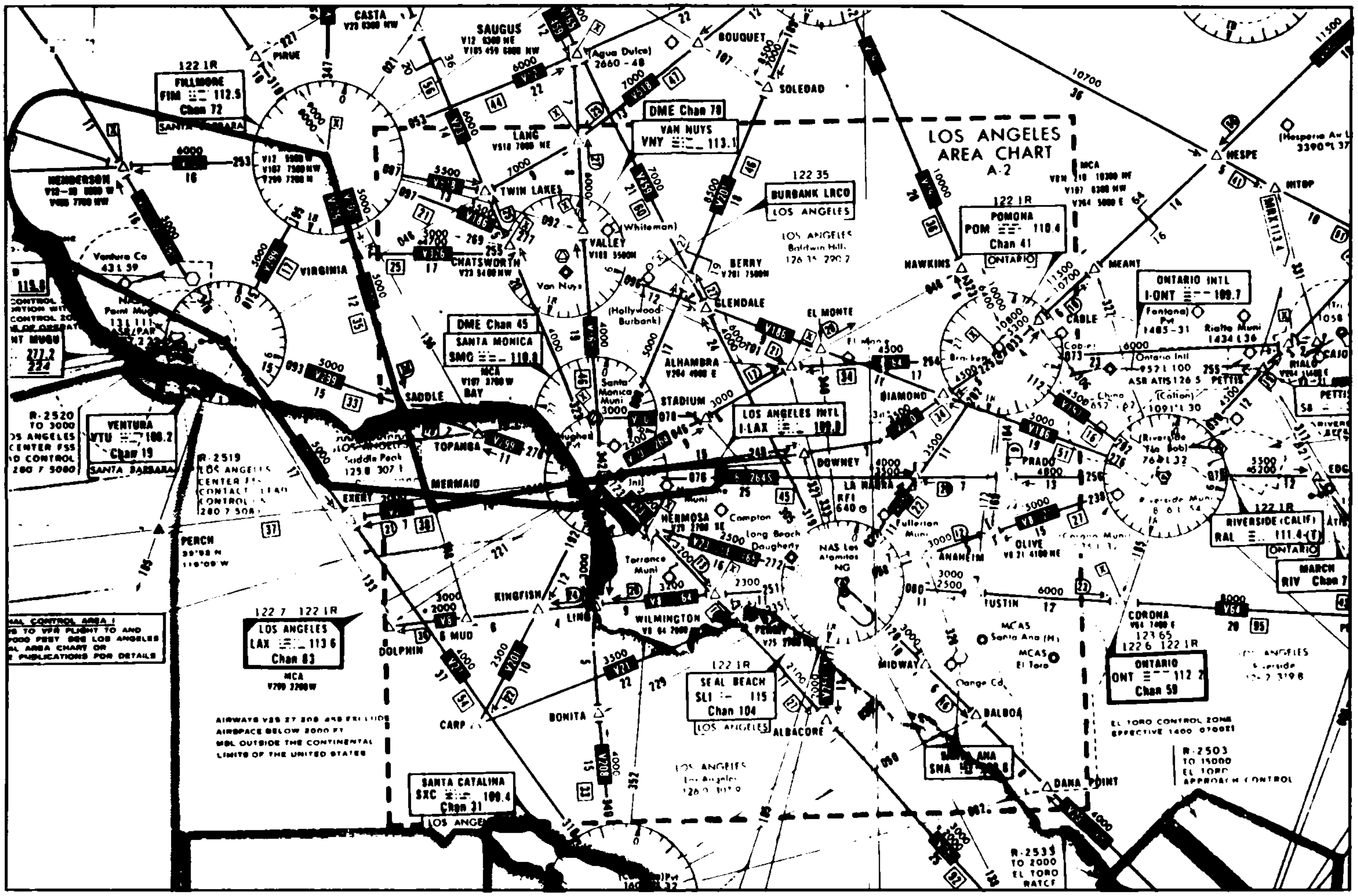


Figure 18. APPROXIMATE FLIGHT PATH, SCENARIO 5

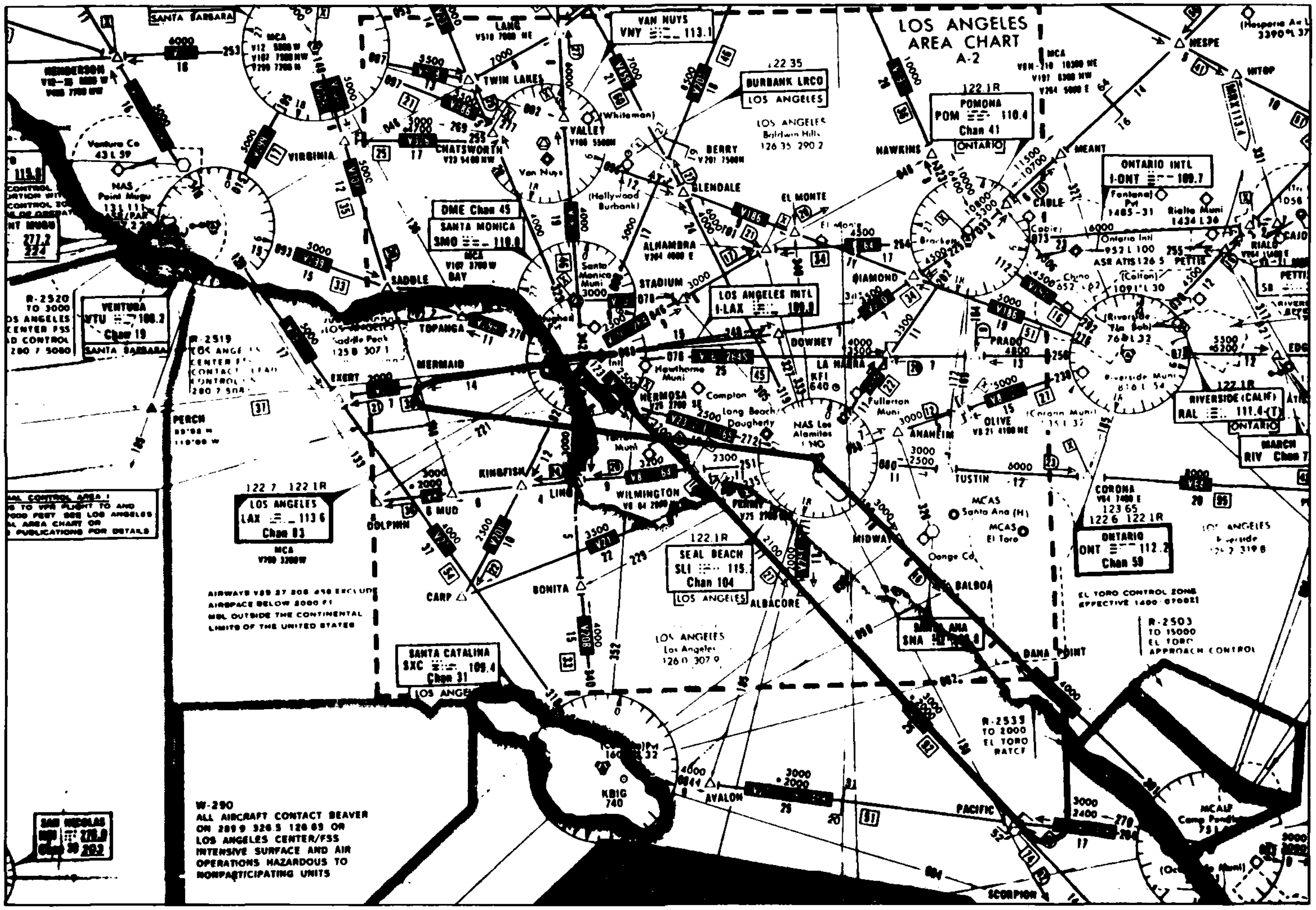


Figure 19. APPROXIMATE FLIGHT PATH, SCENARIO 6

APPENDIX C

SUBJECT PILOT PRE-BRIEFING

This appendix addresses the material and information associated with the pre-briefing given to each subject crew before the simulation session. The pre-briefing consisted of a slide show and video tape recording, a discussion of pilot procedures regarding conflict escape maneuvers, a description of the specific scenarios that the crew would be flying, and an orientation session in the cockpit simulator.

The slide show amplified and clarified the information sent to the pilots in the advanced briefing (Appendix B). It also incorporated all of the changes made to the program since the advanced briefing was mailed. These slides are presented at the end of this appendix.

Additional slides and a video tape recording were used to further explain the displays used in the simulation. A separate slide was shown for each of the possible commands that could be displayed on the IVSI and LED displays. Due to the greater complexity of the CRT display, a video tape of a developing conflict was presented to the test subjects for further explanation.

The escape maneuver discussion established the following procedures:

• CLIMB COMMAND	Rotate to a pitch-up attitude approximating a go-around configuration. Apply thrust as required.
• DESCENT COMMAND	Reduce thrust. Pitch over at an attitude approximating a profile descent.
• TURN COMMAND	Roll into a 30° bank in the direction of the command.
• LIMIT VERTICAL COMMAND	Obey the limit instruction.
• NO TURN COMMAND	Cease or avoid turning in the direction of the command.

INITIATE AN ESCAPE MANEUVER IF.....

1. A conflict is perceived in the cockpit visual system.
2. A conflict is perceived based on display traffic advisory information.
3. A command is presented on one of the ASA displays.

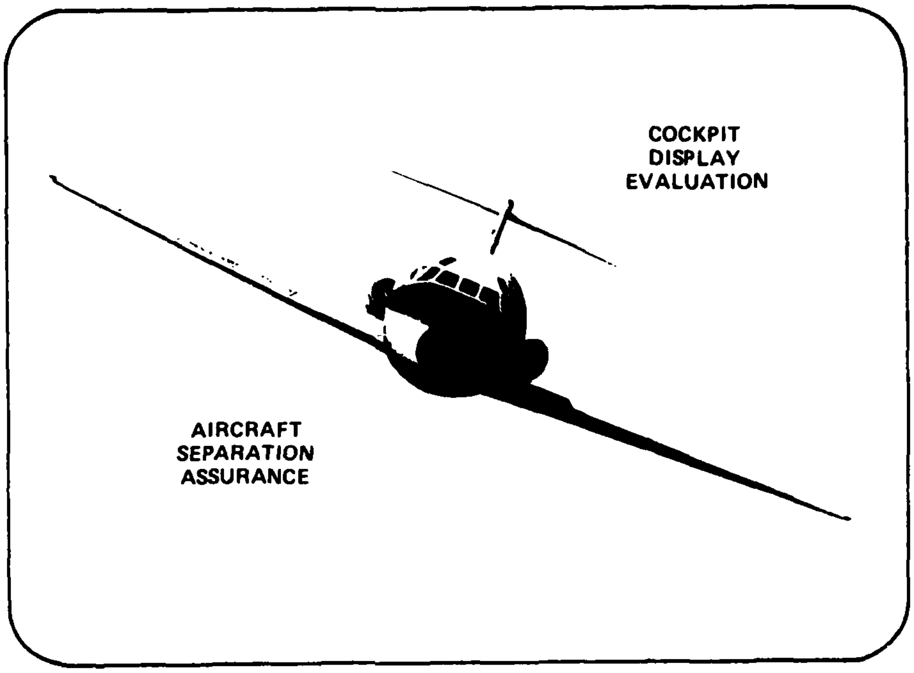
TERMINATE AN ESCAPE MANEUVER IF.....

1. The displayed command is cleared.
2. The conflict no longer exists and the display is clear.

Negative and limit vertical commands may occur even if the aircraft is straight and level or maneuvering in the opposite direction. These commands are advisory in nature. Positive commands should always be followed.

After the pre-briefing, the pilots were given a packet of information, which included the appropriate charts, for navigation in the Los Angeles area (Low Altitude En Route Charts, Area Charts, Standard Terminal Arrival Route (STAR) Charts, Standard Instrument Departure (SID) Charts, etc). The three scenarios to be flown were illustrated on the Area Charts. The pilots were informed of the order that the scenarios would be flown, the display that would be active during the scenario, and the proposed flight plan. They were not given information on the conflict geometries or locations.

The pre-briefing was concluded in the cockpit simulator. Pilots that were unfamiliar with the United Airlines 727 simulator were briefed on its operation and the associated visuals. In addition, before each scenario, the appropriate display was exercised to review the display presentation and interpretation.



BRIEFING OUTLINE

- Objectives
- CAS/ASA Background
- ASA System – Combination of Techniques/Modes
  - •• BCAS
    - ••• Active Mode
    - ••• Full BCAS Mode
  - •• DABS
- ASA System Logic
- ASA Commands
- SOP Flying ASA

(continued)

BRIEFING OUTLINE (continued)

- Displays
  - •• Modified IVSI
  - •• LED
  - •• CRT
- Test Equipment Setup
  - •• B727 Simulator with CGI
  - •• Test Computer
  - •• ATC Controller
  - •• Test Computer Operator
  - •• Cockpit Observer
  - •• Data Recording
- Scenario Review and Display Assignment
- Test Session
- Debriefing

OBJECTIVES

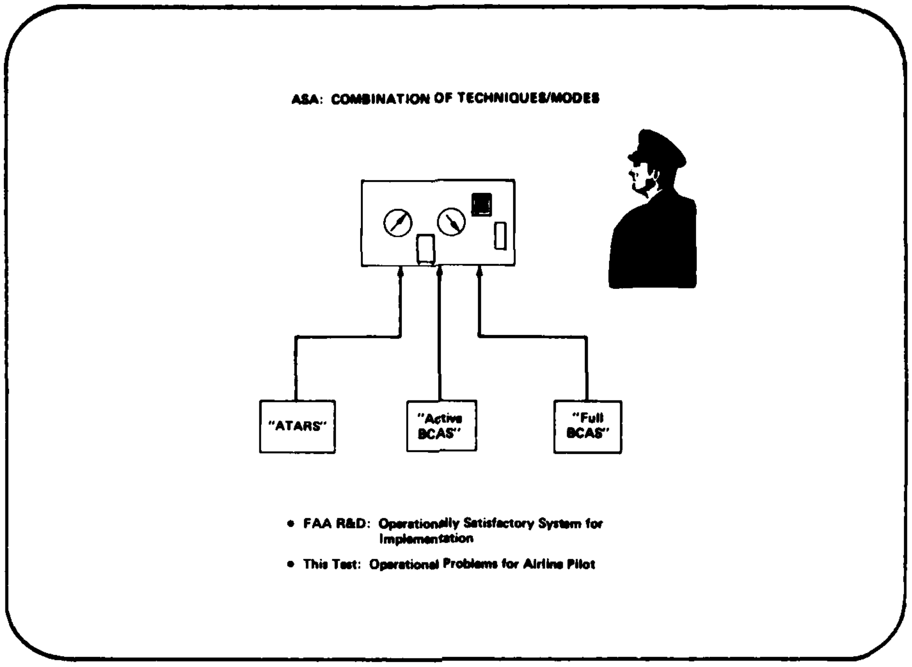
- Evaluate Display Concepts
  - •• Determine information required by flight crew
  - •• Most effective way to display it
- Evaluate Operational Impact on Flight Crew of Utilizing Proposed Displays

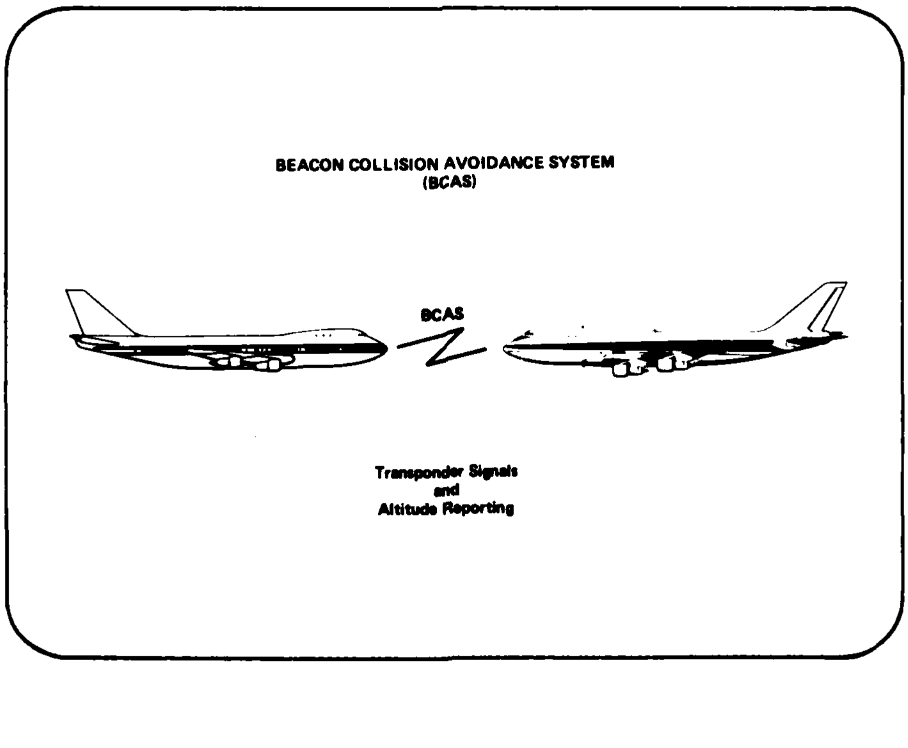
BASIC PRINCIPLES

- ATC Controller Responsible for IFR Separation
- Pilot Responsible for Safety of His Flight
- Collision Avoidance System is a Backup to Basic ATC System

BACKGROUND

- Industry Collision Avoidance System Program Since 1950s
  - Compatible equipment in aircraft
  - Based on tracking ATC transponder signals


ASA: COMBINATION OF TECHNIQUES/MODES
"ATARS"
"Active BCAS"
"Full BCAS"
• FAA R&D: Operationally Satisfactory System for Implementation
• This Test: Operational Problems for Airline Pilot


BEACON COLLISION AVOIDANCE SYSTEM (BCAS)
BCAS
Transponder Signals and Altitude Reporting

ASA MODES

- Active
  - No bearing
  - Vertical maneuvers only
- Full
  - Bearing
  - Vertical or horizontal maneuvers

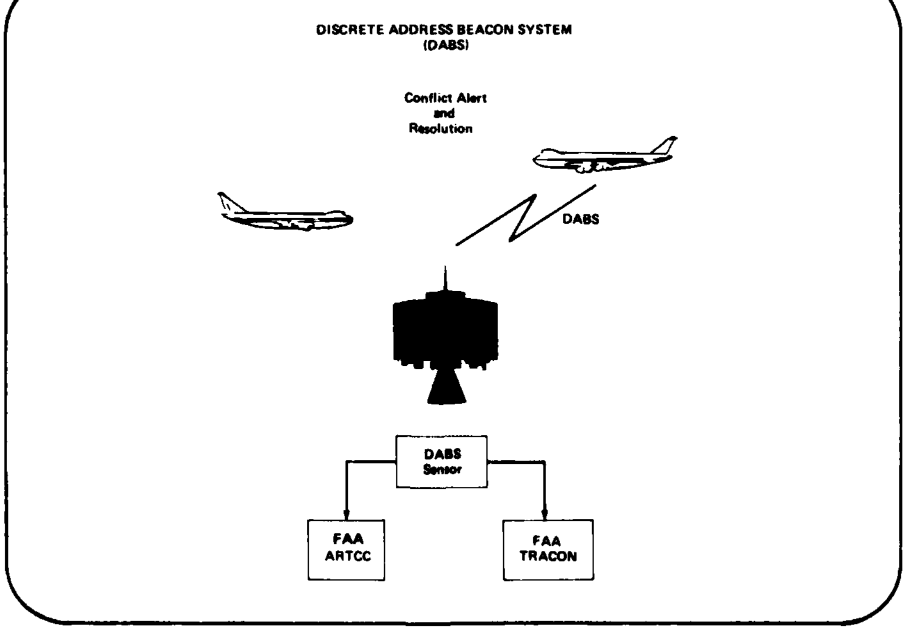
ACTIVE BCAS MODE

Actively Interrogates Other Aircraft in Same Way as Ground Radar

- Advantage
  - Can operate without ground radar
  - Will provide protection in majority of areas
- Problem
  - Causes radar interference – limited to low-traffic-density airspace
  - Cannot determine bearing to intruder

FULL BCAS MODE

- **Can Determine Bearing of Intruder**
- **Requires Ground Radar Signals**



ASA SYSTEM LOGIC

- Tracks Aircraft within Specified Distance
- Determines Range and Closure Rate
- Selects Command
- Provides Separation Even If Only One Aircraft Follows Command

ASA COMMANDS

- Limited Vertical
  - Limits climb/descent to 2000, 1000, 500 fpm
- Negative Commands
  - Don't Climb
  - Don't Descend
  - Don't Turn Right
  - Don't Turn Left
- Positive Commands
  - Climb
  - Descend
  - Turn Left
  - Turn Right

SOP (ALL DISPLAYS)

- Start the Maneuver When You Believe It Necessary
- Advise ATC if Deviation from Flight Path
- Acquire Target Visually if Possible

DISPLAYS

- Modified IVSI
- LED
- CRT

MODIFIED IVSI DISPLAY

- Display Characteristics
  - •• Standard IVSI and command indicators
  - •• Replaces IVSI for captain and first officer
- Symbology
  - •• Arrows
  - •• "Don't Turn" lights
  - •• "Limit Climb" commands

MODIFIED IVSI DISPLAY (continued)

- How to Fly IVSI Display
  - •• Follow red arrows and "Don't Turn" lights
  - •• Don't climb/descend into lighted yellow arc
- Modes
  - •• Full Mode: Climb/Descend/Turn commands
  - •• Active Mode: No-Turn commands

LED DISPLAY

• Display Characteristics

•• 3 lines of information

••• Traffic

••• Commands

•• Colors

••• Green: Traffic advisory

••• Orange: Limited vertical

••• Red: Positive Command

CRT DISPLAY

• Display Characteristics

•• Located where weather radar is normally mounted

•• Traffic filtered by logic so that only traffic of concern is displayed

••• Range

••• Closure Rate

••• Range/Range Rate

••• Altitude

(continued)

CRT DISPLAY (continued)

- Symbology: Full Mode
  - •• Ownship and altitude
  - •• Range marks: 3, 6, 9 miles
  - •• Traffic symbol
  - •• Intruder symbol
- Symbology: Active Mode
  - •• Range
  - •• Altitude
  - •• Command (vertical only)

TEST EQUIPMENT SETUP

- B727 Simulator with CGI Visual
  - •• 2-window visual
  - •• LAX city lights and navigational aids
  - •• Intruder aircraft — red flashing beacon; white steady taillight
  - •• 3 displays (IVSI, LED, CRT)
- Test Computer
  - •• Tracks simulator
  - •• Establishes conflicts
  - •• Provides ATC controller display
  - •• Records data

(continued)

TEST EQUIPMENT SETUP (continued)

- ATC Controller
  - •• Provides ATC instructions
    - ••• Not call traffic due to simulated high workload
    - ••• Allow conflicts to develop
- Test Computer Operator
  - •• Arranges intruder aircraft tracks
  - •• Data recording

(continued)

TEST EQUIPMENT SETUP (continued)

- Cockpit Observer
  - •• Notes crew reaction:
    - ••• Did you see intruder aircraft?
    - ••• Was command maneuver satisfactory?
  - •• Coordinates with test computer OPR
  - •• Answers crew questions
  - •• Briefs and debriefs crews
- Recording Data
  - •• Automatically by computer
  - •• Crew reaction and irregularities manually by cockpit observer
  - •• Tape recording of cockpit conversations

APPENDIX D

FLIGHT CREW QUESTIONNAIRE

Immediately following each simulator session, each member of the flight crew was asked to complete a questionnaire which addressed the following areas:

- Pilot Background
- Quality of Displayed Commands
- Display Characteristics
- Display Usability
- Traffic Advisories
- Command Presentation
- ASA Concepts
- Display Evaluation
- ASA Program

This appendix reproduces the questions and tabulated responses from the flight crew questionnaires. The results are presented as a percentage of all pilots that responded to the question followed by the number that responded (in parentheses). Following the results are the comments offered by the participants. The comments are included with only minor editorial changes to improve readability. Preceding each comment is a number that was assigned to each pilot and the responses made by that pilot.

An abbreviated version of the questionnaire was given to the first three crews (10 pilots). Additional questions were added following discussions with the FAA and are noted.

The pilot background data are summarized in Section 3.3 and not repeated here; however, the questions are included for completeness.

AIRCRAFT SEPARATION ASSURANCE

COCKPIT EVALUATION

FLIGHT CREW QUESTIONNAIRE

Name: ____

Company: ____

Present Position: ____________________ Aircraft: ____________________

Pilot Certificate(s) Held: ______________________________________

Total Hours: ______________________ Past Year: ____________________

Other Aircraft Regularly Flown: _________________________________

____

Were you familiar with the ASA program prior to your solicitation or selection to participate in this experiment?

YES 11% (8) NO 55% (41) VAGUELY 34% (25)

Do you regularly fly into LAX?

YES 54% (40) NO 46% (34)

(Approximately _____ times a year)

SECTION I

This section examines the quality of the displayed commands. Please answer each question for each display. If you wish to qualify any answer, please comment in the blank space below the question.

1. In general, were the actions required by the commands clear and unambiguous?

	ALWAYS	USUALLY	SELDOM	NEVER
IVSI:	56% (41)	38% (28)	6% (4)	0
LED:	57% (42)	36% (27)	7% (5)	0
CRT:	59% (43)	37% (27)	4% (3)	0

PILOT #		RESPONSES	COMMENTS
(6)	IVSI:	Usually	At one point on IVSI, a descent command was given followed by a max climb of 500 FPM followed by a descent - during that period, a continuous descent of over 1000 FPM or more was maintained.
	LED:	Always	
	CRT:	Always	
(9)	IVSI:	Usually	IVSI takes getting used to. One time you go to the light, the other you go away from the light.
	LED:	Always	
	CRT:	Always	
(39)	IVSI:	Always	CRT - Hard to read - display too small in readout. LED - Should be relocated for better vision.
	LED:	Always	
	CRT:	Usually	
(40)	IVSI:	Always	CRT - Display too small. Difficult to read quickly.
	LED:	Always	
	CRT:	Seldom	
(41)	IVSI:	Usually	IVSI - Don't turn not prominent. CRT - On this test, was very wavy and probably would have been easier to give a better rating.
	LED:	Always	
	CRT:	(No answer)	
(43)	IVSI:	Usually	Misread limited vertical speed indication at first. (Interpreted it as a command to climb at _____ FPM).
	LED:	Always	
	CRT:	Always	

SECTION I

PILOT #		RESPONSES	COMMENTS
(59)	IVSI:	Always	Commands on IVSI and LED had red to attract attention and arrows to assist rapid interpretation.
	LED:	Always	
	CRT:	Usually	
(67)	IVSI:	Always	Poor readout on LED.
	LED:	Seldom	
	CRT:	Always	

2. Were the vertical commands, "CLIMB", and "DESCEND" clearly understandable when presented on the:

	ALWAYS	USUALLY	SELDOM	NEVER
IVSI:	82% (60)	18% (13)	0	0
LED:	77% (57)	20% (15)	3% (2)	0
CRT:	78% (58)	20% (15)	2% (1)	0

PILOT #		RESPONSES	COMMENTS
(39)	IVSI:	Always	LED - Too dim to read sometimes; maybe due to location on the F/O's side. CRT - Little hard to read - readings flicker.
	LED:	Usually	
	CRT:	Usually	
(66)	IVSI:	Usually	Need bigger arrows on IVSI.
	LED:	Always	
	CRT:	Always	
(67)	IVSI:	Always	Poor readout on LED.
	LED:	Seldom	
	CRT:	Always	

3. Were the horizontal commands "TURN LEFT" and "TURN RIGHT" clearly understandable when presented on the:

	ALWAYS	USUALLY	SELDOM	NEVER
IVSI:	80% (58)	19% (14)	1% (1)	0
LED:	85% (63)	12% (9)	3% (2)	0
CRT:	72% (53)	24% (18)	3% (2)	1% (1)

3. Continued

PILOT #		RESPONSES	COMMENTS
(44)	IVSI:	Always	Still feel the LED should read TURN RIGHT.
	LED:	Always	
	CRT:	Always	
(60)	IVSI:	Always	Not presented (Left only, I believe).
	LED:	Always	
	CRT:	Always	
(61)	IVSI:	Always	Speed brake lever blocks lower left portion of scope.
	LED:	Always	
	CRT:	Always	
(66)	IVSI:	Usually	Need bigger arrows on IVSI.
	LED:	Always	
	CRT:	Always	
(67)	IVSI:	Always	Poor readout on LED.
	LED:	Seldom	
	CRT:	Always	

4. Were the limited vertical commands (e.g., "MAX CLIMB 2ØØØ") readable and understandable on the:

	ALWAYS	USUALLY	SELDOM	NEVER
IVSI:	56% (39)	39% (27)	5% (4)	0
LED:	72% (52)	21% (15)	7% (5)	0
CRT:	67% (48)	31% (22)	2% (2)	0

PILOT #	RESPONSES	COMMENTS
(6)	IVSI: (No answer) LED: Always CRT: Seldom	IVSI - From copilot seat, max climb 500, 1000, 2000 FPM light bar can't be seen with seat in normal height position. Hard to see from observer seat. CRT - From pilot seat, the left side instruction (i.e., LMT or DON'T) is partially or completely blotted out by the speed brake lever handle. Also, positive commands are blocked out by reverse lever knobs when throttles are in high power position.
(11)	IVSI: Usually LED: Always CRT: Usually	Would command, max descent 500-1000-2000, require any descent?
(19)	IVSI: Usually LED: Always CRT: Always	Climb barely visible.
(39)	IVSI: Usually LED: Always CRT: Usually	IVSI - F/O side with seat up; Could not see it until looked at Capt's side.

PILOT #		RESPONSES	COMMENTS
(40)	IVSI:	Always	When I was flying simulator, CRT display too small and in awkward place. Of little value to person flying unless other pilot constantly watches CRT and keeps pilot flying informed.
	LED:	Always	
	CRT:	(No answer)	
(41)	IVSI:	Usually	IVSI - climb limit is recessed too deep with the instrument in its present position.
	LED:	Always	
	CRT:	Usually	
(44)	IVSI:	Always	If LED or CRT winds up as final configuration, the use of limited vert command on IVSI would still be useful.
	LED:	Always	
	CRT:	Always	
(49)	IVSI:	(No answer)	LMT climb on F/O panel not completely visible.
	LED:	Always	
	CRT:	Always	
(60)	IVSI:	Always	Light too dim - instrument in poor position.
	LED:	Seldom	
	CRT:	Always	
(61)	IVSI:	Usually	At normal seat position, the climb unit lights cannot be seen directly.
	LED:	Always	
	CRT:	Always	
(66)	IVSI:	Usually	Yellow arcs on IVSI somewhat hard to see when you sit as far forward and up as high as I do (I'm short).
	LED:	Always	
	CRT:	Always	
(67)	IVSI:	Always	Poor readout on LED.
	LED:	Seldom	
	CRT:	Always	
(71)	IVSI:	Usually	Top half lights hard to see; top of case blocked.
	LED:	Always	
	CRT:	Always	

5. Are the no left and no right turn commands readable on the:

	ALWAYS	USUALLY	SELDOM	NEVER
IVSI:	38% (27)	45% (32)	11% (8)	6% (4)
LED:	81% (58)	19% (14)	0	0
CRT:	75% (55)	21% (15)	4% (3)	0

PILOT #		RESPONSES	COMMENTS
(6)	IVSI:	Usually	No right turn can't be seen from observer seat.
	LED:	Always	
	CRT:	Seldom	The word "DON'T" is blocked by speed brake handle.
(39)	IVSI:	Always	IVSI could be changed to green instead of a red light display.
	LED:	Always	
	CRT:	Always	
(54)	IVSI:	Usually	After learning what they meant on the IVSI it was no problem.
	LED:	Always	
	CRT:	Always	
(58)	IVSI:	Seldom	Hard to see and include in cross check.
	LED:	Usually	
	CRT:	Usually	
(60)	IVSI:	Never	Did not have command.
	LED:	Always	
	CRT:	Always	
(61)	IVSI:	Seldom	IVSI was very dim and was seen only in initial test run.
	LED:	Usually	
	CRT:	Always	
(63)	IVSI:	Never	Did not see.
	LED:	Always	
	CRT:	Always	
(74)	IVSI:	(No answer)	Hard to see on F/O side.
	LED:	Always	
	CRT:	Always	

6. a) What changes in format should be made to improve the:

IVSI:
LED:
CRT:

PILOT #		COMMENTS
(1)	LED:	Instrument placement
	CRT:	Instrument placement, color commands
(2)	IVSI:	No turn lights-larger
	CRT:	Range circles lighted for night use
(3)	IVSI:	Position instrument where more visible
	LED:	Reposition to where all crew members can see
(4)	IVSI:	Improve "No Left" and "No Right" readability; also, limit climb lights are hard to see.
	LED:	Hard to interpret intruder's heading compared to our own. Difficult to relate intruder's position to our own - not easy to decipher degree of threat quickly.
	CRT:	Move data tag away from intruder tail so that speed and direction are easier to see.
(5)	LED:	When an action is required, delete the traffic advisory message. The "LED" display, if used, should be mounted to allow S/O to observe display (one display visible to all).
(6)	IVSI:	Signals more prominent, plus additional information, i.e., LED altitude and distance information.
	CRT:	Altitude indications not big enough, commands hard to see.
(7)	IVSI:	Larger letters
	CRT:	Targets too small
(9)	CRT:	Too bright in active mode; to get full benefit of the system, we should be able to call up all targets on the CRT if we choose. That way, we can provide separation on targets that may not be a threat.
(10)	IVSI:	More positive expression of "Don't Turn Left/Right"
	LED:	Format O.K., position distracts scan
	CRT:	Format O.K., takes some time to evaluate (no basic problem)
(11)	LED:	Little out of scan
	CRT:	Very hard to read numbers; location a problem; has tendency to lock viewer to screen.

Question #6a continued

PILOT #		COMMENTS
(12)	CRT:	Better range marks
(13)	LED:	Lights need to be brighter
(14)	LED:	More differentiation between clock position and range.
(15)	IVSI:	Location
	LED:	Location
	CRT:	Two - on forward panel
(21)	IVSI:	Larger negative command displays
	CRT:	Better and larger symbols; some confusion apparent in logic
(22)	LED:	The readout of information is too small; instrument located in bad position on instrument panel.
(24)	IVSI:	More visible limit vertical speed
	LED:	Location of LED
(25)	IVSI:	Turn Left, Turn Right symbology with arrows; no alpha
	LED:	F/O brighter display needed
(26)	LED:	Relocate LED on Capt's side
(30)	IVSI:	Would like to have this information on the approach horizon
	LED:	Physical location bad - F/E out of the loop
	CRT:	Visibility in daylight may be a problem
(31)	IVSI:	No Left and No Right commands could be displayed larger
	LED:	Position instrument at higher eye position
(32)	IVSI:	Arrows, left-right should be out of instrument IVSI is a "vertical speed" device. A fatigued pilot may not associate left-right with IVSI.
(33)	IVSI:	Larger-brighter
	LED:	Same
	CRT:	Need more clarity
(34)	CRT:	Aircraft information too small - couldn't read
(35)	IVSI:	O.K.
	LED:	Very poor display; cannot recommend a fix
	CRT:	Larger printing for altitude

Question #6a continued

PILOT #		COMMENTS
(36)	IVSI:	Larger display on NO TURN
	CRT:	Did not like active mode format. (No need for the format as you would learn symbols). Symbols too small.
(37)	IVSI:	No change
	LED:	No change
	CRT:	Did not like active format
(38)	IVSI:	None
	LED:	None
	CRT:	Not clear enough for the pilot flying without taxing concentration. Perhaps larger target display.
(39)	IVSI:	Relocate or tilt to see climb portion
	LED:	Relocate higher up
	CRT:	Larger readout on aircraft display
(40)	CRT:	Display must be much larger, and this unit also requires thinking time more so than others (IVSI and LED) in determining how close the traffic was.
(41)	IVSI:	Change location or bring face closer to glass
(42)	IVSI:	"No turn commands" larger
	LED:	None
	CRT:	None
(44)	IVSI:	O.K.
	LED:	Add turn direction i.e., TURN RIGHT
(45)	IVSI:	No turn lights too small
(46)	CRT:	Difficult to read from Capt. seat. Speed brake handle and throttles in way.
(48)	IVSI:	No left/no right turn lights too small
	LED:	Eliminate direction of flight information
(49)	IVSI:	Location - "Don't turn" ambiguous
	LED:	Location
(50)	IVSI:	Make no left and no right brighter. At level flight, left turn arrow obscured by IVSI needle.
	LED:	Less text and more symbolic displays

Question #6a continued

PILOT #		COMMENTS
(53)	IVSI:	Brighter display
	LED:	Brighter display
(54)	IVSI:	Not worth improving
	LED:	Can't really say after such short exposure to both these systems.
	CRT:	Same
(55)	IVSI:	Better no left/right - hard to see
(57)	IVSI:	Good
	LED:	Good
	CRT:	More distinctive command display
(58)	IVSI:	Better (larger) no turn indicators
	LED:	Place closer to normal scan pattern
	CRT:	It was outside my normal scan pattern; Consequently, I did not cross check frequently.
(59)	IVSI:	None within constraints of instrument
	LED:	None
	CRT:	Red commands and amber for maneuvers limit. Arrows for commands.
(60)	IVSI:	Don't like negative commands
(61)	IVSI:	Perhaps use one light in corner (red) to signal no turn.
	LED:	Location is very poor as is. Doesn't draw your attention.
(62)	CRT:	More distinctive audio
(63)	IVSI:	O.K.
	LED:	O.K.
	CRT:	Larger symbols and relocate
(65)	IVSI:	Eliminate instrument
	CRT:	Use color coding of LED
(66)	CRT:	Use arrows instead of text for positive commands
(67)	LED:	Improve readout clarity
	CRT:	Altitude readout too small
(68)	CRT:	Symbology of altitude readout

Question #6a continued

PILOT #		COMMENTS
(69)	LED:	Too much data (i.e., second target)
	CRT:	Too much symbology
(70)	CRT:	None - would be better as experience is gained with CRT presentation
(71)	IVSI:	Top lights (limit climb) should be made more visible
(72)	CRT:	Too much writing on scope in active mode
(73)	CRT:	Active mode could use less words in constant display
(74)	CRT:	Active mode writing should be left off

6. b) In your opinion, what is the best presentation for positive commands (e.g., text, arrows)?

(Added as part of questionnaire revision)

PILOT #	COMMENTS
(11)	Arrows or combination of both
(12)	Arrows
(13)	Arrows - there is no doubt which way to turn - best in my opinion
(14)	Text
(15)	Arrows
(16)	Text
(17)	Arrows
(18)	IVSI
(20)	Arrows
(21)	LED

Question #6b continued

PILOT #	COMMENTS
(22)	Text
(23)	Arrows
(24)	Red text
(25)	Arrows
(26)	LED
(27)	CRT
(28)	LED - better to see arrows than to read it
(29)	Text
(30)	The arrows are quite effective. They stand out, but the text is quite satisfactory.
(31)	Text
(32)	LED - for arrows; trying to associate position of aircraft with target was a bit confusing.
(33)	Arrows
(34)	Arrows
(35)	IVSI - a simple positive presentation
(36)	LED - was best - plain language
(37)	IVSI
(38)	Arrows
(39)	Text and arrows - maybe combination of arrows on CRT; descent or climb - left turn or right turn
(40)	Either the LED or the IVSI arrows were acceptable. Note: I'd prefer to see green arrows used to indicate where to go instead of red.

Question #6b continued

PILOT #	COMMENTS
(41)	Arrows and text
(42)	Text
(43)	Likes the LED presentation
(44)	Text and arrows
(45)	Combinations
(46)	IVSI
(47)	Arrows
(48)	Arrows best, but I found no difficulty interpreting text either
(49)	LED
(50)	Arrows
(51)	LED
(52)	Arrows - they require only a glance for full recognition
(53)	Text
(54)	Combination of text and arrows
(55)	Combination of a picture with text as in the CRT
(56)	CRT display
(57)	Arrows
(58)	Arrows - or arrows and text
(59)	Arrows (with text to improve interpretation)
(60)	A bright display that will immediately catch your attention. Perhaps similar to master caution on B737.
(61)	Arrows - they are simple - direct - positive

Question #6b continued

PILOT #	COMMENTS
(62)	Text and arrows
(63)	For positive command, the IVSI is best but doesn't give any information to the pilot for him to decide what degree of a maneuver to use. For that case the LED serves better.
(64)	Text
(65)	Text and arrows combined
(66)	Arrows are much easier to react quickly to
(67)	Arrows
(68)	Text
(69)	Text (LED)
(70)	LED - at present
(71)	Arrows
(72)	Arrows with word climb
(73)	LED
(74)	Arrows first - then text

SECTION II

This section examines the characteristics of the displays.

7. Did the use of color (green for advisories, yellow for maneuver limits and red for commands) help in interpreting the information presented on the:

	VERY MUCH	SOME	VERY LITTLE	NONE
IVSI:	44% (31)	39% (28)	16% (11)	1% (1)
LED:	55% (40)	32% (23)	11% (8)	2% (2)

PILOT #		RESPONSE	COMMENTS
(42)	IVSI: LED:	Very Little Very Little	They would help after more familiarization.
(43)	IVSI: LED:	Very Little Very Much	Red got my attention on LED. Couldn't care less about color on IVSI.
(49)	(No answer)		I did not think of the color code but am sure that subconsciously it did have an effect on the action.
(71)	IVSI: LED:	Very Little Very Little	Might depend on experience
(74)	IVSI: LED:	Some Very Much	Hard to see on F/O

8. a) On the CRT, were you able to differentiate between threat targets and non-threat targets prior to commands?

YES 76% (45) NO 24% (14)

(Added as part of questionnaire revision)

PILOT #	RESPONSE	COMMENTS
(15)	YES	After some thought
(25)	NO	Because I did not respond to display unless alert sounded.

Question #8a continued

PILOT #	RESPONSE	COMMENTS
(39)	YES	If in level flight; in a turn, have to think which way he's going in relation to your aircraft.
(58)	YES	Somewhat, however, that was difficult because of CRT placement.
(62)	(No answer)	Time consuming to analyze initial presentation, requires head down.
(63)	YES	But very time consuming
(64)	YES	But took time to completely understand information presented - direction of intruder aircraft track would be more helpful than the tail.
(70)	NO	Believe with experience I could differentiate much better.

8. b) Would the use of colors (green for advisories, yellow for maneuver limits and red for commands) help you in interpreting the information presented on the CRT?

VERY MUCH	SAME	VERY LITTLE	NONE
44% (31)	48% (34)	7% (5)	1% (1)

PILOT #	RESPONSE	COMMENTS
(4)	Some	If filled in intruder circle turned red, it would enhance warning signal.
(42)	Some	After more familiarization

9. a) Was the range information used for this test satisfactory?

	VERY MUCH	SOME	LITTLE	NONE
LED:	59% (42)	32% (23)	9% (6)	0
CRT:	59% (43)	34% (25)	7% (5)	0

PILOT #		RESPONSES	COMMENTS
(14)	LED:	Some	For CRT, would rather not have pop-up targets at short range if possible.
	CRT:	Some	
(24)	LED:	Very Much	Larger scale with more warning would allow time to deviate and advise ATC sooner.
	CRT:	Very Much	
(60)	LED:	Very Much	However, in CRT test, I did not notice 3 & 6 mile radii - my attention was more on traffic itself.
	CRT:	Very Much	
(62)	LED:	Little	Requires head down and time
	CRT:	Little	
(74)	LED:	Some	Hard to interpret
	CRT:	Very Much	

9. b) A better scale factor would be:

LED:
CRT:

PILOT #		COMMENTS
(9)	CRT:	Selectable
(10)	LED:	If the display came on infrequently, one could forget the positional meaning (heading, range, etc.)
(12)	CRT:	Scale needs visibility improved
	CRT:	2 mile scales 2-4-6-8
(14)	CRT:	At short range, increase scale so that full scale is, for example, 4.5 versus 9 miles

Question 9b continued

PILOT #		COMMENTS
(21)	CRT:	One or two mile increments
(24)	LED:	Didn't know what scale was
(37)	LED:	No change
	CRT:	Some type of grid
(41)	CRT:	Might be better if unit was smaller and placed on both panels
(43)	CRT:	I don't feel good about critiqueing CRT. Of the three I think I like it least. Probably need more time with CRT, but still probably would like it least (except in active mode).
(61)	CRT:	Range lines could be more distinct
(63)	CRT:	Lighted range scale is needed, similar to a radar,
(65)		More experience would help before making a judgment
(70)	CRT:	Range marks on CRT which I understand would be put on.

SECTION III

This section examines the usability of the displays.

10. Do any of the displays contain TOO MUCH or TOO LITTLE information, that is -- is the display too busy or not informative?

(Added as part of questionnaire revision)

	IVSI	LED	CRT
About right			
Add the following			
Delete the following			

PILOT #		RESPONSES	COMMENTS
(9)	CRT:	Add the following	Would like heading readout at top and eliminate range marks.
(12)	LED:	Delete the following	This presentation is busy but I don't know what to delete.
	CRT:	Delete the following	Better range information rate information would be a help.
	CRT:	Delete the following	When in active mode, wording on screen distracted from information.
(15)	CRT:	Add the following	Relative bearing
(20)	CRT:	Add the following	Color and better range information

Question #10 continued

PILOT #		RESPONSES	COMMENTS
(21)	CRT:	Add the following	Projected ground track of intruder, color
(23)	LED:	Delete the following	Too busy
(24)	CRT:	Add the following	Arrow too small indicating climb or descent of opposing traffic
(25)	LED:	Delete the following	Should not display if not conflicting with aircraft
(26)	IVSI:	Add the following	Larger no turn lettering
	CRT:	Add the following	Larger letter and numbers on scope
(27)	LED:	Add the following	Confusing at first; miles and altitude
(28)	IVSI:	Add the following	Would help to have distance and bearing to intruder
	LED:	Add the following	Would help to have pictorial display like CRT
	CRT:	Add the following	Would like to see arrows instead of words like LED
(29)	IVSI:	Add the following	Could use range and bearing
	LED:	Delete the following	Could be confusing with 3 lines
	CRT:	About right	Has potential to handle information
(33)	IVSI:	About right	
	LED:	(No answer)	Simplify readout
	CRT:	(No answer)	Simplify readout
(34)	LED:	Delete the following	Too much information; information displayed of no value, not relevant
	CRT:	Delete the following	Difficult to read small numbers, too many displays not relevant
(35)	IVSI:	About right	
	LED:	(No answer)	Did not care for other display - both are too busy
	CRT:	(No answer)	

Question #10 continued

PILOT #		RESPONSES	COMMENTS
(36)	IVSI:	Add the following	Range of traffic; bearing of traffic
	CRT:	Add the following	Symbols too small
(37)	IVSI:	About right	
	LED:	About right	
	CRT:	Add the following	Larger letters and numbers
(38)	IVSI:	About right	
	LED:	About right	
	CRT:	Add the following	Targets too small
(39)	IVSI:	About right	
	LED:	About right	
	CRT:	Add the following	Arrows for descent, climb, left and right turns.
(40)	IVSI:	About right	
	LED:	About right	
	CRT:	Delete the following	The characters in the display and eliminate the tendency for pilot to evaluate the target threat.
(42)	IVSI:	Delete the following	*500 foot limit climb or descent*
	LED:	About right	
	CRT:	About right	
(44)	IVSI:	About right	
	LED:	About right	Traffic aircraft track information as clock relative own aircraft
	CRT:	Add the following	Indication of own aircraft rate in horizontal path prediction
(46)	CRT:	Delete the following	"Active wording"
(48)	IVSI:	About right	
	LED:	Delete the following	Heading and possibly altitude of threat of aircraft
	CRT:	About right	
(49)	IVSI:	Add the following	Let turn commands correct turns; if in left turn, would be sufficient to stop turn
	IVSI:	Delete the following	Don't turn commands
	LED:	About right	
	CRT:	(No answer)	An airplane or "H" could make direction of flight easier to determine in place of "O".

Question #10 continued

PILOT #	RESPONSES	COMMENTS
(50)	IVSI: About right	
	LED: Delete the following	Too much text; replace with symbols For display of target positions. Text could be replaced with symbols for some of the commands.
	CRT: About right	
(52)	IVSI: About right	
	LED: Add the following	Positive commands could flash on and off to help attract attention to essential information. Positive commands should be displayed initially by themselves to reduce the amount of information necessary to assimilate at a glance.
(55)	IVSI: About right	
	LED: About right	
	CRT: Add the following	Coloring
(58)	IVSI: About right	
	LED: About right	
	CRT: Add the following	I found the small aircraft signs hard to see, also placed outside normal scan.
(59)	LED: About right	
	IVSI: Add the following	I liked the advisories of LED and CRT but could not add within constraints of IVSI
	CRT: About right	
(60)	IVSI: About right	Calculation of max rate of climb - also a good feature of the LED
	LED: About right	Range, data presentation
	CRT: Add the following	Arrows on targets should be bolder, perhaps instead of solid dot to represent conflict - a blinking dot could be used.
(61)	IVSI: Add the following	Make no turn signals more distinct
	LED: About right	
	CRT: Add the following	Range lines could be clearer

Question #10 continued

PILOT#	RESPONSES	COMMENTS
(62)	IVSI: About right	
	LED: Add the following	Simplify advisory information
	CRT: Add the following	More positive target direction; high or low information; descending or climbing information
(63)	IVSI: Add the following	A minimum rate of maneuvering should be established. Example: 2000 descent whenever that is required.
(65)	LED: About right	
	CRT: Add the following	Color coding; bigger readout of numerals
(66)	IVSI: Add the following	Unfortunately, this display provides no information on where threat is -- this is useful information.
(67)	IVSI: About right	
	LED: Add the following	Altitude
	CRT: About right	
(69)	IVSI: About right	
	LED: Delete the following	Too much data when 2 targets presented
	CRT: Delete the following	
(71)	IVSI: About right	
	LED: Delete the following	Could delete course information
	CRT: About right	
(72)	IVSI: (No answer)	Couple the IVSI command display with the CRT information display for the best combination.
(73)	LED: About right	Display gets busy with more than one target.
	CRT: Delete the following	Fewer words to indicate "active mode"
(74)	IVSI: Delete the following	Maybe only have 2 minimum and maximum climbs instead of 3
	LED: Delete the following	Too much traffic information; confusing to read and quickly interpret
	CRT: Delete the following	No active paint out on mode on top of CRT

11. Do you feel that the audio alert was necessary to draw your attention to commands on the:

	ALWAYS	USUALLY	ABOUT HALF THE TIME	SOMETIMES	NEVER
IVSI:	34% (24)	18% (13)	18% (13)	23% (16)	7% (5)
LED:	38% (27)	17% (12)	25% (18)	15% (11)	5% (4)
CRT:	40% (29)	25% (18)	13% (9)	15% (11)	7% (5)

PILOT #	RESPONSES	COMMENTS
(4)	IVSI: Sometimes LED: Sometimes CRT: Sometimes	Easy to notice visual signal at night. Audio alert probably much needed in daylight.
(10)	IVSI: Never LED: Never CRT: Never	Never - but most likely because we were "primed" for this alert system.
(15)	(No answer)	I did not hear it.
(30)	IVSI: Never LED: Never CRT: Never	At night, my attention was drawn to the display. In fact, at one time I got a fixation on it and forgot the horizon. During the daylight, the alert might be more important.
(34)	(No answer)	Difficult to hear any of the audio alert systems.
(39)	IVSI: Usually LED: Usually CRT: Usually	If not on radio talking or listening, how about combination audio and light.
(42)	IVSI: Sometimes LED: Usually CRT: Usually	Depends on day or night.
(4[illegible])	IVSI: Usually LED: Usually CRT: Always	LED needed to be in a better position.
[illegible]	IVSI: Sometimes LED: Sometimes CRT: Sometimes	However, I don't think audio is loud or strong enough.

Question #11 continued

PILOT #	RESPONSES	COMMENTS
(55)	IVSI: Always LED: Always CRT: Always	Should be a more distinctive sound and possibly louder.
(60)	IVSI: Always LED: Always CRT: Always	Had not used similar equipment before; also, due to location of presentation.
(62)	IVSI: Sometimes LED: Sometimes CRT: Sometimes	Need more distinctive audio signal standard for collision avoidance.
(63)	IVSI: About half the time LED: About half the time CRT: Always	(only because of location)
(66)	IVSI: Always LED: Always CRT: Always	I don't want another aural sound, but I do feel it was necessary.

12. a) Does the modification of the IVSI by addition of command lights detract from the primary purpose of the instrument?

YES 7% (5)   NO 93% (66)

PILOT #	RESPONSES	COMMENTS
(9)	Yes	Probably would get used to it.
(39)	Yes	Maybe a single light at 500, 1,000, 2,000.

12. b) Could another existing aircraft instrument be modified to provide CAS information?

YES ________   NO ________

If yes, which ________________________

(Added as part of questionnaire revision)

PILOT #	RESPONSES	COMMENTS
(11)	Yes	Anything in scan pattern would help.
(15)	Yes	HSI
(16)	Yes	Separate instrument at top of panel.
(21)	Yes	VSI for climb/descent and HSI for turns.
(22)	Yes	(1) the radar screen (2) a heads up display
(23)	Yes	HSI
(24)	Yes	HSI
(29)	Yes	CI or HSI
(30)	Yes	The approach horizon
(33)	Yes	Existing radar scope

Question #12b continued

PILOT #	RESPONSES	COMMENTS
(35)	Yes	RMI
(36)	Yes	CRT (HSI) 767
(40)	Yes	Altimeter -- but might be much more costly and clutter up the instrument too much.
(42)	Yes	Weather radar
(44)	Yes	EHSI in 767
(50)	Yes	Possibly FDI
(51)	Yes	Flight director
(53)	Yes	Horizon
(55)	Yes	Altimeter? HSI
(60)	Yes	Vertical gyro -- could have a pitch command bar incorporate the IVSI information -- same with the bank steering bar.
(62)	Yes	Flight director command signals should be interfaced with command bars to provide both manual and automatic action, particularly during auto pilot operation.
(65)	Yes	HUD - whenever
(66)	No	Not what we currently have available.

13. a) When you were not in a conflict situation, how frequently did you include the display in your cross-check?

	ABOUT ONCE A SECOND	EVERY TWO TO FOUR SECONDS	ABOUT EVERY FIVE TO TEN SECONDS	LESS THAN ONCE IN TEN SECONDS
IVSI:	11% (7)	42% (28)	33% (22)	14% (9)
LED:	3% (2)	21% (14)	41% (28)	35% (24)
CRT:	4% (3)	17% (12)	54% (38)	25% (17)

PILOT #		RESPONSES	COMMENTS
(8)	IVSI:	About once a second	LED needs to be in better condition
	LED:	Less than once in ten seconds	
	CRT:	About every five to ten seconds	
(9)	IVSI:	Every two to four seconds	In practice though, it would probably be less.
	LED:	Every two to four seconds	
	CRT:	Every two to four seconds	
(11)	IVSI:	Every two to four seconds	Possibly because it's new.
	LED:	Every two to four seconds	
	CRT:	Every two to four seconds	
(13)		(No answer)	Did not fly the instrument long enough to work into the cross-check. If further tests are conducted, the same crews should be used again.
(14)	IVSI:	Every two to four seconds	Obviously a function of the test situation.
	LED:	Every two to four seconds	
	CRT:	Every two to four seconds	

Question #13a continued

PILOT #		RESPONSES	COMMENTS
(40)	IVSI:	About every five to ten seconds	Found myself cross checking for commands -- needless effort.
	LED:	About every five to ten seconds	
	CRT:	Every two to four seconds	
(42)	IVSI:	Every two to four seconds	Probably much less in line flying.
	LED:	Every two to four seconds	
	CRT:	Every two to four seconds	
(49)		(No answer)	It is hard to say. Initially, I was waiting for it to go off. I think after some time using the system you would not notice it as as much. (Audio needed)
(55)	IVSI:	Every two to four seconds	LED - Could have been bad location of instrument.
	LED:	Less than once in ten seconds	
	CRT:	About every five to ten seconds	
(59)	IVSI:	Every two to four seconds	LED - Cross check was less because of its poor location, out of scan.
	LED:	Less than once in ten seconds	
	CRT:	About every five to ten seconds	
(61)	IVSI:	Every two to four seconds	Location of LED -- also was hand flying and did not engage auto pilot
	LED:	Less than once in ten seconds	
	CRT:	About every five to ten seconds	
(64)		(No answer)	Too often, however, it was new and I consider that to be the reason for fixation.

Question 13a continued

PILOT #		RESPONSES	COMMENTS
(72)	IVSI:	About once a second or every two to four seconds	Because it is already in cross-check.
	LED:	Less than once in ten seconds	
	CRT:	About every five to ten seconds	

13. b) When in a conflict situation?

	ABOUT ONCE A SECOND	EVERY TWO TO FOUR SECONDS	ABOUT EVERY FIVE TO TEN SECONDS	LESS THAN ONCE IN TEN SECONDS
IVSI:	51% (29)	46% (26)	3% (2)	0
LED:	44% (26)	51% (30)	5% (3)	0
CRT:	38% (23)	52% (32)	10% (6)	0

(Added as part of questionnaire revision)

PILOT #		RESPONSES	COMMENTS
(14)	IVSI:	About once a second	Probably checked it too often to the determent of primary instruments.
	LED:	About once a second	
	CRT:	About once a second	
(40)	IVSI:	Every two to four seconds	Found myself glued to the CRT when conflict arose, often because display was small and difficult to read.
	LED:	Every two to four seconds	
	CRT:	About once a second	
(62)	IVSI:	About once a seoncd	Requires constant attention and detracts from heads up vigilance.
	LED:	About once a second	
	CRT:	About once a second	

SECTION IV

This section examines your reaction to the presentation of traffic advisories. Traffic advisories are given on the LED and CRT displays only.

14. Were traffic advisories presented in time to be useful?

ALWAYS 30% (22) OFTEN 56% (41) SOMETIMES 14% (10) NEVER 0

PILOT #	RESPONSES	COMMENTS
(4)	Often	In CRT
	Sometimes	In LED
(21)	Always	In LED
	Often	In CRT
(27)	Yes	In CRT
	Sometimes	In LED
(42)	Sometimes	Only in climb and descents
(60)	Always	One CRT test had conflict immediately upon presentation.

15. Were the ASA traffic advisories as useful as verbal advisories from ATC?

	MORE USEFUL	ABOUT AS USEFUL	SELDOM AS USEFUL	NEVER AS USEFUL
LED:	45% (33)	42% (31)	10% (8)	3% (2)
CRT:	62% (46)	28% (21)	7% (5)	3% (2)

PILOT #		RESPONSES	COMMENTS
(14)	LED:	Seldom as useful	With LED, it took time to interpret and convert. Therefore, more time than with ATC advisories.
	CRT:	More useful	
(66)	LED:	More useful	These always included altitude.
	CRT:	More useful	

16. Were the ASA traffic advisories presented in a useful format on the:

LED: YES 84% (54) NO 16% (10)

CRT: YES 86% (55) NO 14% (9)

(Added as part of questionnaire revision).

PILOT #		RESPONSES	COMMENTS
(14)	LED: CRT:	No Yes	Didn't like the clock position and range arrangement.
(16)	LED: CRT:	Yes Yes	CRT - except in active mode
(21)	LED: CRT:	Yes Yes	CRT - less so than on LED
(27)	LED: CRT:	Yes Yes	LED - O.K. CRT - Best
(42)	LED: CRT:	No No	They can confuse an actual alert.
(44)	LED: CRT:	Yes Yes	CRT - but need improvement.
(57)	LED: CRT:	Yes No	CRT - need interpretation - increases pilot workload.
(58)	LED: CRT:	Yes Yes	CRT - but not as useful to me.
(59)	LED: CRT:	Yes Yes	LED - within constraints of instrument. CRT - Map format easier to interpret quickly.
(63)	LED: CRT:	Yes Yes	LED - active mainly
(71)	LED: CRT:	Yes Yes	CRT - numbers could be made a little larger.
(72)	LED: CRT:	Yes Yes	CRT - best
(74)	LED: CRT:	Yes Yes	LED - hard to interpret quickly.

17. Should the altitude of other aircraft be given in MSL or relative to your own aircraft?

MSL 89% (66)

RELATIVE 11% (8)

ALTITUDE INFORMATION NOT REQUIRED 0

PILOT#	RESPONSES	COMMENTS
(6)	MSL	In some parts of the world, altimeter settings are given so that when the airplane lands, it indicates an elevation of zero, regardless of what the actual field evaluation is.
(10)	MSL	Relative would need to know +/-
(16)	MSL	To correlate with ATC information.
(48)	RELATIVE	Perhaps altitude information not required.
(66)	MSL	Much easier to relate to MSL.

18. How does ASA advisories affect your workload as compared to the current advisories from ATC?

	UNACCEPTABLE INCREASE IN WORKLOAD	ACCEPTABLE INCREASE IN WORKLOAD	NO EFFECT ON WORKLOAD WORKLOAD	SMALL DECREASE IN WORKLOAD	LARGE DECREASE IN WORKLOAD
LED:	7% (5)	71% (51)	13% (9)	8% (6)	1% (1)
CRT:	13% (9)	65% (47)	15% (11)	3% (2)	4% (3)

PILOT#	RESPONSES	COMMENTS
(6)	LED: Acceptable increase in workload. CRT: Acceptable increase in workload.	The continuous aural warning of the altitude alert is very distracting. There should be a precedence and warnings, i.e.; the lesser precedence should be cut out until the primary is taken care of. The GPWS should be included in precedence of warning system.

Question #18 continued

PILOT#	RESPONSES	COMMENTS
(14)	LED: Between Acceptable and Unacceptable increase in workload. CRT: Acceptable increase in workload.	LED - possible increase due to lack of familiarity with LED device.
(23)	(No answer)	The workload given in the simulator exercise was acceptable. I believe that the conflicting traffic at certain times in certain high density traffic areas may increase the pilots workload beyond the acceptable point. i.e., Taking off on runway 1 at SFO into traffic at both Alameda and Oakland.
(32)	(No answer)	System came to be depended upon as another tool. Felt comfortable with it, however, it would be difficult to ascertain effect on workload. Suggest getting some very fatigued pilots to fly the systems.
(36)	LED: Acceptable increase in workload. CRT: Acceptable increase in workload.	Why not both?
(43)	LED: Acceptable increase in workload. CRT: Acceptable increase in workload.	ASA is believable and I'm thinking about the traffic and what I'm going to do. Verbal advisories mean I look out for awhile and worry, but don't really work much harder. (Assume I don't have conflict in former and visual contact in latter.)
(51)	LED: Acceptable increase in workload. CRT: Acceptable increase in workload.	Distracting sometimes.
(60)	LED: Acceptable increase in workload. CRT: No effect on workload.	CRT data can be assimilated and used immediately.

19. During this simulation, were you able to visually acquire traffic and quickly correlate it with the advisories presented on the:

	OFTEN	SOMETIMES	NEVER
LED:	32% (24)	58% (43)	10% (7)
CRT:	37% (27)	57% (42)	6% (5)

PILOT #	RESPONSES	COMMENTS
(6)	LED: Never CRT: Sometimes	From pilot's seat, light from the instructor's panel caused a reflection on windshield to block out side view of a small part of the pilot's windshield effectively.
(8)	LED: Never CRT: Never	No visual contact.
(61)	LED: Sometimes CRT: Often	One target appeared on CRT, directly on top of aircraft and wasn't seen until after evasion.

20. Would the display help you locate traffic you would not normally use?

	OFTEN	SOMETIMES	NEVER
LED:	43% (31)	53% (39)	4% (3)
CRT:	49% (36)	48% (35)	3% (2)

PILOT#	RESPONSES	COMMENTS
(8)	LED: Never CRT: Never	No visual contact.
(9)	LED: Sometimes CRT: Sometimes	Hard to judge.
(32)	LED: Never CRT: Never	Please remember that aircraft was somewhat strange to me, therefore, spent a great deal of time concentrating on flying aircraft. Ergo, system was extremely helpful.

21. Do you feel some form of traffic advisories are an essential part of ASA?

YES 92% (57) NO 8% (5)

(Added as part of questionnaire revision)

PILOT #	RESPONSES	COMMENTS
(31)	Yes	Especially during IFR condition.
(50)	Possibly	Not essential, but a good idea.
(66)	Yes	Gives you much more confidence in the maneuvers that are presented.

22. Were more aircraft advisories than necessary displayed on the:

	OFTEN	SOMETIMES	NEVER
LED:	14% (10)	41% (30)	45% (33)
CRT:	3% (2)	42% (30)	55% (40)

PILOT #	RESPONSES	COMMENTS
(22)	LED: Sometimes CRT: Sometimes	Yes - on parallel approaches.
(60)	LED: Sometimes CRT: Sometimes	With exception of dual approaches to parallel runways.
(72)	LED: Often CRT: Never	Due to easier interpretation of CRT display.

23. A recommended maximum number of aircraft advisories to be simultaneously displayed is:

LED: ________
CRT: ________

Question #23 continued

PILOT #	RESPONSES	COMMENTS
(2)	LED: 2 CRT: 2	Maximum; more clutters presentation.
(40)	LED: 1	The closest one
(46)	LED: 2 CRT: No limit	
(64)	(No answer)	All that are in conflict plus those that will be predicated on maneuver commands given by ASA.
(67)	LED: All CRT: All	
(68)	(No answer)	Any aircraft that is a threat should be displayed.
(72)	LED:Only closest one CRT:Up to four	

RECOMMENDED MAXIMUM NUMBER								
	Ø	1	2	3	4	5	6	˜ 6
LED	1	8	31	21	4	0	0	2
CRT	1	2	19	25	12	1	4	3

AD-A083 897 ARINC RESEARCH CORP ANNAPOLIS MD F/G 17/7
AN EVALUATION OF AIRCRAFT SEPARATION ASSURANCE CONCEPTS USING A--ETC(U)
NOV 79 B MORGENSTERN, T P BERRY DOT-FA78WA-4091
UNCLASSIFIED 1343-01-3-2058-VOL-2 FAA/RD -79-124-2 NL

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24. When a conflict occurred, were you concerned about maneuvering into other traffic during the escape maneuver? With the:

	ALWAYS	OFTEN	SOMETIMES	NEVER
IVSI:	18% (13)	23% (17)	37% (27)	22% (16)
LED:	10% (7)	20% (15)	47% (35)	23% (17)
CRT:	10% (7)	11% (8)	38% (28)	41% (30)

PILOT #		RESPONSES	COMMENTS
(11)	IVSI:	Often	Possibly natural
	LED:	Often	
	CRT:	Often	
(14)	IVSI:	Sometimes	CRT - once at a very short range to target.
	LED:	Sometimes	
	CRT:	Once	
(30)	IVSI:	Sometimes	When only one can be displayed that possibility exists.
	LED:	Never	
	CRT:	Never	
(43)	IVSI:	Never	Assumed that ASA would keep me out of trouble in all cases, assuming that I followed its advice/command.
	LED:	Never	
	CRT:	Never	

25. Did the intruder position information provide enough information to allow you to minimize the deviation from your planned flight path?

	ALWAYS	OFTEN	SOMETIMES	NEVER
IVSI:	12% (9)	40% (29)	45% (33)	3% (2)
CRT:	22% (16)	53% (39)	23% (17)	2% (1)

PILOT #		RESPONSES	COMMENTS
(1)	LED:	Sometimes	LED took too long to interpret partly because of format. Took pilot's attention away from flying.
	CRT:	Often	
(20)	LED:	Often	With both, a trend must be noted and mentally compacted.
	CRT:	Always	
(43)	LED:	Sometimes	Didn't worry much about deviation. First things first.
	CRT:	Sometimes	

26. Was your response to an ASA command different in IMC versus your response in VMC with the:

	ALWAYS	OFTEN	SOMETIMES	NEVER
IVSI:	12% (8)	12% (8)	42% (28)	34% (23)
LED:	9% (6)	12% (8)	50% (34)	29% (20)
CRT:	9% (6)	16% (11)	46% (31)	29% (19)

Please comment on your answers.

PILOT #		RESPONSE	COMMENTS
(2)	IVSI: LED: CRT:	Never Never Never	No difference at all. Respond to command in same manner under both conditions.
(6)	IVSI: LED: CRT:	Never Never Never	Because depth and distance perception is poor in a night environment, I would tend to rely on the instrument instructions as long as I had confidence in them.
(7)	IVSI: LED: CRT:	Never Never Never	Tried to follow commands called for.
(10)	IVSI: LED: CRT:	Never Never Never	Night flight essentially <u>instrument</u>. All instrumentation <u>and</u> human senses are adjunct, best used <u>collectively</u>.
(11)	IVSI: LED: CRT:	Sometimes Sometimes Sometimes	I think you always feel somewhat better when you see traffic.
(12)	IVSI: LED: CRT:	Sometimes Sometimes Sometimes	Several times I anticipated a command and did not get one. This was usually true if the traffic was either sighted or called by ATC.
(13)		(No answer)	I do not recall the difference.
(14)	IVSI: LED: CRT:	Never Never Often	The CRT does not have the ambiguity present in the other displays notably the IVSI. No building of the traffic picture is required. You have it in front of you.

Question #26 continued

PILOT #		RESPONSE	COMMENTS
(15)	IVSI:	Sometimes	Because in the clouds I have to rely either upon ATC or my ASA instruments. Out of the clouds, I would look visually to back up but not deter a movement away from a conflict.
	LED:	Sometimes	
	CRT:	Sometimes	
(16)	IVSI:	Sometimes	If bearing to aircraft is known, this would affect the response.
	LED:	Sometimes	
	CRT:	Sometimes	
(17)	IVSI:	Sometimes	If visual, I would usually take a quick look to try for visual separation. Also in IMC, thought was given before descent.
	LED:	Sometimes	
	CRT:	Sometimes	
(21)	IVSI:	Sometimes	If the intruder could be acquired visually, I had more confidence in the escape maneuver or negative command.
	LED:	Sometimes	
	CRT:	Sometimes	
(23)	IVSI:	Sometimes	Quite often after making the correction called for on any ASA device, you did not have adequate additional visual information to feel that you could override the avoidance maneuver called for by the CAD (Collision Avoidance Device).
	LED:	Sometimes	
	CRT:	Sometimes	
(24)	IVSI:	Sometimes	VFR you are able to clear yourself on turns and descent from terrain and other traffic. IFR you must check minimum obstruction altitude which may not be available in mountainous terrain off airways.
	LED:	Sometimes	
	CRT:	Sometimes	
(25)	IVSI:	Sometimes	Low altitude VFR, you tend to "see" target and not react as rapidly as in IFR.
	LED:	Sometimes	
	CRT:	Sometimes	
(26)	IVSI:	Never	No conflict IFR or VFR.
	LED:	Never	
	CRT:	Never	

Question #26 continued

PILOT #		RESPONSE	COMMENTS
(28)	IVSI: LED: CRT:	Always Always Always	To visually confirm that the instrument says - made the response with more confidence.
(29)	IVSI: LED: CRT:	Never Never Never	The CRT gives a better picture of your situation, and can show more aircraft with less confusion; with exposure, it would be very easy to work with.
(30)	IVSI: LED: CRT:	Always Always Always	When IMC, I am unable to visually find him and would take immediate action. In visual conditions, the action might be tempered because of visual contact.
(31)	IVSI: LED: CRT:	Never Never Never	The ASA command supplemented the response in VMC.
(32)	IVSI: LED: CRT:	Never Never Never	Determined that at night it is almost impossible to ascertain relative distance. Therefore, felt required to obey commands.
(33)	IVSI: LED: CRT:	Often Often Often	Need visual contact in VMC to smoothly avoid conflict.
(35)	IVSI: LED: CRT:	Sometimes Sometimes Sometimes	One test in a simulator is not adequate to establish this. Simulators require considerable more attention to the instruments than an airplane. There isn't a "true" visual situation in a simulator due to this shortcoming.
(36)	IVSI: LED: CRT:	Always Always Always	I feel that three sets of eyes VMC looking for the intruder would be much better than having only an instrument in IMC.
(38)	IVSI: LED: CRT:	Never Never Sometimes	Not knowing the azimuth created some doubt as to action required.

Question #26 continued

PILOT #		RESPONSE	COMMENTS
(41)	IVSI:	Sometimes	While flying in F/O seat, traffic appeared to be unrealistic (diving at a very fast rate).
	LED:	Sometimes	
	CRT:	Sometimes	
(42)	IVSI:	Never	It might be different in an actual aircraft as the simulator is not the real world.
	LED:	Never	
	CRT:	Never	
(43)	IVSI:	Often	VMC is not really so with this simulator. In a real life situation (especially daytime), I think response to ASA might be tempered greatly if the intruder was clearly visible.
	LED:	Often	
	CRT:	Often	
(44)	IVSI:	Often	IVSI - command without situation difficult to modulate. LED - situation allowed some maneuvering prior to command.
	LED:	Sometimes	
(46)	IVSI:	Sometimes	With intruder in sight, deviations tended to be slower and less extreme.
	LED:	Sometimes	
	CRT:	Sometimes	
(47)	IVSI:	Always	IFR, I followed commands because I could not see other traffic.
	LED:	Always	
	CRT:	Always	
(48)	IVSI:	Never	Alert aural warnings are most important.
	LED:	Sometimes	
	CRT:	Sometimes	
(49)	IVSI:	Often	I would usually look out during evasive maneuver.
	LED:	Often	
	CRT:	Often	
(51)		(No answer)	First experience in simulation makes answering difficult to this question. Perhaps "sometimes" but recalling response afterward is difficult to accurately answer.
(53)	IVSI:	Sometimes	I used less evasive control when in VMC. I think.
	LED:	Sometimes	
	CRT:	Sometimes	

Question #26 continued

PILOT #		RESPONSE	COMMENTS
(57)	IVSI: LED: CRT:	Often Often Often	CRT display seems least desirable. Requires concentration to interpret, need constant reference to target to estimate its threat potential, too much head down time.
(58)	IVSI: LED: CRT:	Sometimes Sometimes Sometimes	When aircraft was sighted visually, I cross checked it frequently with display visually.
(59)	IVSI: LED: CRT:	Often Sometimes Sometimes	The visual acquisition of a target allows a "graded" (gentle or rapid) maneuver depending upon location and collision potential. Sometimes turning away from a target removes him from visual contact, whereas a climbing or descending turn toward the target may reduce the collision potential because you can keep him in sight.
(60)	IVSI: LED: CRT:	Always Sometimes Never	To me, the CRT enables your eyeballs to immediately see the situation, VMC or IMC. I would be hesitant in IMC to enter airspace other than my own when using the IVSI.
(61)		(No answer)	Don't feel justified in making a decision between the two based on the simulation. Would seem obvious, that in VFR conditions one would be able to modify actions based on observation of conflicting aircraft, if seen when alert was given.
(63)	IVSI: LED: CRT:	Always Always Always	LED - If you need to present more than (1) aircraft, then allow more space between the print-out. During the flight (3) were presented at once which was too much to untangle.
(64)	IVSI: LED: CRT:	Sometimes Sometimes Sometimes	A bold new concept to gain confidence in, when flying IMC - may be a detractor in VMC conditions, however, if in a heads up display, you may alleviate the detraction in VMC.

Question #26 continued

PILOT #		RESPONSE	COMMENTS
(65)	IVSI:	Always	Not seeing the intruder made me react faster; then I tended to over-control, i.e., pitch and bank.
	LED:	Always	
	CRT:	Always	
(66)	IVSI:	Never	The more information you have about the traffic, the more you would vary your responses under conditions of not seeing the traffic versus seeing the traffic.
	LED:	Sometimes	
	CRT:	Often	
(69)	IVSI:	Sometimes	It's rattling to have an intruder advisory while in IMC. Is the advisory real or false?
	LED:	Sometimes	
	CRT:	Sometimes	
(70)	IVSI:	Sometimes	I'm sure if I saw the traffic in VMC, I could better relate to avoiding it, but just having a CAS there would alert me to the many other aircraft that one fails to see when doing other cockpit duties.
	LED:	Sometimes	
	CRT:	Sometimes	
(72)	IVSI:	Sometimes	The CRT is by far the best way to stay in the information loop and keep track of the traffic situation as it develops.
	LED:	Sometimes	
	CRT:	Sometimes	
(73)	IVSI:	Often	Not being able to possibly "see" the traffic increases speed desire to react.
	LED:	Often	
	CRT:	Often	
(74)	IVSI:	Never	The CRT not only gives the numbers but gives the pilot good information on track of intruder and his change in altitude.
	LED:	Never	
	CRT:	Sometimes	

Section V

This section examines your reaction to the presentation of positive, negative and limit maneuver commands.

27. Do you feel that the commands are presented in sufficient time to avoid a potential collision?

	ALWAYS	OFTEN	SOMETIMES	NEVER
IVSI:	58% (42)	35% (25)	7% (5)	0
LED:	56% (41)	28% (28)	6% (4)	0
CRT:	53% (39)	37% (27)	10% (7)	0

PILOT #		RESPONSE	COMMENTS
(63)	IVSI:	Always	I hope so. The point here again, is the degree of maneuvering required to avoid a collision. Why upset the passengers any more than necessary? If it says go down first, say, how fast, to avoid a collision.
	LED:	Always	
	CRT:	Always	

28. Did you agree with the maneuver command given?

ALWAYS 42% (30) OFTEN 57% (41)

SELDOM 1% (1) NEVER 0

PILOT #	RESPONSE	COMMENTS
(6)	Always	I suppose I agree because I'm not sure we have sufficient information to agree or disagree. One exception was the IVSI, where 3 signals did not seem to agree. (i.e., descent, max 500 climb, descent in quick succession).
(10)	Often	Interpretive decisions possible and valid in this test.
(11)	Often	CRT tends to confuse you some in turn.

Question #28 continued

PILOT #	RESPONSE	COMMENTS
(64)	Often	However, not enough exposure to system to thoroughly understand its capability.
(66)	Often	More with the CRT than the LED.

29. Which system do you feel presented the most accurately determined maneuver commands?

IVSI 23% (16) LED 37% (26) CRT 40% (28)

PILOT #	RESPONSE	COMMENTS
(5)	IVSI	They were all accurate; however, the IVSI commands are simpler, given within the normal instrument scan, with subsequent immediate response.
(6)	(No answer)	I felt LED and CRT were about the same, but I thought LED gave sufficient information, more compactly and was easier to include in scan.
(11)	IVSI LED CRT	Easy to follow, LED Easy to follow Probably most accurate but not as easy to follow.
(19)	IVSI	However, LED excellent if positioned in a more desirable central cockpit position in front of yoke.
(23)	IVSI & CTY	Were equal

30. Are all of the command types necessary?

	YES	NO
Positive Commands	97% (61)	3% (2)
Negative Commands	77% (47)	23% (14)
Limit Commands	87% (53)	13% (8)

PILOT #	RESPONSE	COMMENTS
(5)	Positive Commands	Yes
	Negative Commands	Yes -- Would rather call this an "advisory" or some similar wording.
	Limit Commands	Yes
(14)	(No answer)	I didn't like the use of the term, limit 1000 etc. I'd rather see a minimum rate required or simply don't climb or descend.

31. When presented with negative commands, were you able to continue your intended flight path without an ATC call?

ALWAYS	7% (5)	OFTEN	41% (31)
SOMETIMES	49% (36)	NEVER	3% (2)

PILOT #	RESPONSE	COMMENTS
(10)	Often	Missed continuing to previously cleared altitude, leveled at prior cleared altitude.

32. When presented with limit commands, were you able to continue your original flight path without a call to ATC?

ALWAYS	4% (3)	OFTEN	45% (33)
SOMETIMES	46% (34)	NEVER	5% (4)

33. Did any of the displays cause you to make larger than normal (1/4G) vertical accelerations?

	ALWAYS	OFTEN	SOMETIMES	NEVER
IVSI:	0	22% (15)	40% (27)	38% (26)
LED:	1% (1)	16% (11)	47% (33)	36% (25)
CRT:	0	13% (9)	42% (29)	45% (31)

PILOT#		RESPONSES	COMMENTS
(6)	IVSI:	Never	Really hard to tell
	LED:	Sometimes	
	CRT:	Sometimes	
(11)	IVSI:	Sometimes	But I think it was me more than the instrument.
	LED:	Sometimes	
	CRT:	Sometimes	
(32)	IVSI:	Sometimes	Must qualify this because aircraft was strange to me.
	LED:	Sometimes	
	CRT:	Sometimes	
(40)	IVSI:	Often	Reaction time to CRT was too slow.
	LED:	Often	
	CRT:	Sometimes	
(44)	IVSI:	Never	Any G >.75 due to pilot technique.
	LED:	Never	
	CRT:	Never	

34. Did any of the displays cause you to make a steeper than normal (30° or 3°/sec) bank to avoid another aircraft?

	ALWAYS	OFTEN	SOMETIMES	NEVER
IVSI:	0	3% (2)	14% (10)	83% (59)
LED:	0	6% (4)	11% (8)	83% (60)
CRT:	0	6% (4)	17% (12)	77% (55)

PILOT #		RESPONSES	COMMENTS
(6)	IVSI:	Never	Really hard to tell.
	LED:	Never	
	CRT:	Never	

Question #34 continued

PILOT #		RESPONSE	COMMENTS
(11)	IVSI:	(No answer)	Only when I looked up on scan
	LED:	(No answer)	
	CRT:	(No answer)	
(40)	IVSI:	Sometimes	Simulator characteristic
	LED:	Sometimes	
	CRT:	Sometimes	
(44)	IVSI:	Never	Bank angles exceeded 30° on occasion again, pilot technique/ not familiar with simulator
	LED:	Never	
	CRT:	Never	
(70)	IVSI:	Sometimes	Not intentional anyway
	LED:	Never	
	CRT:	Never	

SECTION VI

This section examines your reaction to the current ASA concept.

35. Because the ASA system does not consider the intentions of your own or the other aircraft, it may present a maneuver command which would normally be resolved by the planned action of either or both aircraft. Did you see this situation during your flight? With the:

	ALWAYS	OFTEN	SOMETIMES	NEVER
IVSI:	3% (2)	6% (4)	41% (26)	50% (32)
LED:	0	9% (6)	55% (37)	36% (24)
CRT:	2% (1)	13% (9)	54% (37)	31% (21)

PILOT #		RESPONSE	COMMENTS
(11)		(No answer)	Possibility always exist - did not notice any difference in this respect.
(44)	IVSI:	Never	If CRT presented path predictors it would be better.
	LED:	Sometimes	
	CRT:	Sometimes	
(60)	IVSI:	Sometimes	Parallel approaches
	LED:	Sometimes	
	CRT:	Sometimes	

36. What effect does the ASA system have on your confidence when overflying/underflying another aircraft by 1000 feet?

IVSI:	Increased Confidence	47% (34)
	Less Confidence	7% (5)
	No Change	46% (33)
LED:	Increased Confidence	71% (52)
	Less Confidence	3% (2)
	No Change	26% (19)
CRT:	Increased Confidence	71% (52)
	Less Confidence	8% (6)
	No Change	21% (15)

Question #36 continued

PILOT #		RESPONSE	COMMENTS
(49)	IVSI:	No change	With use could increase confidence
	LED:	No change	
	CRT:	No change	
(66)	IVSI:	No change	
	LED:	More confidence	LED: you know his altitude
	CRT:	More confidence	CRT: you know his altitude

37. Do you feel that use of the ASA could allow reduced separation? With:

	MUCH REDUCED	SOMEWHAT REDUCED	NO REDUCTION	INCREASED SEPARATION
IVSI:	0	17% (12)	83% (60)	0
LED:	1% (1)	32% (23)	67% (49)	0
CRT:	10% (7)	33% (24)	57% (42)	0

PILOT #		RESPONSE	COMMENTS
(11)	IVSI:	No reduction	Very doubtful
	LED:	No reduction	
	CRT:	No reduction	
(33)	IVSI:	Somewhat reduced	If with better readout
	LED:	Somewhat reduced	
	CRT:	Much reduced	

38. Do you feel that the ASA system will result in less or more communications with ATC?

MUCH LESS 4% (3) SOMEWHAT LESS 31% (23) NO CHANGE 13% (10)

SOMEWHAT MORE 45% (33) MUCH MORE 7% (5)

PILOT #	RESPONSE	COMMENTS
(10)	Somewhat more	Advisory of action (intended or taken)
(11)	Somewhat more	Very doubtful

Question #38 continued

PILOT #	RESPONSE	COMMENTS
(14)	Somewhat more	Especially until crews become more adept.
(21)	Somewhat more	Due to calls to ATC to explain non-compliance with clearances if the traffic advisories by ATC were transferred to the ASA system, then communication would probably be reduced. I would have more confidence in a reliable ASA system than ATC.
(28)	Somewhat more	This depends on experience level. It probably would drop with time.
(30)	Somewhat more	If we must explain each deviation
(32)	No change	It is my opinion that any other than "normal" behavior by aircraft should be reported to ATC.
(66)	Somewhat less	They wouldn't have to give traffic advisories.

39. Do you feel that the ASA system as used in this simulation will result in safer operation in respect to midair collision?

PILOT #	COMMENTS
(1)	In most respects, yes; may not change climb/descent accidents and may reduce overall safety due to increased cockpit workload and interruption of normal duties.
(2)	Definitely yes; all of the methods of presenting the ASA system in the cockpit are an aid, although the CRT gives the best overall "picture".
(3)	Don't know; if aircraft show up unexpectedly, without prior ATC notification, maneuver may present another hazard.
(4)	Yes, if full mode and displayed on CRT can be used.

Question #39 continued

PILOT #	COMMENTS
(5)	Yes, the "LED" and "CRT" both require more heads in the cockpit to monitor tracked traffic at a time when eyes should be looking out.
(7)	Needs refinement; if unable to contact controller due to workload, can cause concern.
(11)	It could.
(15)	Some form certainly would be a help.
(16)	This system would aid in detection of other aircraft; however, in the terminal area there may be too many potential conflicts.
(17)	Depends on number of false alarms.
(23)	Yes, any one of the systems would be an improvement over what we have now - nothing!
(24)	Yes, any additional warning of conflicting traffic makes a safer operation.
(32)	Ask PSA about San Diego! Of course!
(39)	Yes, once it's flight tested.
(40)	Yes, especially in VFR conditions with generally more aircraft to be seen.
(49)	Yes, however, I would like to see the parameters kept to a point that false signals would not cut the usability of the system.
(61)	Perhaps - as pilots we are slowly gaining more confidence in the reliability of black boxes.
(63)	Yes, but not for many years to come. Most of the midairs are with general aviation and airline or military.
(64)	? may cause more conflicts than it resolves especially in high density areas.

Question #39 continued

PILOT #	COMMENTS
(66)	Yes, if the crews have more information on traffic there will be fewer midair collisions.
(69)	If the computer program in the box is valid, and if the pilots have confidence in the system - yes.

40. Did the active mode (regardless of display type) provide enough information to avoid a collision?

YES 86% (54) NO 14% (9)

(Added as part of questionnaire revision)

PILOT #	REVISION	COMMENTS
(11)	Yes	Better in full mode
(14)	Yes	Depending on weather and crossing angles
(36)	Yes	Excluding ATC clearance
(49)	Yes	But kept you in suspense
(58)	No	Need more information
(66)	Yes	But it was more like the IVSI
(69)	Yes	But I was slow to follow
(70)	Yes	In most cases, but prefer full mode

41. Rate the following items in relative importance to resolution of a conflict. (1 = most important, 11 = least important)

(Projected miss distance was added to list of elements, and "check if essential" was included as part of questionnaire revision).

	Rank	Check if Essential
. Altitude of other aircraft	1	85% (53)
. Heading of other aircraft	4	51% (31)
. Relative bearing	3	59% (38)
. Range of other aircraft	2	81% (50)
. Other aircraft type	10	5% (3)
. Vertical speed of other aircraft	7	20% (12)
. Horizontal closure rate	5	21% (13)
. Vertical closure rate	6	17% (10)
. Closure angle	9	7% (4)
. Other aircraft identity	11	3% (2)
. Projected miss distance	8	14% (8)

PILOT #	COMMENTS
(1)	Relative bearing and closure rate are the only important factors. If relative bearing is changing, there can be no conflict and if closure rate is negative, there can be no conflict.
(2)	Other aircraft identity rated 4th for VMC.

SECTION VII

This section allows you to evaluate the displays.

42. a) Based on this simulation period, rate the displays in order of preference. (1 - 3 with 1 = most preferred)

IVSI ____	1-26% (19) 2-27% (20) 3-47% (35)	LED ____	1-27% (20) 2-43% (32) 3-28% (21)	CRT ____	1-47% (35) 2-28% (21) 3-23% (17)

PILOT #	COMMENTS
(5)	1,3,2 with respect to collision avoidance; 3,2,1 with respect to traffic information.
(10)	2,3,1 IVSI second with backup LED information.
(21)	2,1,3 May be due to little experience with CRT.
(59)	3,2,1 if located in better position/with color commands
(61)	3,2,1 with a more noticeable position for LED.
(63)	3,1,2 Larger display only.
(71)	3,2,1 I have mixed opinion here - I like the simplicity of the IVSI, that is the least distraction from other duties, but like the information of the CRT & LED.

b) Would your second choice be acceptable if the first were not available?

YES 96% (69) NO 4% (3)

PILOT #	RESPONSES	COMMENTS
(4)	Yes	But reluctantly (LED)
(6)	Yes	But it is too large for amount of information (CRT)
(14)	(No answer)	Barely
(46)	(No answer)	CRT for command information, I rate 3, LED 2.

Question #42 continued

c) If the quality of the second choice were improved, and given sufficient practice, would the second choice be acceptable?

YES 97% (60) NO 3% (2)

(Added as part of questionnaire revision).

PILOT #	RESPONSE	COMMENTS
(14)	(No answer)	Barely
(44)	Yes	Probably better
(58)	Yes	Prefer LED
(66)	(No answer)	Possibly

d) Would your third choice be acceptable if the first and second choices were not available?

YES 73% (53) NO 27% (20)

PILOT #	RESPONSE	COMMENTS
(1)	Yes	Qualified yes, LED display needs better readability (LED).
(4)	Yes	But reluctantly (IVSI)
(46)	Yes	For information but not command
(58)	Yes	If CRT placement improved and enlarged figures.
(66)	(No answer)	It would be better than nothing.

Question #42 continued

e) If the quality of the third choice were improved, and given sufficient practice, would the third choice be acceptable?

YES 83% (48) NO 17% (10)

(Added as part of questionnaire revision).

PILOT #	RESPONSE	COMMENTS
(21)	Yes	In fact, the CRT would probably be #1 with enough experience.
(38)	No	Only for ground capability to avoid takeoff collisions.
(46)	(No answer)	CRT good for information - inadequate for command.
(60)	(No answer)	Maybe
(61)	Yes	Include selectability of climb limit bands and noticeability of no turn lights.
(63)	No	I won't accept it now that you've shown the other two.
(66)	(No answer)	Not as acceptable as the other two.

43. Do you feel that a combination of display devices would provide more usable information than the best test display?

NO	42% (31)	YES, IVSI and CRT	27% (20)
YES, IVSI and LED	16% (12)	YES, LED and CRT	15% (11)

PILOT #	REVISION	COMMENTS
(1)	(No answer)	IVSI for active and CRT for full mode
(4)	No	CRT would do if full mode
(12)	Yes, IVSI & CRT	This combination would give us more information. However, I think to be workable in our present system, it should be kept as simple as possible.
(29)	Yes, IVSI & CRT	The best part of the IVSI is the good response to the arrows, if they were added to the CI or HSI, with the CRT display included, to supplement, the combination would be the most complete.
(61)	Yes, IVSI & CRT	CRT would be superior in a non-terminal area environment cruise for example. IVSI would be superior in more congested areas, as you would normally be including it in your cross check and wouldn't have time to monitor another interior display.
(63)	No	You should have only one. With more than one it takes away from the cross check.
(74)	No	Too much more to add to scan

SECTION VIII

This section asks for your overall comments on the ASA program.

44. What comments do you have on the realism of this simulation?

PILOT #	COMMENTS
(1)	As in all simulators, the acceleration forces of real flight are missing; and also, you can't really look for traffic except in a very small visual segment.
(2)	Very well done. Real scenarios. Conflicts presented as in true developments.
(3)	More ATC advisories of other aircraft and better visuals to correlate with display.
(4)	Very realistic, by the time 60-90 pilots evaluate the systems, it will be obvious which display is best. It appears that if the system selected is refined to work reliably, pilots will probably find themselves looking at the CAS instead of out the window.
(6)	Very good
(7)	A good start
(8)	As good as can be expected without actual airborne testing.
(9)	Not bad
(10)	Reasonable - good effects throughout
(11)	Very well done
(12)	Excellent
(13)	It was an excellent simulation.
(14)	Fairly good. No side vision is a real deficiency. Possibly a practice session prior to test with each pilot evaluating all displays would provide a more sensitive test.

Question #44 continued

PILOT#	COMMENTS
(15)	Realism was very good. The visual cues were presented very well.
(16)	The cockpit environment including 3 man crews, distractions for aircraft problems, and other outside factors not included.
(17)	95% of the time, very good. Some extra time spent with crew coordination.
(18)	Very well conceived and realistic test.
(19)	Excellent
(20)	Good
(21)	Excellent simulation
(22)	Very good simulation
(23)	Fair
(24)	Good except ability to see VFR traffic.
(25)	Good, realistic, however, the program has to keep in mind that we adapt device to the pilot, not the pilot to the device.
(26)	Realistic as electronic automation can be.
(27)	Realism was excellent.
(28)	I thought the realism was excellent.
(29)	Very realistic, good simulator, program well thought out.
(30)	Excellent realism
(31)	Very good
(32)	No comment - well done
(33)	Participating crews should be qualified in aircraft first; need more practice with all systems before answering these questions.

Question #44 continued

PILOT#	COMMENTS
(34)	Visual sightings were confusing in that some intruder lights appeared to climb & dive continuously as you watched them.
(35)	Rushed - otherwise O.K.
(36)	Good
(37)	Satisfactory simulation
(38)	Good
(39)	Good but still has to be flight proven.
(40)	Good
(41)	Traffic simulation was not realistic.
(42)	Very real except a false sense of security in the simulator, I would not feel as secure in an actual aircraft.
(43)	Very realistic. No improvement needed.
(44)	Good
(45)	Seemed fairly acceptable as realism for terminal area.
(46)	Good simulation
(47)	I found it to be quite real.
(48)	Good
(49)	Good training crew did excellent job.
(50)	Good
(51)	Good, the system helps me to visualize the position, of course, closure rate of an intruder more rapidly.
(52)	Very realistic - from ATC, to other aircraft - radio traffic clutter.

Question #44 continued

PILOT #	COMMENTS
(53)	Very good
(54)	I thought it was realistic.
(55)	Very good - projects a good idea of what reality would be.
(56)	Good program
(57)	Very good ATC activity and CGI traffic provide high degree of realism.
(58)	Excellent
(59)	Excellent - because combined head-up and head-down with realistic ATC situation.
(60)	Good
(61)	Very good, for conditions
(62)	Excellent
(63)	Very well prepared
(64)	Very good - except for density
(65)	Excellent
(66)	Very realistic especially with the CGI display - only problem possibly too rushed.
(67)	Acceptable
(69)	Good simulation of entire trip.
(70)	Much better than I thought it would be and would probably be better with practice.
(71)	Very real

Question #44 continued

PILOT #	COMMENTS
(72)	Very realistic
(73)	Very good
(74)	I thought the simulation (especially ATC) was very realistic

45. What changes would be required in ATC operations if ASA were implemented?

(Added as part of questionnaire revision).

PILOT #	COMMENTS
(11)	Altitude and course buffers to keep from turning or diving into other targets.
(12)	A provision to immediately alert ATC of a deviation from our cleared flight path. This would need to be done other than verbal due to inability to transmit in many terminal areas. Transponder could be used.
(14)	Flexibility
(15)	More communication if this program implemented.
(16)	Possibly might allow for deletion of some traffic call outs; however, other call outs of traffic may be necessary to prevent aircraft from making unnecessary evasions.
(18)	May require fewer aircraft under each sector controller.
(19)	ASA training
(21)	None required. However, reduced communication and separation may be possible in some situations.
(22)	I hope none.
(23)	How does ATC resolve the fact that numerous deviations from assigned headings and altitudes would cause serious interference with planned traffic flow.

Question #45 continued

PILOT #	COMMENTS
(24)	I don't know of any, other than additional deviations.
(25)	Could probably get rid of 250 below 10,000 - would increase traffic flow.
(26)	Transponders for all aircraft in the sky.
(27)	All aircraft would be required to comply with minimum equipment to be located. Transponder and altitude readout.
(28)	Perhaps less advisories
(29)	I'm not aware of any
(30)	Very little
(31)	Very little
(32)	Feel the ATC controller was acclimated to system. Would be interesting to place an uninitiated controller with fatigued pilots.
(33)	Participating crews should be more aware of the usage of these systems before using them in an ATC environment.
(35)	Strong possibility of increased separation in terminal areas.
(36)	Leniency in violations
(37)	ATC will question the pilots action in many cases.
(38)	Loosening of regulations
(40)	The problem of what to do regarding returning to flight plan, heading, etc. after following a command given by one of displays.

Question #45 continued

PILOT #	COMMENTS
(41)	1. Level at an altitude above or below when climbing to cleared altitude. 2. Stopping turns before reaching a vector heading.
(42)	Cut down on controller advisories
(44)	Probably some changes in communications
(45)	Possible increased separation due to deviation of aircraft
(46)	Have to assume that action might be taken without ATC coordination particularly with CRT and LED.
(47)	None
(48)	Perhaps less traffic advisories from ATC.
(49)	Emergency evasive action
(52)	More immediate communication from flight crews advising ATC of course and altitude changes might at times increase ATC problems - ATC reactions to a possible traffic conflict could possibly be different because of their knowledge of a more expanded traffic picture.
(53)	Much less radio chatter to allow for communication during a conflict deviation.
(54)	I think the ASA would not require any changes in ATC
(55)	None, ASA would be back up
(56)	None
(57)	Spacing would have to provide for unanticipated avoidance maneuvers initiated by the pilot.
(58)	Very little, perhaps more traffic identification
(59)	Don't feel any. Controllers may be encouraged to pass more of the traffic separation burden to the pilot.

Question #45 continued

PILOT #	COMMENTS
(60)	Terminal areas could become troublesome due to many aircraft in small area. A large number of false or unwarranted warnings would have the effect of possibly allowing operator to sometime tune out the warning and pass it off as a normal conflict.
(61)	You would have more chatter between crew and controllers to verify aircraft under positive control. i.e. - parallel approaches.
(63)	Coordination with ATC would be a nightmare with 2 or more aircraft changing altitude and heading during busy periods.
(64)	Basic change in primary concept and design of the ATC system in terminal environment.
(65)	Revamp
(67)	None
(68)	More traffic information would have to be exchanged with the IVSI system.
(69)	As with ground proximity system in its early days, I would wonder about false warnings and the resulting overload on ATC.
(70)	Deviation from assigned altitude without prior clearance from ATC. Especially in high density areas.
(71)	Not too many - concern about avoiding traffic unnecessarily.
(72)	Hard for me to foresee.
(73)	Very little
(74)	None

46. What changes would be required in aircraft operating procedures if ASA were implemented?

(Added as part of questionnaire revision).

PILOT #	COMMENTS
(11)	Added duties for all but especially non-flying pilot
(13)	Very little or none
(14)	Didn't really see any
(15)	Including ASA in scan
(18)	None
(19)	None
(21)	No major changes required
(22)	Another instrument that becomes part of the panel scan. This could also cause more eyes in the cockpit than outside looking for traffic.
(23)	No aircraft should be allowed into a high density traffic area without a coded transponder.
(24)	None
(26)	Transponders for all aircraft
(29)	Shouldn't require any changes
(30)	Use of F/E to monitor the display and help interpret
(32)	Can think of none, now.
(33)	Passenger seat belt would be on more of the time
(35)	S/O required to monitor CRT; no change if IVSI used
(36)	None
(38)	None
(42)	None

Question #46 continued

PILOT #	COMMENTS
(43)	None
(45)	None
(46)	Transmit
(47)	Very little
(48)	None
(50)	Checklist changes
(52)	None
(53)	None
(55)	None
(56)	None
(57)	Very few - integration of ASA utilization
(58)	Very little
(59)	Closer watch on ASA displays
(61)	None
(62)	None
(63)	Keep the little guy under more restrictive controls
(67)	ASA training
(68)	None
(69)	Pilots second guessing
(70)	All would detract from visual reference in VFR conditions but would help IFR. Head would be in the cockpit more.
(72)	Crew duties defined to prevent all heads in cockpit and to insure pilot flying is not diverted from basic instrument scan.
(73)	None
(74)	None

47. What additional test do you recommend be conducted before implementing ASA?

(Added as part of questionnaire revision).

PILOT #	COMMENTS
(11)	Actual flight checks
(12)	Training of pilots to be familiar with system
(14)	Extensive in-flight testing to provide exposure to all possible real situations.
(15)	Testing aircraft at extreme aircraft limits to see how it would react to commands (i.e., climb when already at high altitude).
(16)	Extensive testing in terminal areas.
(17)	Line operations
(18)	Line flight evaluation by various air carriers
(20)	Line test
(21)	Another series of tests (simulator) like this one plus in flight evaluation.
(22)	Each airline should have an ASA installed in one or two aircraft for evaluation of all the pilots.
(23)	See if there really will not be an oversaturation on the system under real time and world conditions.
(24)	Use in high density areas to determine number of false warnings.
(25)	Extensive flight testing
(26)	The sooner the better! Need no more test if present instrumentation proves reliable.
(27)	Hardware must be refined and cost accounting be evaluated
(29)	Testing to eliminate false signals. If the system gives false signals, the pilots will lose confidence and won't use it.

Question #47 continued

PILOT #	COMMENTS
(30)	Test in aircraft
(31)	Actual flight
(32)	Suggest again, closely monitoring reactions of fatigued pilots and controller re: UAL at Salt Lake City 12/18/77.
(33)	More practice
(34)	Certainly; get the hardware and see if it works in the real world.
(35)	Much greater participation by line and management pilots in actually flying the simulator. A minimum of 5 flights for each type of display.
(36)	Line operation
(37)	Must be tested in actual environment
(38)	Actual condition test
(41)	Many hours experience on line flights before installation
(42)	Flight tests
(43)	None
(44)	In flight tests
(45)	Real time testing
(46)	Better displays-more data-real world tests-through training
(47)	Flight test
(52)	The LED display could be moved to be included in instrument scan for more rapid recognition of advisory and other information.
(53)	Reliability. That is to say will it work every time with very few false activations. Like every other such type of instrument system, it will eventually become a crutch and therefore be regarded as reliable by air crews and controllers alike. It must be believed to be effective.

Question #47 continued

PILOT#	COMMENTS
(56)	On line experience
(58)	Line trial period perhaps 3 to 6 months
(59)	Combination of CRT and LED
(60)	Actual aircraft test by all facets of aviation
(61)	Naturally - on board flight testing. Perhaps hooking into a center on approach radar for actual conditions.
(62)	Flight test
(63)	In flight in a high density area, to see ATC's reactions
(66)	In flight actual hardware and threats
(67)	Flight tests LAX or ORD
(69)	Difficult to say in 10 words. If the initial tests are anything like ground proximity and ELT's, you can't have too much testing.
(70)	A good briefing for all crews prior to use, and some sort of malfunction indicator should the system go out of service while in flight.
(71)	Actual operations
(72)	Test CRT and IVSI displays together
(73)	None
(74)	Operational test on line aircraft with line pilots

48. How useful do you feel the ASA system will be in each phase of flight?

	VERY USEFUL	MODERATELY USEFUL	NOT USEFUL	UNDESIRABLE
Takeoff	22% (14)	37% (23)	35% (22)	6% (4)
Climb	72% (46)	28% (18)	0	0
Cruise	39% (25)	58% (37)	3% (2)	0
Descent	84% (54)	16% (10)	0	0
Approach	72% (46)	26% (17)	2% (1)	0
Landing	29% (18)	31% (19)	34% (21)	6% (4)

(Added as part of questionnaire revision).

PILOT #	COMMENTS
(40)	Nose angle in climbout

49. What type of maneuver command is preferable to avoid a collision during each phase of flight?

	HORIZONTAL	VERTICAL	EITHER
Takeoff	63% (39)	13% (8)	24% (15)
Climb	24% (15)	19% (12)	57% (36)
Cruise	27% (17)	16% (10)	57% (36)
Descent	21% (13)	17% (11)	62% (38)
Approach	50% (31)	5% (3)	45% (28)
Landing	61% (34)	14% (8)	25% (14)

(Added as part of questionnaire revision).

PILOT #	COMMENTS
(24)	Depends on command, terrain, airspeed
(40)	Stop descent
(46)	None

50. Would a voice command be desirable for the ASA function (e.g., "TURN RIGHT WHOOP WHOOP TURN RIGHT")?

VERY DESIRABLE 6% (4)   ACCEPTABLE 23% (14)   UNDESIRABLE 71% (44)

(Added as part of questionnaire revision).

PILOT #	RESPONSES	COMMENTS
(26)	Undesirable	Audio warning O.K. without command. To indicate on collision course and check ASA instrumentation.
(27)	Acceptable	Maybe
(30)	Very desirable	But no whoop whoop!
(32)	Desirable	We have enough racket in the cock-pit now. The simple alarm as installed is quite sufficient.
(41)	Undesirable	No way!
(49)	Undesirable	Too many tones now. I still feel that ASA audio could be more obvious.
(51)	Undesirable	I think you should run some tests using this idea.
(63)	Undesirable	Please. Not another whoop, whoop!

51. a) Would you like to have a sensitivity control which could control the alarm rate by controlling the point at which an aircraft is declared a potential threat?

VERY DESIRABLE 26% (17) ACCEPTABLE 37% (23) UNDESIRABLE 37% (23)

(Added as part of questionnaire revision).

PILOT #	RESPONSE	COMMENTS
(49)	Undesirable	Design system to be compatible and not just another piece of equipment to be disarmed.
(63)	Undesirable	No! You have to have some standards to work from.
(65)	Acceptable	A function of closure rate

51. b) One of the factors controlling the point at which an aircraft is declared a potential threat is the TIME-TO-COLLISION (TAU). During the test it was always set at 25 seconds, which values would you prefer during various flight phases?

	MINIMUM	PREFERRED	MAXIMUM
Takeoff/Climb	______	______	______
Enroute	______	______	______
Descent/Landing	______	______	______

(Added as part of questionnaire revision).

Question #51b continued

PHASE OF FLIGHT	MINIMUM TAU		PREFERRED TAU		MAXIMUM TAU	
	TAU (secs)	Number of Responses	TAU (secs)	Number of Responses	TAU (secs)	Number of Responses
TAKEOFF/ CLIMB	20	4	20	1	30	8
	25	3	25	2	40	4
	30	15	30	23	45	4
	40	1	40	2	60	4
			45	2	120	1
			60	2		
ENROUTE	25	4	30	13	30	3
	30	13	40	1	40	1
	40	2	45	6	45	2
	60	1	50	1	60	9
			60	8	90	2
			90	1	120	2
DESCENT/ LANDING	20	4	30	24	30	7
	25	4	35	1	40	3
	30	14	40	2	45	5
			45	3	60	5
			60	2	120	1

PILOT #	COMMENTS
(14)	Don't really know without trying in simulation.
(30)	Time quite satisfactory
(68)	Enough time to start and complete maneuver to miss the potential threat.

52. Do you feel the traffic depiction on the CRT would be used to make minor course, typed, or attitude changes to avoid getting a maneuver command?

YES (I did it during the test) 27% (17)

YES (With practice) 39% (25)

YES (With very close attention to the display) 13% (8)

YES (With practice and close attention) 17% (11)

NO 4% (3)

(Added as part of questionnaire revision).

PILOT #	RESPONSE	COMMENTS
(52)	Yes (during the test)	This is a negative feature.
(64)	Yes (with practice)	Some pilots would use it always-even though it may not be necessary.

53. What is your overall reaction to having an ASA system similar to any of the ones you tested tonight being installed in air carrier aircraft?

(Added as part of questionnaire revision).

PILOT #	COMMENTS
(11)	Yes, when developed fully.
(12)	I believe that these systems are workable in our present work environment. They would add a safety factor to every airplane that is so equipped. There is no operational change required to gain this extra safety. A small amount of crew training is all that is required. This could be done on PC PT training. Procedures for flight path deviation could be worked out by ATC. We need ASA systems now and will need them more as each day without them passes.
(13)	It should have been done years ago!

Question #53 continued

PILOT #	COMMENTS
(14)	Good - especially of the CRT variety.
(15)	I think it would add an additional safety function which at this time is badly needed.
(16)	System has possibilities; however, CRT and others force eyes in the cockpit too much during avoidance maneuvers. I am not convinced it will work in high density area.
(17)	Has good potential
(18)	IVSI and LED would work well and be acceptable. CRT requires too much interpretation, and attention is diverted from other duties in order to utilize CRT.
(19)	IVSI and LED (located in scan pattern are both excellent. CRT is out of scan pattern especially while maneuvering for CRT commands. Under many operating conditions, as in heavy weather, radar plus CRT would be difficult at best.
(20)	Very good
(21)	What are we waiting for?
(22)	The system is good - but there will be a lot of evasive maneuvers or near misses given by an instrument command, where before the ASA system and with the "eyeball", it was a wait-and-see attitude.
(23)	Yeah! Particularly IVSI or CRT.
(24)	I feel the CRT with greater range would be a great asset to air carriers provided it doesn't give a lot of false warnings so that pilots lose confidence in its ability to determine true potential hazards.
(25)	IVSI, because it is in normal scan and could be adapted to present system with minimum amount of difficulty.
(26)	The sooner the better!

Question #53 continued

PILOT #	COMMENTS
(27)	I feel we need some type of ASA system and the need grows each day with increased traffic. I feel we still need to explore and perfect a workable and affordable product.
(28)	We needed it years ago.
(29)	The sooner the better.
(30)	I would favor the installation.
(31)	My reaction was very favorable. We need an ASA system.
(32)	With refinements of placement of device and proper practice it would be a very useful tool. Would like to test system at different time.
(33)	Please ASAP.
(34)	Although I did not have an opportunity to use the IVSI, it appeared to be the best presentation.
(35)	Would like the IVSI installed - simple with no increase in scan pattern.
(36)	Good idea
(37)	I think we should proceed with ___________?
(39)	Need something
(40)	Good
(41)	Yesterday wasn't soon enough.
(42)	Very positive to the CRT.
(43)	Should do it! My comments should carry very little weight here because they're based on one 2 hour session as 1st officer in a relatively strange environment (727). A lot of comment is based on instructive thoughts, and I might change my mind with more practice in the use of these displays.

Question #53 continued

PILOT #	COMMENTS
(44)	Favorable
(45)	The system would be acceptable provided all aircraft are equipped with transponders. Delete all false warnings and provide a command, etc., only when an emergency is real. If I had to choose one of the systems or part of a system, an information display rather than a command display would be desirable.
(46)	I believe some sort of CAS is mandatory. I would prefer a CRT type display for information and planning but a panel-mounted command instrument. One without the other? CRT is nice, but the IVSI command is of questionable value without the information background. If I had to settle for one, would prefer information to command!
(47)	I would like to have one installed.
(48)	Problem of false alerts could reduce pilot acceptance; a properly functioning system would be welcomed. I especially like the CRT display in full CAS.
(49)	Good
(50)	Outstanding idea! Worth a try.
(51)	Very helpful
(52)	I believe the system would be acceptable and consider all of the displays to be also acceptable. Simplicity is essential when necessary information is being presented during periods of high cockpit workload. This allows the crew to accept the information with a minimum of confusion. For this reason, I believe the LED display could be improved if when necessary for a positive command -- all other information is absent from the display at least momentary.
(53)	Would be valuable provided it worked all the time and did not provide too many false problems.
(54)	I would like to see a system installed in all IFR equipped airplanes, both air carrier and general aviation.

Question #53 continued

PILOT #	COMMENTS
(55)	An excellent idea. Will allow the cockpit as well as the ground to see impending or possible collisions. Areas like SFO, SAN, ORD, etc., are becoming increasingly clogged with traffic; a voiced warning may not be possible in many cases.
(56)	Good idea.
(57)	Unfortunately, but necessary to improve safety levels.
(58)	Yes, after a trial period and operator experience, I feel they would be very useful.
(59)	Positive
(60)	A display such as CRT would be a plus in air carrier operations. All the ASA systems are good for confidence building. If IVSI is used - more range information should be provided.
(61)	If we save one life - it is well worth it!
(62)	Positive
(63)	At this stage of the game with many recent accidents, the question should answer itself.
(64)	Great
(65)	O.K.
(66)	Can't happen soon enough.
(67)	Airborne presentation sorely needed to back-up system.
(68)	Very favorable

Question #53 continued

PILOT #	COMMENTS
(69)	I have both practical and philosophical problems with the ASA system. Practical: 1) Too much head down in the cockpit. There's enough of that already. 2) Please not another ground proximity system! 3) Pilots will second guess it unless the computer program is airtight! Philosophical: I suppose more and more regulations are inevitable - but a ground-based ASA system (even though "best") will provide justification for even bigger FAA beaurocracy! Do we really want this. Does the San Diego tragedy really justify all this?
(70)	Any help we can get would be a benefit, but crews should not become too reliant on these systems and not continue visual avoidance too. I liked them all and feel I could learn to use any of the systems. Reliability is essential - proper maintenance is also very important. MEL (minimum equipment) for dispatch would also be required (i.e., would we need the equipment to leave small non-maintenance stations).
(71)	I believe it is desirable and inevitable.
(72)	Any one of the three would be a much needed safeguard which I would welcome, but my preference would be the CRT and IVSI or if not that the CRT in its present form but not the IVSI by itself because we do need to know the position information to have confidence in the box.
(73)	I would welcome installation ASAP.
(74)	I would like to see one of these units installed especially the CRT incorporated with the weather radar. Our cockpits are already clogged with boxes.

APPENDIX E

SUPPLEMENTAL QUESTIONNAIRE

A supplemental questionnaire was mailed to each of the pilots who participated in the ASA cockpit evaluation approximately 2.5 months after the close of testing. The purpose of the questionnaire was to help clarify responses from the original questionnaire and to solicit additional comments. Of the 74 questionnaires mailed, 50 completed forms were returned.

Questions are presented in the appendix exactly as they appeared in the questionnaire and are followed by the tabulated results. All comments are presented at the end of the appendix. Minor editorial changes have been made to improve readability. Results for questions 1 and 2 are not significant in themselves and are not presented. The responses were solicited for use in the data analysis.

AIRCRAFT SEPARATION ASSURANCE
COCKPIT EVALUATION

FOLLOW-UP QUESTIONNAIRE

1. To the best of your recollection, which seat did you occupy during the evaluation of the:

	Captain	1st Officer	2nd Officer	Don't Recall
IVSI:	____	____	____	____
LED:	____	____	____	____
CRT:	____	____	____	____

2. Were you flying the simulator during the evaluation of the:

	YES	NO	Don't Recall
IVSI:	___	___	___
LED:	___	___	___
CRT:	___	___	___

3. Do you feel that traffic advisories are an essential part of a BCAS display?

YES 79% (37) NO 21% (10)

4. If the traffic advisories contain only altitude and range of the surrounding traffic (a limitation of active BCAS), would they still be considered an essential part of a BCAS display?

YES 76% (35) NO 24% (11)

5. How would you describe your overall work load during the simulation as compared to any other typical simulator training session?

	Unacceptable Increase in Workload	Acceptable Increase in Workload	No Effect on Workland	Small Decrease in Workload	Large Decrease in Workload
IVSI:	2% (1)	64% (30)	30% (14)	4% (2)	0
LED:	26% (13)	54% (27)	16% (8)	2% (1)	2% (1)
CRT:	31% (15)	59% (28)	8% (4)	2% (1)	0

6. Active BCAS provides positive commands (CLIMB, DESCEND), Negative Commands (DON'T CLIMB, DON'T DESCEND) and Limit Commands (LIMIT CLIMB 2000 FPM, LIMIT CLIMB 1000 FPM, LIMIT CLIMB 500 FPM, LIMIT DESCENT 2000 FPM, LIMIT DESCENT 1000 FPM, and LIMIT DESCENT 500 FPM). Are all these commands necessary?

	YES	NO
Positive Commands	96% (47)	4% (2)
Negative Commands	77% (37)	23% (11)
Limit Commands	60% (29)	40% (19)

7a. How would you rank the three displays for active BCAS? (The IVSI and LED displays would be as presented during the simulation; the CRT, in a strictly active BCAS environment would contain a graphical representation of relative range and altitude; no bearing information would be available. Rank each display as first, second, or third choice.

	IVSI ____	LED ____	CRT ____
1	1-33% (16)	1-20% (10)	1-47% (23)
2	2-31% (15)	2-51% (25)	2-18% (9)
3	3-37% (18)	3-29% (14)	3-34% (17)

b. Would your second choice be acceptable if the first choice was not available?

YES 94% (47) NO 6% (3)

c. Would your third choice be acceptable if the first and second choices were not available?

YES 52% (26) NO 48% (24)

8. Would you like to receive a copy of the simulation study final report?

YES 100% (50) NO 0

9. Do you have any additional comments on the ASA program?

Where possible, aircraft separation information should be three dimensional.

Well thought out program. A new system is needed to be sure.

The sooner it can be put to use - the better. The aural alert should be included, although confusing, perhaps, when first used. As soon as flight crews become used to an aural signal, it becomes an accepted and useful tool.

First preference is for CRT with range and relative bearing.

Given the test situation, a combination of the "IVSI" and "CRT" would seem most beneficial:

> The "IVSI" gives necessary DO IT NOW information in simply perceived form.
>
> The "CRT" adds the capability for limited "TOTAL" situation analysis from within the cockpit.

I was extremely impressed with the CRT equipment's ability to provide a unambiguous display of the traffic situation. This was especially true where the relative bearing information was available. Where bearing information is not available, the CRT and LED displays were roughly equivalent. The IVSI display, I found to be extremely difficult to decipher. Granted, one has only to follow specific commands to avoid the conflict. However, I feel that this runs counter to any human instinct; i.e., to attempt to visualize the situation in one's own mind before acting. A system such as this would be viewed as another way to removing the pilot from the control loop.

1. I was flying an approach using the LED display. I had difficulty flying the approach while trying to follow the evasive action called for. Later on at the debriefing, I found we were making a parallel ILS approach with another aircraft.

2. Even though the briefing was quite adequate on the operational aspects, I feel that the crew would have to spend a period of time in VFR conditions until they feel comfortable in most of the more common closing situation. Some problems also exist in high density traffic areas with heavy radio traffic. I would be very reluctant to deviate from an assigned heading or altitude knowing I probably had other traffic around.

3. All things considered, I feel any reliable system would be helpful and the systems we worked with have great potential to prevent collisions after the crew has the experience to quickly assimilate the important information.

The LED & IVSI are both excellent displays of vital information. A pilot can see and react as easily as one reacts to a glide slope, localizer or airspeed indicator. The CRT is unacceptable. It requires excessive heads down time to read and react.

A type of HUD display would help.

A flight test program putting an active BCAS in selective air carrier aircraft would seem a better idea than letting the FAA flight test the equipment. Airline pilots will ultimately be the main users of the BCAS and therefore their evaluation of the system would be more valid than the FAA's.

Excellent program. Need more like it.

I believe this program should have been implemented at least four years ago. We would have a viable system today. Let us hope no impediments prevent institution of the BCAS as soon as possible.

Traffic advisories are important, especially at night. A target spotted visually might appear to be in conflict when in effect it is not. The IVSI is the easiest to fly but gives no information as to location of targets. Panel location of the LED display was unacceptable and mental gymnastics were required to-read-translate-and look for the targets. CRT display was a little better, as far as location is concerned, but the same mental computations were required. Its location allowed the second officer to participate and accept part of the workload. Positive commands are necessary. Negative limit commands are convenience commands. Negative and limit commands always make me wonder how close I'll come to the target if I follow the commands and never spot it visually. The latter two displays caused me to have fixation on the display and forget about the flight instruments. After much thought, I now agree that vertical correction is the most rapid and effective means of collision avoidance.

With a CRT display having relative range and altitude representation, I believe the pilot could determine his own climb or descent rate thereby eliminating the need for limit commands. IVSI and LED displays would need limit commands. Altitude and range advisories would help determine the proximity of the traffic and give early alert as to the necessity for evasive action.

The problem with the CRT was the inability to see it as well as compared with the LED. Secondly, the LED data assimilation (ability to see and correlate mentally the information in order to integrate that data into the total mental picture) seemed easier. Because I was not that familiar with the aircraft, this assimilation made it all the more difficult. It would be interesting to test the data in my own aircraft.

The IVSI display was the most satisfactory for me with only a slight increase in workload and at times no additional increase. The other two systems required too much interpretation by the pilot to be useful without detracting markedly from other piloting functions.

1. The potential for CRT traffic display in new aircraft (767/757) employing an electronic HSI or map presentations is good.

2. As implemented in the simulation, the CRT is poor (location and lack of relative heading/track information).

The program does tend to make you concentrate your attention inside the cockpit and I believe you should be looking outside in this situation.

There has been a lot of discussion about the BCAS and all collision avoidance since I was able to fly the test, a lot of good ideas brought up. I am sorry I can't remember them all. But one idea is, or question is, has any of the radar manufacturers worked with the idea of a CRT/Radar/BCAS combined. This would lower cost and also save space.

I would like to be able to fly the system again since I have been able to think about it. I do hope that this program is continued, as I feel that it is of utmost importance and although I do prefer the CRT, any of the systems would, if installed and crews properly trained, would be an asset to the safety of airline travel.

Keep it simple. IVSI displays appeared the simplest to me.

I believe it is important to separate separation assurance from collision avoidance. Collision avoidance must constitute just the simplest and least confusing commands.

A real necessity in the cockpit! One of these systems should become a reality of airline flying. This combined with ATC reports should eliminate a substantial portion of the near hits encountered (known or unknown) each day.

I felt most comfortable with the CRT. It gives a graphic presentation at a glance with minimum interpretation necessary; this is essential since the unit will be most used when cockpit work loads are highest, i.e., approach, landing, and departure phase.

Enjoyed the testing and the professional attitude of the test crew.

I feel that the LED display is okay in straight and level flight but can be very confusing during a turn.

Press on.

When you remove bearing from the CRT, you greatly degrade its usefulness. Any other aircraft that maintains a constant relative bearing on the windshield and continually gets larger in size (decreasing range) is a theoretical midair. I tend to evaluate constant bearing, decreasing range before altitude, since the other aircraft may be climbing towards me or descending towards me. To the unaided (and non-computerized) human eye, constant bearing, decreasing range is a vital key to evaluating a midair threat.

The best combination of all would be CRT for information with IVSI for commands.

I felt this simulator test was authentically presented (ATC environment) and professionally administered.

APPENDIX F

DATA ANALYSIS FORMULAS

This appendix provides a detailed description of the statistical tests that were used in the quantitative data analysis. A short glossary of the statistical terminology used is included at the end of this discussion.

The first three tests are distribution-free statistical tests that have been applied to the response time data.

I. Kruskal-Wallis One-Way Analysis of Variance by Ranks

This test is a difference in location test. It compares distributions of response times by several treatments to determine treatment effects. Significant differences between distributions are noted.

II. Kolmogorov-Smirnov Two-Sample Test

This test is a comparison test between two sample distributions. The cumulative probability distributions of the two samples are compared for significant differences. The following statistical tests were performed (based on the normal distribution) on pitch rate and roll angle data since their measurements are continuous and follow normal distributions more closely.

III. Analysis of Variance (ANOVA)

A. One-way classification. This method determines the differences caused by a single influencing factor among several sets of measurements.

B. Two-factor experiment. This method determines the differences caused by two influencing factors among several sets of measurements. These two tests were used in the analysis of response magnitude measurement.

IV. Significance of Difference Between Variances (F-Test)

This aids in determining whether the variances of two sample sets are equal. The direction of difference may also be tested.

V. Significance of Difference Between Means (t-Test)

This test aids in determining whether the means of two sample sets are equal. The direction of difference may also be tested.

I. Kruskal-Wallis One-Way Analysis of Variance by Ranks*

Data: $N = \sum_{j=1}^{k} n_j$ observations

n_j observations from the j^{th} treatment, $j = 1, \ldots, k$

treatments

1	2	. . . .	k
X_{11}	X_{12}	. . . .	X_{1k}
X_{21}	X_{22}	. . . .	X_{2k}
.	.		.
.	.		.
.	.		.
.	$X_{n_2 2}$		.
.			
.			$X_{n_k k}$
$X_{n_1 1}$			

Hypotheses:

Null -- H_0: $T_1 = \ldots = T_k$ T_j is the treatment effect

Alternate -- H_1: T_j's are not equal

Procedure:

1. Rank all N observations jointly, from least to greatest. Let r_{ij} denote the rank of X_{ij} in this joint ranking.

2. Set , for j=1, ..., k

$$R_j = \sum_{i=1}^{n_j} r_{ij} \qquad R_{\cdot j} = \frac{R_j}{n_j} \qquad R_{\cdot\cdot} = \frac{N+1}{2}$$

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*Hollander, M. and Wolfe, D.A., *Non-Parametric Statistical Methods;* John Wiley and Sons, Inc., 1973; pp 114-116.

3. Compute

$$H = \frac{\frac{12}{N(N+1)} \sum_{j=1}^{k} n_j \, (R_{\bullet j} - R_{\bullet\bullet})^2}{1 - \sum_{j=1}^{g} T_j / [N^3 - N]}$$

where g = number of tied groups

$T_j = (t_j^3 - t_j)$

t_j = size of tied group j.

4. When H_0 is true, the statistic H has an asymptomatic χ^2 distribution based on k-1 degrees of freedom. The approximate α-level test is:

reject H_0 if $H \geq \chi^2_{(k-1,\alpha)}$

accept H_0 if $H < \chi^2_{(k-1,\alpha)}$

5. Note: For ties use average ranks.

II. Kolmogorov-Smirnov Two-Sample Test*

Data: Two independent samples of data with number of samples n_1 in sample 1, and n_2 in sample 2.

Procedure:

H_0: the two samples have been drawn from the same population.

H_1: the two samples have not been drawn from the same population.

1. For each observed value X, compute the observed cumulative step functions for samples 1 and 2.

Let $S_{n_1}(X) = K/n_1$, where K = the number of measurements equal to or less than X, and let $S_{n_2}(X) = K/n_2$, where K = the number of measurements equal to or less than X.

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*Seigel, Sidney, *Non-Parametric Statistics;* McGraw-Hill, Inc., 1956; pp 127-136, 279.

2. The Kolmogorov-Smirnov two-sample test focuses on

$$D = \text{maximum} \left| S_{n_1}(X) - S_{n_2}(X) \right|$$

3. For $n_1, n_2 \geq 40$ (not necessary for $n_1 = n_2$) the following table is used to determine whether or not to reject H_0:

TABLE OF CRITICAL VALUES OF D IN THE KOLMOGOROV-SMIRNOV TWO-SAMPLE TEST	
Level of Significance	Value of D so large to call for rejection of H_0 at the indicated level of significance where $D = \text{maximum} \left\| S_{n_1}(X) - S_{n_2}(X) \right\|$
.10	$1.22 \sqrt{\frac{n_1 + n_2}{n_1 n_2}}$
.05	$1.36 \sqrt{\frac{n_1 + n_2}{n_1 n_2}}$
.025	$1.48 \sqrt{\frac{n_1 + n_2}{n_1 n_2}}$
.01	$1.63 \sqrt{\frac{n_1 + n_2}{n_1 n_2}}$
.005	$1.73 \sqrt{\frac{n_1 + n_2}{n_1 n_2}}$
.001	$1.95 \sqrt{\frac{n_1 + n_2}{n_1 n_2}}$

4. When $n_1, n_2 < 40$ (not necessary for $n_1 = n_2$), compute the chi-squared statistic

$$\chi^2 = 4D^2 \frac{n_1 n_2}{n_1 + n_2} \text{ with 2 degrees of freedom}$$

Reject H_0 in favor of H_1 if at the α level of significance

$$\chi^2 \geq \chi^2 \ (2,\alpha)$$

III. Analysis of Variance (ANOVA)*

A. One-way classification

Data:

MEASUREMENTS		
Treatment 1	X_{11} X_{12} . . . . . . X_{1b}	$\bar{X}_{1\cdot}$
Treatment 2	X_{21} X_{22} . . . . . . X_{2b}	$\bar{X}_{2\cdot}$
.		
.		
.		
Treatment a	X_{a1} X_{a2} . . . . . . X_{ab}	$\bar{X}_{a\cdot}$

Treatment mean: $\bar{X}_{j\cdot} = \frac{1}{b} \sum_{k=1}^{b} X_{jk}$ $\quad j = 1, 2, \ldots, a$

Overall mean: $\bar{X} = \frac{1}{ab} \sum_{j=1}^{a} \sum_{k=1}^{b} X_{jk}$

Variation: $V = V_w + V_b$

V is the total variation

V_w is the variation within treatments

V_b is the variation between treatments

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*Spiegel, Murray R., *Probability and Statistics;* McGraw-Hill, Inc., 1975; pp 306-313.

Analysis of Variance Table:

Variation	Degrees of Freedom	Mean Square	F
Between treatments $V_b = b\sum_j (\bar{X}_{j\cdot} - \bar{X})^2$	a-1	$\hat{S}_b^2 = \frac{V_b}{a-1}$	$\frac{\hat{S}_b^2}{\hat{S}_w^2}$ with a-1, a(b-1) degrees of freedom
Within treatment $V_w = V - V_b$	a(b-1)	$\hat{S}_w^2 = \frac{V_w}{a(b-1)}$	
Total $V = V_b + V_w$ $= \sum_{j,k} (X_{jk} - \bar{X})^2$	ab-1		

To test:

H_0: $\mu_j = \mu$ $\quad j = 1, \ldots, a$

H_1: $\mu_j \neq \mu$ $\quad j = 1, \ldots, a$

where μ_j is the actual population mean for treatment j and μ is the overall population mean.

H_0 is the hypothesis that the treatment means are all equal. H_1 is the alternate hypothesis that the treatment means are not all equal.

$\frac{\hat{S}_b^2}{\hat{S}_w^2}$ is χ^2 distributed with a-1, a(b-1) degrees of freedom.

Accept H_0 if $\frac{S_b^2}{S_w^2} \leq F_{1-\alpha}$

Reject H_0 if $\frac{S_b^2}{S_w^2} > F_{1-\alpha}$

at the α level of significance.

Modification for unequal numbers of observations:

Let n_j be the number of measurements from treatment j.

$$\sum_{j=1}^{a} n_j = n \text{ total number of measurements}$$

The following analysis of variance table shows the computation of variations:

Variation	Degrees of Freedom	Mean Square	F
Between Treatments $V_b = \sum_j n_j (\bar{X}_{j\cdot} - \bar{X})^2$	a-1	$\hat{S}_b^2 = \frac{V_b}{a-1}$	$\frac{\hat{S}_b^2}{\hat{S}_w^2}$ with a-1, n-a degrees of freedom
With Treatments $V_w = V - V_b$	n-a	$\hat{S}_w^2 = \frac{V_w}{n-a}$	
Total $V = V_b + V_w$ $= \sum_{j,k} (X_{jk} - \bar{X})^2$	n-1		

B. Two-factor experiments

<u>Data</u>:

Treatments	Blocks				
	1	2	. . . . .	b	
1	X_{11}	X_{12}		X_{1b}	$\bar{X}_{1\cdot}$
2	X_{21}	X_{22}		X_{2b}	$\bar{X}_{2\cdot}$
.					
.					
a	X_{a1}	X_{a2}		X_{ab}	$\bar{X}_{a\cdot}$
	$\bar{X}_{\cdot 1}$	$\bar{X}_{\cdot 2}$		$\bar{X}_{\cdot b}$	

$$\bar{X}_{j\cdot} = \frac{1}{b} \sum_{k=1}^{b} X_{jk}$$ treatment mean

$$\bar{X}_{\cdot k} = \frac{1}{a} \sum_{j=1}^{a} X_{jk}$$ block mean

$$\bar{X} = \frac{1}{ab} \sum_{j,k} X_{jk}$$ overall or grand mean

Variation: $V = V_e + V_r + V_c$

V_e is variation due to error or chance

V_r is variation between rows (treatments)

V_c is variation between columns (blocks)

Analysis of Variance Table:

Variation	Degrees of Freedom	Mean Square	F
Between Treatments $V_r = b\sum_j (\bar{X}_{j\cdot} - \bar{X})^2$	a-1	$\hat{S}_r^2 = \frac{V_r}{a-1}$	$\hat{S}_r^2/\hat{S}_c^2$ with a-1, (a-1)(b-1) degree of freedom
Between Blocks $V_c = a\sum_k (\bar{X}_{\cdot k} - \bar{X})^2$	b-1	$\hat{S}_c^2 = \frac{V_c}{b-1}$	$\hat{S}_c^2/\hat{S}_e^2$ with b-1, (a-1)(b-1) degree of freedom
Residual or Random $V_e = V - V_r - V_c$	(a-1)(b-1)	$\hat{S}_e^2 = \frac{V_e}{(a-1)(b-1)}$	
Total $V = V_r + V_c + V_e = \sum_{j,k} (X_{jk} - \bar{X})^2$	ab-1		

To test:

$H_0^{(1)}$: All treatment means are equal

$H_0^{(2)}$: All block means are equal

IV. Significance of Difference Between Variances (F-Test)*

The F-test is a test of significance between two sample variances S_x^2, S_y^2 of data sets X and Y assumed to come from the same population with actual variances $\sigma_x^2 = \sigma_y^2$

Sample variance: $$S_x^2 = \left(\frac{N}{N-1}\right)\left[\frac{\sum_{i=1}^{N} x_i^2}{N} - \left(\frac{\sum_{i=1}^{N} x_i}{N}\right)^2\right]$$

Procedure:

1. Compute the F-ratio:

$$F = \begin{cases} S_x^2/S_y^2 & \text{if } S_x^2 > S_y^2 \\ S_y^2/S_x^2 & \text{if } S_x^2 \leq S_y^2 \end{cases}$$

Let m_1 and m_2 be the number of samples used in computing the variance in the numerator and denominator, respectively.

2. To test for significance of variance:

H_0: $\sigma_x^2 = \sigma_y^2$

H_1: $\sigma_x^2 \neq \sigma_y^2$

H_0 is the hypothesis that the variances for X and Y are equal; H_1 is the alternate hypothesis that the variances for X and Y are unequal.

3. Since F has F distribution with $M_1 - 1$, $M_2 - 1$ degrees of freedom, test at the α level of significance:

Accept H_0 if $F_{\frac{\alpha}{2}} \leq F \leq F_{1-\frac{\alpha}{2}}$; Reject H_0 otherwise

*Hoel, Paul G., *Introduction to Mathematical Statistics;* John Wiley and Sons, Inc., 1971; pp 271-273.

V. Significance of Difference Between Means (t-Test)*

The t-test is a test of significance between two sample means $\bar{X}$ and $\bar{Y}$ of data sets X and Y assumed to come from the same population.

Sample mean: $\bar{X} = \frac{1}{N} \sum_{i=1}^{N} x_i$

Sample variance: $s_x^2 = \left(\frac{N}{N+1}\right) \left[\frac{\sum_{i=1}^{N} x_i^2}{N} - \left(\frac{\sum_{i=1}^{N} x_i}{N} \right)^2 \right]$

Let M_1 and M_2 be the number of samples used in computing the variance in the numerator and denominator, respectively.

Procedure:

1. If $\sigma_x^2 \neq \sigma_y^2$, then compute the t-test statistic and degrees of freedom given by:

$$t = \frac{|\bar{X} - \bar{Y}|}{\sqrt{\frac{s_x^2}{M_1} + \frac{s_y^2}{M_2}}} \quad \text{test statistic}$$

$$\nu = \frac{\left(\frac{s_x^2}{M_1} + \frac{s_y^2}{M_2}\right)^2}{\frac{\left(\frac{s_x^2}{M_1}\right)^2}{M_1+1} + \frac{\left(\frac{s_y^2}{M_2}\right)^2}{M_2+1}} - 2 \quad \text{degrees of freedom}$$

2. If $\sigma_x^2 = \sigma_y^2$, then compute the t-test statistic and degrees of freedom given by:

$$t = \frac{|\bar{X} - \bar{Y}|}{\sqrt{\frac{s_x^2}{M_1} + \frac{s_y^2}{M_2}}} \cdot \sqrt{\frac{M_1 M_2 (M_1 + M_2 - 2)}{M_1 + M_2}} \quad \text{test statistic}$$

$$\nu = M_1 + M_2 - 2 \quad \text{degrees of freedom}$$

*Hoel, Paul G., *Introduction to Mathematical Statistics;* John Wiley and Sons, Inc., 1971; pp 262-265.

3. The significance test for the mean is based on the following hypothesis:

H_0: $\bar{X} = \bar{Y}$

H_1: $\bar{X} \neq \bar{Y}$

H_0 is the hypothesis that the means for sample X and Y are equal; H_1 is the alternative hypothesis that the means for sample X and Y are unequal.

4. Since t has student's t distribution, test at the level of significance α:

Accept H_0 if: $-t_{1-\frac{\alpha}{2}} \leq t \leq t_{1-\frac{\alpha}{2}}$

with ν degrees of freedom. Reject H_0 otherwise.

DEFINITIONS

1. Block — A block is an influencing factor in an experiment. Examples of blocks may be:

- Individual pilots responding to a specific question
- Groups of pilots responding to a specific question in the same way
- Different command types

2. Hypothesis Testing — A hypothesis is assumed to be true at the onset of an experiment. This hypothesis is noted by H_0, the null hypothesis. In addition, an alternative to the null hypothesis is proposed; this is noted by H_1, the alternative hypothesis. Two possible outcomes of the experiment are:

- H_0 is accepted -- the null hypothesis is accepted as being true (i.e., cannot be rejected)
- H_0 is rejected in favor of H_1 -- the first hypothesis is rejected and hence, the alternative hypothesis is accepted.

3. Level of Significance (α) — The level of significance (α) is the maximum probability risk of a Type I error, where the Type I error is defined to be the error of rejecting the null hypothesis, H_0, when H_0 is actually true.

4. **Population and Sample Parameters** — The population parameters are the actual parameters of the underlying population from which a sample is derived. Most often, values for these parameters are unknown. Hence, estimates are computed from the sample set.

5. **Treatments** — A treatment is a factor in an experiment applied to blocks or measurements. An example of a treatment is the effect of display type (IVSI, LED, CRT) on pilot response time.

APPENDIX G

TEST BED DESCRIPTION DETAILS

This appendix provides details on the simulation test bed that have not been covered in the body of the report. Specifically, the areas covered are the software design details, the interface between the computer-generated image (CGI) computer and the simulation control computer, and the display device drivers.

1. SOFTWARE DESIGN DETAILS

This section describes the software developed under contract for the PDP-11/34, which was used as the simulation control computer. The software was written in both FORTRAN and assembly language under Digital Equipment Corporation's RSX-11M operating system. The only purchased software was a graphics package purchased from TEKTRONIX, Inc. to drive the graphics terminal used for the air traffic controller's position.

The software was developed under RSX-11M's multitasking environment which allows several executable modules (called tasks) to compete simultaneously for the computer's resources. Tasks can be executed continuously, periodically, or on request. A predetermined priority scheme is used to decide which tasks are executed at any point in time.

The simulation tasks can be described in terms of five areas: parameter initialization, the simulator interface service routine, the main loop, the console operator, and the display drivers. This section describes the first four areas. The software description of the display drivers is included in Section 3 since it is difficult to separate the software and hardware descriptions.

1.1 Parameter Initialization

A separate task was executed at the beginning of each simulated flight to initialize the simulation parameters which were stored in a shared data region. The simulation parameters are categorized as follows:

- Collision Avoidance System Parameters - These are the values used by the tracking, detection, resolution, and proximity warning indication (PWI) logic to determine if a conflict situation exists. (See Table G-1 for values.)

Table G-1. COLLISION AVOIDANCE SYSTEM PARAMETERS		
Name	Description	Value
ALFAR	Tracking constant for range (Active mode only)	0.4
ALFAX	Tracking constant for X and Y position (Full mode only)	0.4
ALFAZ	Tracking constant for altitude	0.4
ALIM	Vertical miss distance threshold used in command selection	400 Feet
ASEPV	Vertical miss distance threshold used in horizontal versus vertical selection logic (Full mode only)	350 Feet
BETAR	Tracking constant for range rate (Active mode only)	0.15
BETAX	Tracking constant for X and Y velocity (Full mode only)	0.15
BETAZ	Tracking constant for altitude rate	0.15
DMOD*	Distance modification of tau threshold for collision avoidance logic	1.0 nmi 0.5 nmi 0.3 nmi
DMODP*	Distance modification of tau threshold for PWI detection logic (Full mode only)	1.0 nmi 0.5 nmi 0.3 nmi
MDCMD*	Square of horizontal miss distance threshold beyond which no commands are requested (Full mode only)	9.0 nmi2 4.0 nmi2 1.0 nmi2
MDPOS*	Square of horizontal miss distance threshold used for positive versus negative command selection (Full mode only)	1.0 nmi2 0.25 nmi2 0.25 nmi2
RDESEN	Range threshold used to desensitize collision avoidance logic at low altitude	15.0 nmi
RDTHR	Range rate threshold used to choose between tau test and immediate range test	10.0 FPS
ROFF	Range threshold used to shut off collision avoidance logic	2.0 nmi
RTHPO*	Immediate range threshold for PWI logic	3.0 nmi 2.0 nmi 1.0 nmi
RTHR	Immediate range threshold for collision avoidance logic	0.1 nmi

*Desensitized parameters

Table G-1. (continued)

Name	Description	Value
RZIPDO	Altitude separation threshold for PWI logic	2,000 Feet 1,500 Feet 1,000 Feet
TIMETX	Time to track crossing point threshold (Full mode only)	10 seconds
TIPDO	Tau threshold for PWI logic	60 seconds
TLARGE	Default tau value	100,000 seconds
TMIN	Minimum time that a command is displayed before being changed	5 seconds
TRTHR*	Modified tau threshold	30 seconds 25 seconds 25 seconds
TVPCMD*	Look-ahead time used to compute the projected vertical miss distance	25 seconds 20 seconds 20 seconds
TVTHR*	Vertical tau threshold	30 seconds 25 seconds 25 seconds
TV1	Look-ahead time used for vertical commands.	8 seconds
TV2	Used in conjunction with TV1 to bracket vertical tau in horizontal versus vertical selection logic (Full mode only)	16 seconds
TXTH	In horizontal resolution, the track crossing angle at which the resolution angle changes (Full mode only)	90 degrees
VTHSQ	Velocity squared threshold used to characterize an aircraft as fast or slow in horizontal versus vertical selection logic (Full mode only)	$(150)^2$ KT2
ZDESEN	Altitude threshold below which logic is desensitized	10,000 Feet
ZDTH2	Vertical rate threshold used in the horizontal versus vertical selection logic (Full mode only)	6 FPS
ZDTHR*	Altitude separation rate threshold (Note: ZDTHR = -ZTHR/TVTHR)	-30 FPS -36 FPS -36 FPS
ZTHR	Altitude separation threshold	900 Feet

Legend: nmi = nautical miles, nmi2 = nautical miles squared, FPS = feet per second, and KT2 = knots squared

- Maneuver Variables - Up to 12 aircraft could be created flying as many as five maneuvers (changes in heading, speed, or altitude). These variables provided the information required to update each aircraft's position and velocity.
- Aircraft State Vector - These variables represent an aircraft's state (position, velocity, identification, etc.) at any point in time (both true and tracked state).
- Simulator Interface Buffer - This buffer area was used for the transfer of simulator parameters (position, velocity, and attitude) from the CGI computer to the simulation control computer and traffic position information from the simulation control computer to the CGI computer.
- Simulation Flags and State Variables - These variables provided simulation control and status.

1.2 Simulator Interface Service Routine

The interface task provides the software interface between the simulation control computer and the computer-generated image (CGI) computer. The purpose of the task is to obtain simulator data from the CGI computer and to transfer traffic data to the CGI computer. The simulator data consists of position (x, y, z), velocity ($\dot{x}$, $\dot{y}$, $\dot{z}$), and attitude (pitch rate, roll, and yaw) of the cockpit simulator. The traffic data consists of position data (x, y, z) for as many as six pairs of lights which represent aircraft in the computer-generated visual scene.

The data are transferred through the UNIBUS window (see Section 2) which provides the hardware link between the two computers. The hardware sets up a window between the simulation control computer's memory and the CGI computer's memory. The interface initializes the hardware, performs the data transfers, and provides error handling.

The interface task executes every 1/20 of a second (corresponding to the cockpit simulator update rate) and at the highest task priority. At 1 second intervals, the interface task initiates the main loop task.

1.3 Main Loop

The main loop task performs most of the simulation functions. These functions include simulation administration, traffic generation, intruder logic, tracking, conflict detection and resolution, and data recording.

Simulation administration consists of file management (opening appropriate files), task initialization (initiating driver tasks based on selected options) and maintaining the simulation clock.

The traffic generation logic reads a file of traffic data, initializes aircraft, flies these aircraft along an arbitrarily complex flight path, and terminates the aircraft at a particular time. The traffic file contains start time, aircraft number (1-12), aircraft identification (e.g., UA107), initial position (x, y, z), heading, and speed. The file also contains data for as many as five maneuvers.

The maneuver data include the time at which the maneuver begins, the maneuver type (heading, speed, or altitude), the maneuver goal, and the maneuver rate. More than one maneuver type may be active at any one time. Maneuvers terminate when the maneuver goal is achieved.

As many as 11 aircraft can be active at any time. Aircraft initialized with the same aircraft number as an active aircraft cause the termination of the active aircraft. Aircraft requiring more than five maneuvers can be terminated and then reinitialized with a new set of maneuvers at the point of termination.

The maneuvers cause updates to the aircraft control variables (heading, speed, and altitude) which in turn are used to update position (x, y) and velocity (x, y) using a simple integration scheme. These data then act as input to the tracker logic.

The position data are also used to update the aircraft lights in the visual scene. This requires coordinate rotation and translation into the visual system coordinates. The data are then stored in the shared data region for retrieval by the simulator interface task.

The intruder logic was responsible for initiating conflicts with the cockpit simulator. Intruder data were stored in a separate file and included information on the intruder's initial position, velocity, and heading as well as any applicable maneuvers.

There were two types of conflicts: those controlled by the simulation computer and those controlled by the air traffic controller. The computer-controlled conflicts initialized the intruder based on the simulator's current position, and adjusted speed and altitude to ensure a conflict. Those controlled by the air traffic controller were initialized at a specific point in space, and it was the responsibility of the controller to ensure the conflict by issuing appropriate clearances to the pilot in the cockpit simulator. This type of control was used primarily for conflicts in which one or both aircraft were turning.

Intruders were initiated in two stages. First, they were released manually by the simulation controller (see Subsection 1.4). This allowed additional control over the conflict. A conflict was not initialized until the simulation controller and air traffic controller were satisfied that the simulator pilot was established on course. Once released, the intruder did not start flying until the simulator reached an established point in his flight path. If he was already past that point, the intruder began immediately. Once started, the intruder was treated internally as any other aircraft with one exception. The simulation controller could modify the intruder's speed and altitude on request (see Subsection 1.4) to help ensure a conflict situation. Intruders were terminated by request or when another intruder was initialized.

The tracker is a simple alpha/beta tracker which operates on the position and velocity data provided by the traffic generator. The tracker operates in both active and full mode. In active mode, the tracker is executed once per second updating range and altitude only. The full mode tracker executes once every 4 seconds and updates position (x, y, z) and velocity ($\dot{x}$, $\dot{y}$, $\dot{z}$).

The collision avoidance software consists of a detection, resolution, and proximity warning indication (PWI) logic for both active and full mode. The logic was executed once per second in active mode and once every 4 seconds in full mode. The logic considers all pairs of aircraft which include the cockpit simulator. The output of the logic are traffic advisories and collision avoidance commands which are used by the display driver software. (See Subsection 1.5.) The collision avoidance logic was furnished by the FAA and is referenced in Chapter One, Section 1.1.

The data recording software saved appropriate data on disk for later transfer to magnetic tape. The data were written in binary form for efficiency and converted to readable form offline. The data included simulator position, velocity, and attitude, command data (time, command type, aircraft number), intruder data (time and initial position, heading, and speed), and simulation controller interaction (Subsection 1.4). All other data were reproducible offline.

1.4 Console Operator Task

This task was initiated by the simulation controller to obtain data about the simulation and to interact with the simulation. The interaction was accomplished by modifying flags which were part of the shared data region. The task was low priority and executed when time was available.

The simulation controller could obtain information about any or all of the aircraft actively flying in the simulation. This data included simulation time, aircraft number, aircraft identification, position (x, y, z), heading, and speed.

The control that the simulation controller could exercise was as follows:

- Kill - the controller could terminate any of the aircraft other than the simulator
- Over - this command terminated the entire simulation and performed the necessary cleanup
- Pause - the controller could suspend the simulation at any time (only applicable during debug)
- Resume - the controller could resume the simulation if suspended
- Mode - this command changed the collision avoidance mode from active to full or full to active
- Display - this command selected the active collision avoidance display (only used during initialization)

- Speed - the controller could modify the speed of the intruder aircraft in increments of 10, 20, 30, 40, or 50 knots at 100 knots per minute
- Altitude - the controller could modify the altitude of intruder in increments of 1,000, 2,000, 3,000, 4,000, 5,000 feet at 3,000 feet per minute
- Start - this command released the next intruder
- Draw - this command redrew the air traffic controller's display centering the display at the cockpit simulator's position
- Simulation Speed - the controller could control the simulation clock speed (not used when interfaced to cockpit simulator - debug mode only)

2. COMPUTER-TO-COMPUTER INTERFACE

The simulation control computer (PDP-11/34) was interfaced to the computer-generated image (CGI) computer (PDP-11/35) through a Digital Equipment Corporation UNIBUS window*. The UNIBUS window is a high speed interbus channel that connects two PDP-11 systems. The window allows a PDP-11 system to access addresses on a companion system's UNIBUS as though they (the addresses) were on its own. It does so by automatically translating requests to a designated part of the bus-address space into requests on the other bus. Since all synchronization is done internally by the window hardware, the operation is completely transparent to the operating software.

The window can be from 512 to 32K words (16 bits) in size and is normally placed directly above the last memory module in each machine. The window size selected was 512 words to minimize the impact on the existing CGI display software. Therefore, since the simulation control computer has 64K words of memory, the window has placed from 64K (address 400000_8) to 64 1/2K (address 402000_8). Once initialized, any access from the simulation control computer to a location between 400000_8 and 402000_8 would be translated automatically into an access to a 1/2K address area on the companion system's UNIBUS. (This 1/2K area is selected as part of window initialization.) While either processor was capable of originating an access through the window, only the simulation control computer was used for this purpose. Again, this was done to minimize the number of software changes required on the CGI computer.

Initialization was accomplished by setting bits in the UNIBUS window's control and status registers. These bits represented transfer enable and write enable flags. In addition, a relocation address register was set to specify the 1/2K area in the CGI computer.

Interrupt on error condition was disabled to eliminate the need for interrupt service routines. Error handling was accomplished in the interface software.

**PDP-11 Peripherals Handbook*, Digital Equipment Corporation, 1976.

Once initialized, the data transfers were very straightforward. To access address data area + 100_8 on the CGI computer, the interface program requested address 400000_8 + 100_8 or 400100_8. This request is translated by the UNIBUS window hardware and transformed to the appropriate address in the CGI computer's memory. A second bus request is generated, this time in the CGI computer, and the transfer is completed.

Since the transfer used the busses on both computers and performed the transfer at a high priority, it essentially stopped all execution on the CGI computer. Therefore, it was critical to create an interface routine that would execute very rapidly to minimize impact. The interface routine used was written in assembly language with an execution of less than 150 microseconds. The routine was executed every 1/20 of a second (50,000 microseconds) and resulted in no noticeable degradation in the computer generated visual scene.

3. DISPLAY DRIVERS

This section describes the hardware and software interfaces to the three display devices used in the simulation.

3.1 IVSI Interface

The IVSI displayed commands only, by lighting arrows and command bars on the instrument face. The positive commands were represented by red arrows in the center of the instrument, the negative horizontal commands by yellow command bars in the lower corners, and limit commands by combinations of yellow command bars at the edge of the instrument dial. The arrows and command bars were composed of combinations of LEDs, and each arrow or command bar was tied back to a specific pin on the input jack.

Since simple relays were not available on the PDP-11 computer, an interface box was developed to translate an asynchronous transmission of characters into a voltage to a specific pin or set of pins. The characters were actually a coded sequence of bits representing the required arrows or command bars for the desired command. These characters were clocked in by the interface box and interpreted by the hardware logic. Since the alarm also required a simple relay, it was handled in the same manner.

3.2 LED Interface

Litton Aero Products provided tremendous assistance in developing the LED interface. They were able to modify their prototype display to accept asynchronous transmission directly from the PDP-11. The device accepted all ASCII characters but used some of the control characters for color and line control.

The LED display presented only 40 characters (4 lines of 10 characters each) but required a buffer of 49 characters. Characters 1, 2, and 3 initialized the device and restored the character pointer of the initial character position, characters 4, 15, 26, and 37 provided color control (red, yellow, green, no color), and characters 48 and 49 represented end of message. The other characters were displayed as transmitted.

The message was developed in the main loop task and could consist of up to three traffic advisories, a traffic advisory and a command, or all blank (to clear the display). The message formats are discussed in Chapter Two, Subsection 2.3.2.

3.3 CRT Interface

The CRT display is actually a converted TV monitor with a custom-made tube used to provide a large display area. Input to the display is a standard video input. An interface card was purchased which was PDP-11 compatible that could provide a composite video signal from a matrix array of on-off bits. These bits represented the raster dots of a 256 × 256 raster scan. The on-off bits were stored in a RAM (Random-Access Memory) which was addressed through registers on the interface card. An X and Y address into the 256 × 256 array is established. A third register is used to indicate whether the dot is to be lit or blanked. By lighting and blanking the appropriate raster dots, an arbitrarily complex picture could be developed.

The software interface included a software generator which represented characters in a 5 × 7 or 9 × 13 matrix (the smaller size was used for the aircraft data blocks and the larger for the collision avoidance commands). In addition to the alphanumerics, there were special symbols representing ownship, normal traffic and intruder traffic. The display presentation is described in Chapter 2, Subsection 2.3.3.