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ACTIVE BEACON COLLISION AVOIDANCE SYSTEM (BCAS) CONFERENCE

JANUARY 27-28, 1981

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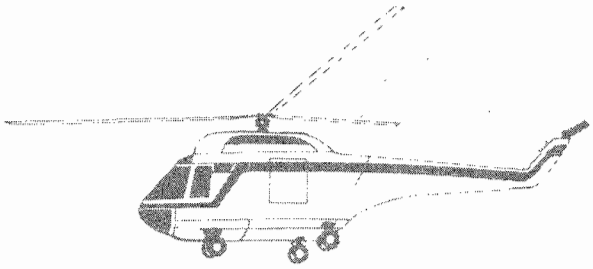

BCAS

U.S. DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
Systems Research & Development Service
Washington, D.C. 20590

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16. Abstract

The Federal Aviation Administration published a National Standard on Beacon Collision Avoidance System (BCAS) on October 27, 1980, with its objective to receive comments from the aviation community by February 27, 1981. To aid them in the preparation of comments on the Standard, a 2-day conference was held in Washington, D.C. on January 27 and 28, 1981, wherein the system was described through presentations, demonstrations, and general discussions.

The first day provided a BCAS background and described an overview of what is involved in implementation of a system like BCAS, avionics certification and flight operations, procedures and rules, and described the technical and operational performance of the system.

The second day explained the architecture of the Active BCAS and its processing performance capabilities and a summary of test performance to date and the agency plan to test in an airline operation.

This proceedings document is a collection of briefings presented during the first day of the conference and handouts from both days.

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METRIC CONVERSION FACTORS

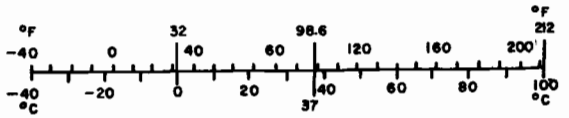
Approximate Conversions to Metric Measures

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



ACTIVE BEACON COLLISION

AVOIDANCE SYSTEM (BCAS)

CONFERENCE

January 27-28, 1981

AGENDA

Tuesday, January 27

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9:55 - 10:20	ASA Program Mr. James L. Bispo Associate Administrator for Air Traffic and Airway Facilities FAA	9
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11:00 - 11:20	Coffee Break	
11:20 - 11:45	Implementation of Active BCAS Mr. Kenneth S. Hunt Director, Office of Flight Operations FAA	27
11:45 - 12:00	Industry View of Active BCAS Mr. Olin McFolin Assistant to the President Dalmo Victor Company	--

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Tuesday, January 27

Second Session

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2:05 - 2:35	Technical Performance of Active BCAS Dr. Clyde Miller Chief, Separation Systems Branch, Communications and Surveillance Division, SRDS, FAA	43
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9:00 - 9:05	Introduction to Second Day Mr. William Hyland Separation Systems Branch, Communications and Surveillance Division, SRDS, FAA
9:05 - 9:40	Active BCAS Technical Program Mr. William Hyland
9:40 - 10:20	Active BCAS Surveillance Processing Dr. Jerry Welch Lincoln Laboratory
10:20 - 10:40	Coffee Break
10:40 - 11:20	Active BCAS Surveillance Performance Dr. William Harman Lincoln Laboratory
11:20 - 12:00	Description of Active BCAS Logic Dr. Al McFarland The MITRE Corporation

Fourth Session

1:30 - 2:10	Active BCAS Logic Assessment Dr. Al McFarland The MITRE Corporation

2:10 - 2:40	Electromagnetic Compatibility of Active BCAS Mr. Bob Frazier Separation Systems Branch, Communications and Surveillance Division, SRDS, FAA
2:40 - 3:00	Coffee Break
3:00 - 3:30	An Industry-Developed Active BCAS Unit Mr. Dick Sobocinski Vice President-Engineering Dalmo Victor Company
3:30 - 4:00	Plans for Operational Evaluation Mr. Tom Berry ARINC Research
4:00 - 5:00	Open Discussion (Panel: Miller, Burgess, Welch, McFarland)

HANDOUTS AT CONFERENCE

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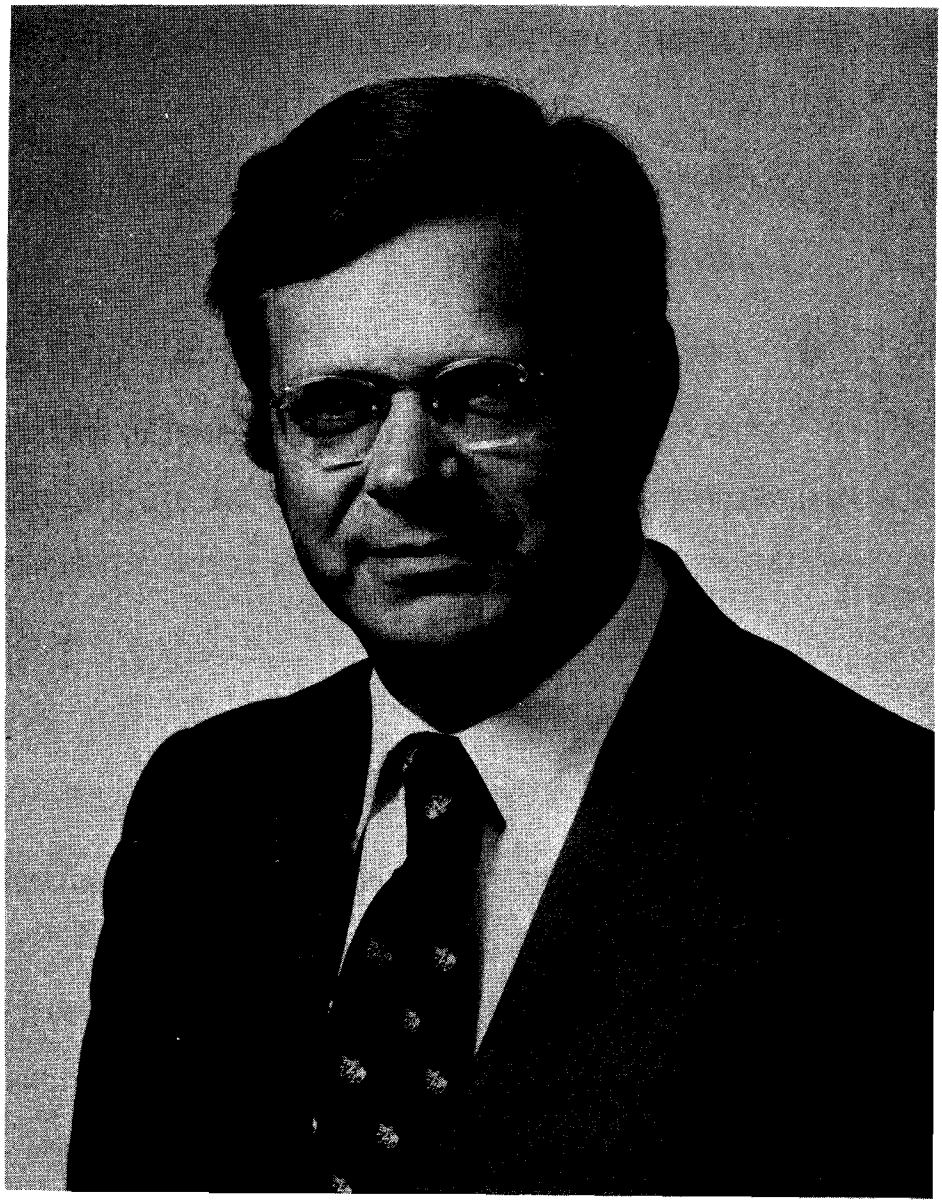
A ..... The FAA Aircraft Separation Assurance Program (FAA).
B ..... Active BCAS Description (FAA).
C ..... Summary of Active BCAS Test and Evaluation Results (FAA).
D ..... Active BCAS Development Program (FAA).
E ..... Operational Flight Test of the Active BCAS (ARINC Res. Corp.).
F ..... Active BCAS Surveillance Processing (M.I.T. Lincoln Lab.).
G ..... Description Active BCAS Collision Avoidance Logic (MITRE Corp.).
H ..... Active BCAS Collision Avoidance Logic Assessment (MITRE Corp.).
I ..... Active BCAS Program (Bell Aerospace, TEXTRON).
J ..... Aircraft Separation Assurance Bibliography (FAA).



Robert W. Wedan
Director, Systems Research and Development Service
Federal Aviation Administration

WELCOME INTRODUCTION

LADIES AND GENTLEMEN, MY NAME IS BOB WEDAN. I AM DIRECTOR OF THE FAA'S SYSTEMS RESEARCH AND DEVELOPMENT SERVICE, AND YOUR CHAIRMAN FOR THE FIRST SESSION OF OUR CONFERENCE. IT'S MY PLEASURE TO WELCOME YOU TODAY. I SINCERELY HOPE THAT THIS CONFERENCE WILL BE CONSIDERED BY YOU AS TIME WELL SPENT. WE IN

THE FAA FEEL THAT BOTH THE SUBJECT OF THIS CONFERENCE AND THE TIMING ARE VERY SIGNIFICANT. ITS SIGNIFICANCE, AS YOU WILL SEE, RELATES TO A MAJOR CONTRIBUTION TO AIR SAFETY THAT WE CAN COLLECTIVELY ACHIEVE IN THE NEAR FUTURE.

PURPOSE

THE PURPOSE OF THIS 2-DAY CONFERENCE IS TO CONVEY TO YOU--AS MEMBERS OF THE AVIATION COMMUNITY, OPERATORS, MANUFACTURERS, BOTH TECHNICAL AND NON-TECHNICAL--WHERE THE ACTIVE BCAS DEVELOPMENT PROGRAM STANDS TODAY. WE BELIEVE MAJOR TECHNICAL ACCOMPLISHMENTS HAVE BEEN REALIZED. ALTHOUGH SOME FURTHER WORK REMAINS, THE TECHNICAL ASPECTS ARE CONSIDERED STRAIGHT-FORWARD AND WILL BE ACCOMPLISHED WITHOUT RISK. THE OPERATIONAL EVALUATION IS WELL UNDERWAY AND RESULTS TO DATE ARE EXCITING.

AT THIS POINT IN TIME, WE HAVE A DRAFT OF THE FINAL NATIONAL STANDARD OUT FOR PUBLIC COMMENT. THE CLOSING DATE IS SCHEDULED FOR FEBRUARY 27. WE HOPE THAT THIS CONFERENCE MAY PRODUCE KNOWLEDGEABLE AND CONSTRUCTIVE COMMENTS. BASED ON THESE COMMENTS, THE COMPLETION OF THE TECHNICAL AND OPERATIONAL EVALUATIONS, WE EXPECT TO PRODUCE THE FINAL, APPROVED STANDARD FOR THE ACTIVE BCAS WITHIN A YEAR. MEANWHILE, THE INDUSTRY IS PRESENTLY ENGAGED IN THE PROCESS OF MOVING BCAS INTO AN OPERATIONAL STATUS. THE WINNER OF A COMPETITIVE CONTRACT FOR AN INDUSTRIAL VERSION OF THE ACTIVE BCAS IS DALMO VICTOR. THEY ARE HERE TODAY TO DESCRIBE THEIR WORK. IN ADDITION, THE RADIO TECHNICAL COMMISSION FOR AERONAUTICS (RTCA) HAS ORGANIZED SPECIAL COMMITTEE 147 TO PREPARE MINIMUM OPERATIONAL PERFORMANCE STANDARDS (or MOPS), WITH A DATE OF MID-1982 TARGETED FOR COMPLETION. THIS, IN TURN, LEADS TO AN FAA TECHNICAL STANDARD ORDER (or TSO).

THESE COMMENTS WOULD NOT BE COMPLETE WITHOUT MENTIONING VERY BRIEFLY THAT

DISCUSSIONS OF ACTIVE BCAS ON AN INTERNATIONAL LEVEL ARE ALSO CURRENTLY UNDERWAY. THESE INCLUDE DISCUSSIONS WITH INDIVIDUAL COUNTRIES, INTERNATIONAL AVIATION ORGANIZATIONS, AND THE INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO).

OUTLINE OF EVENTS

IN GENERAL, THIS CONFERENCE IS DIVIDED INTO TWO PARTS. TODAY OUR PURPOSE IS TO SUMMARIZE IN GENERAL TERMS THE STATUS AND RESULTS OF AN ACTIVE BCAS PROGRAM. THIS WILL BE DONE IN THE CONTEXT OF POLICY AND PROGRAMS PRESENTATIONS THIS MORNING. A SUMMARY OF OUR TECHNICAL RESULTS AND OPERATIONAL EVALUATION EXPERIENCE TO DATE WILL BE COVERED THIS AFTERNOON.

THE PROGRAM TOMORROW IS AIMED MORE TO THOSE INTERESTED IN THE TECHNICAL ASPECTS OF THE PROGRAM. WE HAVE SPEAKERS WHO REPRESENT THE MAJOR ORGANIZATIONS--BOTH FROM WITHIN AND FROM OUTSIDE FAA--WHO HAVE PARTICIPATED AND WHO SHARE THE CREDITS.

SOME OF YOU HAVE PARTICIPATED IN THE FLIGHT EVALUATIONS INVOLVING FAA TEST AIRCRAFT. PRIMARILY FOR THOSE OF YOU WHO HAVE NOT SEEN THE EQUIPMENT BEING TESTED, WE'VE BROUGHT OUR BOEING 727 FROM THE FAA TECHNICAL CENTER IN ATLANTIC CITY, AND HAVE PARKED IT BY PAGE AVIATION. SHUTTLE VANS ARE AVAILABLE FOR THOSE OF YOU WHO WISH TO INSPECT THE EQUIPMENT, AND A 2-HOUR PERIOD HAS BEEN SCHEDULED FROM 3 to 5 TODAY FOR THIS ACTIVITY. IN ORDER TO SPREAD OUT THE PARTICIPATION, A SIGN-UP SHEET WILL BE AVAILABLE AT THE REGISTRATION DESK WHEN WE BREAK FOR LUNCH.

ALSO, WE'VE ASKED EACH OF THE MAJOR PARTICIPATING ORGANIZATIONS TO PROVIDE A STATIC DISPLAY FOR YOUR INSPECTION. THESE EXHIBITS ARE DOWNSTAIRS. FEEL

FREE TO ASK QUESTIONS OF THE REPRESENTATIVE OF THESE ORGANIZATIONS.

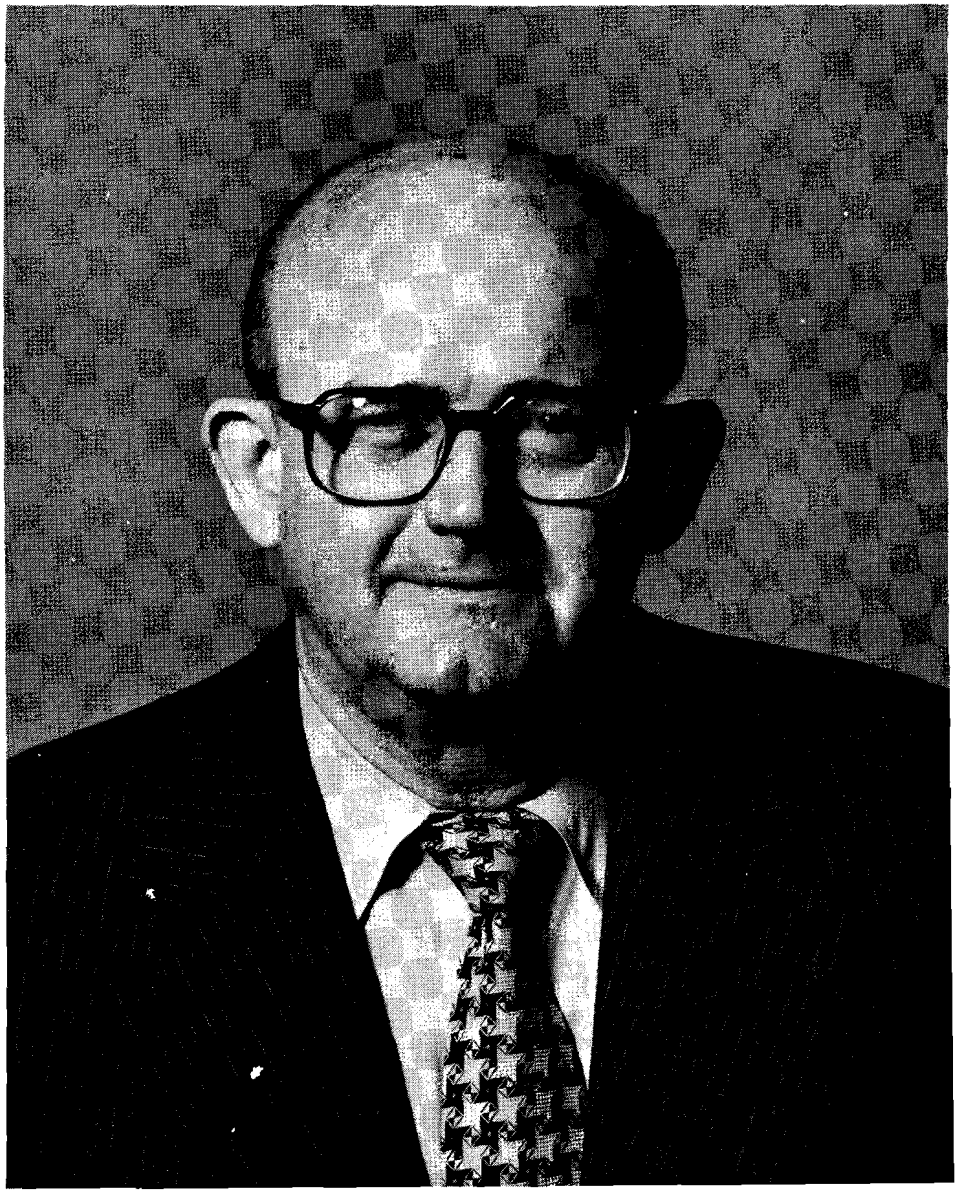
FOR THOSE WHO WISH A COPY OF SOME OF THE KEY DOCUMENTS AROUND WHICH THE PROGRAM REVOLVES, PLEASE HELP YOURSELF TO THEM FROM A TABLE IN THE EXHIBIT AREA. A BIBLIOGRAPHY IS AVAILABLE FOR YOUR CONVENIENCE IN ORDERING ADDITIONAL COPIES.

LUNCHEON SPEAKER

IT IS ALSO MY PLEASURE TO ANNOUNCE THAT MR. FRANK WHITE, AIR TRANSPORT ASSOCIATION, HAS AGREED TO ADDRESS THOSE THAT JOIN FOR LUNCH TODAY. MR. WHITE HAS CONSISTENTLY BEEN INTERESTED IN THE FAA'S RESEARCH AND DEVELOPMENT ACTIVITIES. I'M SURE THAT WE ALL LOOK FORWARD TO HIS COMMENTS ABOUT OUR SEPARATION ASSURANCE PROGRAM.

NOW, IT IS MY PLEASURE TO INTRODUCE OUR FIRST SPEAKER: AL ALBRECHT.

MR. ALBRECHT IS CURRENTLY THE ASSOCIATE ADMINISTRATOR FOR ENGINEERING AND DEVELOPMENT AT THE FAA, AND WILL SPEAK TO US ABOUT THIS PROGRAM.



A. P. Albrecht

Associate Administrator for Engineering and Development
Federal Aviation Administration

ROLE OF SEPARATION ASSURANCE

LADIES, GENTLEMEN, AND HONORED GUESTS, LET ME ADD MY WORDS OF WELCOME TO THOSE YOU HAVE HEARD FROM BOB WEDAN. IT IS A DISTINCT PLEASURE TO SEE YOU HERE TODAY.

NO PROGRAM WITHIN THE FEDERAL AVIATION ADMINISTRATION HAS GREATER IMPOR-

TANCE THAN THOSE AIMED AT ASSURING THE SAFE SEPARATION OF AIRCRAFT IN FLIGHT. MANY OF THE IMPROVEMENTS WE HAVE MADE TO TODAY'S AIR TRAFFIC CONTROL SYSTEM, INCLUDING THE RESULTS FROM A SUBSTANTIAL PORTION OF OUR RESEACH AND DEVELOPMENT EFFORT, HAVE BEEN DESIGNED TO ATTAIN THIS GOAL.

OVER THE NEXT 2 DAYS WE WILL SHARE WITH YOU THE RESULTS OF OUR EFFORTS TO DEVELOP THE ACTIVE BEACON COLLISION AVOIDANCE SYSTEM, OTHERWISE KNOWN AS ACTIVE BCAS. THESE RESULTS, WHICH DERIVE FROM EXTENSIVE ENGINEERING TESTS AS WELL AS FROM A LIMITED OPERATIONAL EVALUATION RECENTLY COMPLETED, ARE EXTREMELY ENCOURAGING. THERE IS A GROWING CONFIDENCE THAT ACTIVE BCAS IS WELL ON ITS WAY TO IMPLEMENTATION.

INTRODUCING NEW SYSTEMS, PARTICULARLY WHERE NEW AVIONICS ARE REQUIRED, IS NOT A SIMPLE TASK. WE BELIEVE THE TASK IS MADE EASIER, HOWEVER, BY GOOD COMMUNICATION WITH ALL CONCERNED: GOVERNMENT, MANUFACTURERS, OPERATORS, AND THE GENERAL PUBLIC, AT KEY STEPS ALONG THE WAY. THAT IS THE REASON FOR THIS CONFERENCE. AS MOST OF YOU KNOW, THE FINAL NATIONAL STANDARD FOR ACTIVE BCAS HAS BEEN PUBLISHED IN THE FEDERAL REGISTER FOR COMMENTS WHICH ARE DUE BY FEBRUARY 27TH. WE HOPE THAT THIS CONFERENCE WILL ASSIST YOU IN PREPARING YOUR COMMENTS WHICH IN TURN WILL HELP US DIRECT OUR EFFORTS TOWARD A SUCCESSFUL CONCLUSION OF THIS DEVELOPMENT PROGRAM.

SAFE SEPARATION OF AIRCRAFT IS THE PRINCIPAL OBJECTIVE OF THE EXISTING GROUND-BASED AIR TRAFFIC CONTROL SYSTEM. THIS SYSTEM, AS REVISED AND IMPROVED OVER THE YEARS, IS HIGHLY EFFECTIVE, WITH A SAFETY RECORD IMPRESSIVE BY ANY STANDARD. IT IS THE BEST IN THE WORLD AND GIVES US MUCH OF WHICH TO BE PROUD.

HOWEVER, WE CONSTANTLY ASK, IS THERE MORE TO BE DONE, IS THE EXISTING STATE OF AFFAIRS FULLY SATISFACTORY? AS AIR TRANSPORTATION GROWS AND DEMANDS ON THE AIR TRAFFIC CONTROL SYSTEM INCREASE ALONG WITH THE EXPECTATIONS OF THE TRAVELING PUBLIC, FURTHER IMPROVEMENTS BECOME NOT JUST DESIRABLE, BUT NECES-

SARY. FOR THESE REASONS, WE IN THE FEDERAL AVIATION ADMINISTRATION CONTINUE OUR WORK. OUR RESPONSIBILITY IS SIMPLE: TO REDUCE THE RISK OF MIDAIR COLLISION TO THE LOWEST PRACTICAL LEVEL.

OUR APPROACH TO REDUCING THE RISK OF MIDAIR COLLISIONS IS TWO-FOLD. THE GROUND-BASED AIR TRAFFIC CONTROL SYSTEM CONTINUES TO PLAY THE PRINCIPAL ROLE IN PROVIDING SAFE SEPARATION OF AIRCRAFT. THIS SYSTEM HAS MANY COMPONENTS. THEY INCLUDE: AIR ROUTE DESIGNATION, PROCEDURES AND RULES OF THE ROAD COVERING BOTH CONTROLLED AND UNCONTROLLED AIRCRAFT, AIRSPACE DESIGNATION, RADAR SURVEILLANCE, AND LARGE-SCALE COMPUTER SYSTEMS FOR PROCESSING RADAR DATA AND DISPLAYING TRAFFIC INFORMATION TO THE CONTROLLER. WE WILL CONTINUE TO REFINE AND IMPROVE THIS SYSTEM TO ASSURE THE SAFE AND EFFICIENT MOVEMENT OF ALL AIRCRAFT.

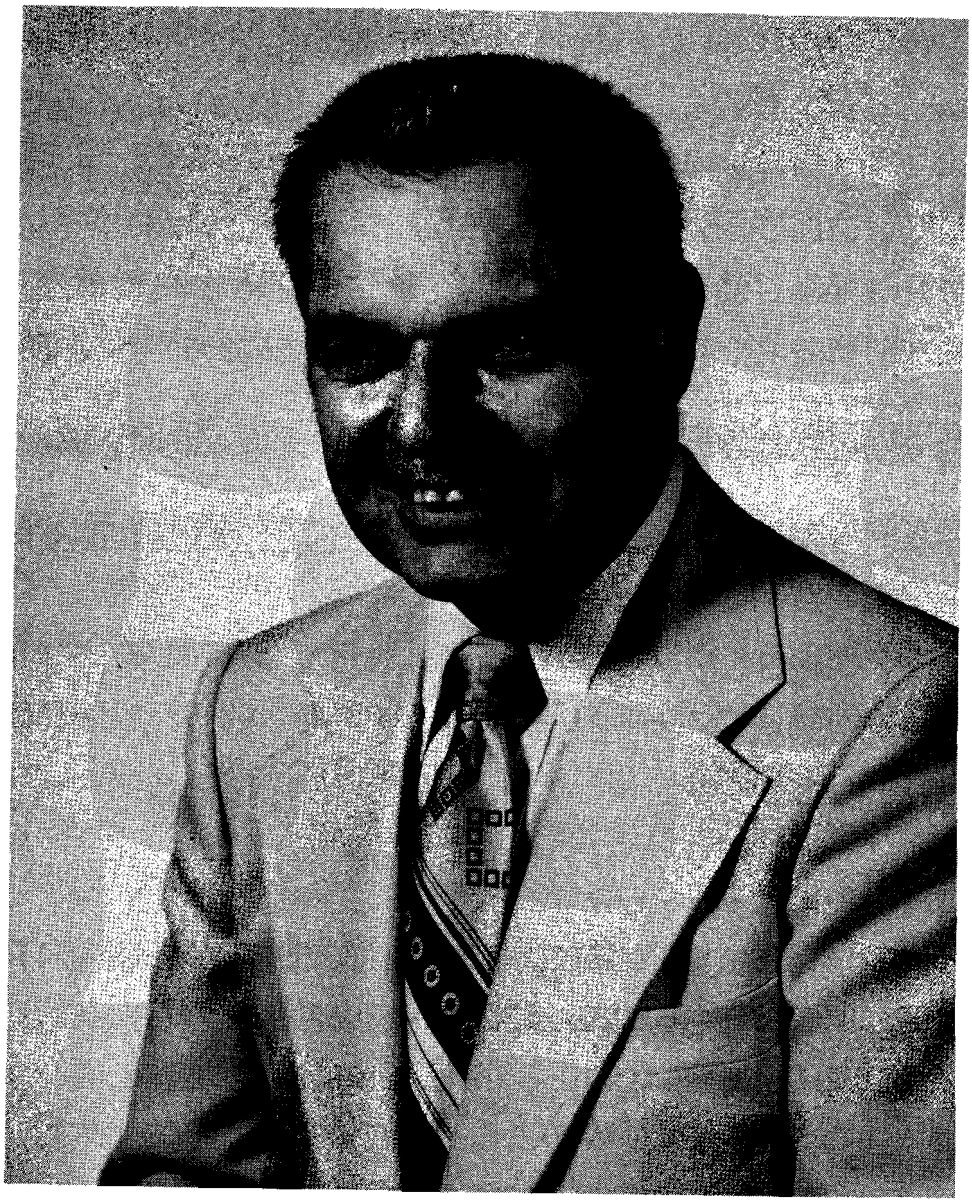
AT THE SAME TIME, WE ARE DEVELOPING AND IMPLEMENTING A BACK-UP SEPARATION ASSURANCE SYSTEM WITH THE SINGLE OBJECTIVE OF PREVENTING MIDAIR COLLISIONS WHEN, FOR WHATEVER REASON, THE PRIMARY SYSTEM FAILS TO PROVIDE ADEQUATE SEPARATION. THE FIRST ELEMENT OF THE BACK-UP SYSTEM, CONFLICT ALERT, IS ALREADY OPERATIONAL THROUGHOUT THE EN ROUTE AIRSPACE UNDER SURVEILLANCE OF GROUND RADARS, AND IN THE 62 MAJOR TERMINAL AREAS SERVICED BY ARTS III AIR TRAFFIC CONTROL COMPUTER EQUIPMENTS. IF OUR GOOD FORTUNES CONTINUE, WE EXPECT THAT ACTIVE BCAS WILL BE THE SECOND ELEMENT OF OUR AIRCRAFT SEPARATION ASSURANCE SYSTEM TO BE IMPLMENTED.

ACTIVE BCAS IS AN AIRBORNE ELEMENT OF OUR SEPARATION ASSURANCE SYSTEM--AIRBORNE IN THE SENSE THAT IT IS INSTALLED IN AND TRAVELS WITH THE AIRCRAFT, AS OPPOSED TO BEING FIXED ON THE GROUND. MOREOVER, ACTIVE BCAS IS CAPABLE OF OPERATING WITHOUT RELIANCE ON GROUND-BASED EQUIPMENTS. HENCE, WHILE ACTIVE BCAS CAN PROVIDE A BACK-UP TO EXISTING AIR TRAFFIC CONTROL OPERATIONS BASED ON GROUND-DERIVED RADAR DATA, IT ALSO OFFERS SEPARATION ASSURANCE IN AIRSPACE, SUCH AS OCEANIC AIRSPACE, WHEN THERE IS NO RADAR SERVICE.

I AM VERY ENTHUSIASTIC ABOUT ACTIVE BCAS BECAUSE I BELIEVE THAT IT OFFERS

A REAL AND IMMEDIATE CAPABILITY FOR SUBSTANTIALLY REDUCING THE RISK OF MIDAIR COLLISIONS. WE HAVE GOTTEN THIS FAR ONLY BY THE GRACE OF THE SUPPORT THAT SO MANY OF YOU IN THIS ROOM HAVE GIVEN TO THE PROGRAM. WITH YOUR CONTINUED SUPPORT, WE WILL SUCCEED.

THANK YOU



James L. Bispo

Associate Administrator for Air Traffic and Airway Facilities
Federal Aviation Administration

AIRCRAFT SEPARATION ASSURANCE PROGRAM

YOU HAVE HEARD AL ALBRECHT TALK ABOUT THE OBJECTIVE AND PRINCIPLES OF OUR PROGRAM TO REDUCE THE RISK OF MIDAIR COLLISIONS. THE PRINCIPLES ARE STRAIGHTFORWARD--THE CONVENTIONAL AIR TRAFFIC

CONTROL SYSTEM WILL RETAIN ITS CENTRAL ROLE, AND A BACK-UP AIRCRAFT SEPARATION ASSURANCE SYSTEM IS BEING IMPLMENTED. THE PURPOSE OF MY TALK IS TO DESCRIBE THE ELEMENTS OF THIS SEPARATION ASSURANCE SYSTEM.

AIRCRAFT SEPARATION ASSURANCE (COLLISION AVOIDANCE) SYSTEM

OUR PROGRAM EMBRACES FIVE PRINCIPAL SYSTEM ELEMENTS, EACH FOCUSED ON A SOMEWHAT DIFFERENT COMBINATION OF AIRSPACE REGIME AND USER, AND EACH WITH A SOMEWHAT DIFFERENT SCHEDULE FOR DEVELOPMENT AND IMPLEMENTATION. INDIVIDUAL ELEMENTS HAVE BEEN OR WILL BE IMPLEMENTED AS FULLY INTEGRATED COMPONENTS OF THE NATIONAL AIRSPACE SYSTEM WHEN DEVELOPMENTAL TESTING AND OPERATIONAL EVALUATIONS DEMONSTRATE ADEQUATE LEVELS OF EFFECTIVENESS. THIS STRATEGY PROVIDES STEADILY INCREASING PROTECTION FROM MIDAIR COLLISIONS FOR AN EXPANDING SEGMENT OF AIRSPACE USERS, OVER A LARGER PORTION OF THE AIRSPACE, AS IMPLEMENTATION PROGRESSES.

THE FIVE ELEMENTS OF THE SEPARATION ASSURANCE PROGRAM ARE: (1) CONFLICT ALERT, (2) CONFLICT RESOLUTION, (3) A LIMITED CAPABILITY BEACON COLLISION AVOIDANCE SYSTEM KNOWN AS ACTIVE BCAS, (4) A FULL CAPABILITY BCAS KNOWN AS FULL BCAS, AND (5) THE AUTOMATIC TRAFFIC ADVISORY AND RESOLUTION SERVICE (ATARS).

CONFLICT ALERT

CONFLICT ALERT IS CURRENTLY IMPLEMENTED IN THE GROUND-BASED AIR TRAFFIC CONTROL COMPUTERS ASSOCIATED WITH THE EN ROUTE AIRSPACE AS WELL AS THE 62 MAJOR TERMINAL AREAS SERVICED BY ARTS III AUTOMATION EQUIPMENTS. THIS FUNCTION WARNS CONTROLLERS THAT

VIOLATIONS OF SEPARATION MINIMA ARE LIKELY TO OCCUR AND INDICATES TO CONTROLLERS WHICH AIRCRAFT ARE IN CONFLICT. IN RESPONSE TO THE ALERT, A CONTROLLER MAY ISSUE APPROPRIATE INSTRUCTIONS TO THE AIRCRAFT INVOLVED IF SUCH INSTRUCTIONS ARE WARRANTED.

CONFLICT RESOLUTION

CONFLICT RESOLUTION IS AN EXTENSION OF CONFLICT ALERT THAT IS UNDER DEVELOPMENT FOR EN ROUTE AIRSPACE. THIS AUTOMATION FEATURE IS DESIGNED TO ADVISE CONTROLLERS OF CANDIDATE INSTRUCTIONS FOR RESOLVING CONFLICTS DISPLAYED BY THE CONFLICT ALERT FUNCTION.

AS OPPOSED TO CONFLICT ALERT AND CONFLICT RESOLUTION, THE REMAINING DEVELOPMENTS IN THE AIRCRAFT SEPARATION ASSURANCE PROGRAM, BCAS AND ATARS, PROVIDE INFORMATION DIRECTLY AND AUTOMATICALLY TO THE COCKPIT, RATHER THAN ONLY TO THE CONTROLLER. THESE SYSTEMS DIFFER AMONG THEMSELVES IN THE SOURCE AND THE EXTENT OF THE INFORMATION PROVIDED.

ACTIVE BCAS

THE FIRST, AND CONCEPTUALLY THE SIMPLEST, OF THESE SYSTEMS IS ACTIVE BCAS. IT OPERATES BY PERIODICALLY INTERROGATING THE TRANSPONDERS IN OTHER AIRCRAFT AS DEPICTED IN THIS SLIDE. INFORMATION RELATING TO THE RANGE AND ALTITUDE OF PROXIMATE AIRCRAFT IS DERIVED FROM THE REPLIES TO THESE INTERROGATIONS. WHEN THE ON-BOARD ACTIVE BCAS COMPUTER RECOGNIZES THE EXISTENCE OF A COLLISION THREAT, IT GENERATES A VERTICAL RESOLUTION ADVISORY (CLIMB OR DESCEND) AND DELIVERS IT TO THE COCKPIT DISPLAY. ACTIVE BCAS IS EXPECTED TO PROVIDE RELIABLE COLLISION PROTECTION IN LOW AND MEDIUM DENSITY AIRSPACE.

ACTIVE BCAS AIRBORNE EQUIPMENTS ARE CAPABLE OF OPERATING

WITHOUT GROUND EQUIPMENTS. HOWEVER, IN RELATIVELY DENSE TERMINAL AREAS, A GROUND STATION CALLED A RADAR BEACON TRANSPONDER CAN BE PROVIDED FOR COORDINATING ACTIVE BCAS WITH THE CONVENTIONAL AIR TRAFFIC CONTROL SYSTEM. A PRINCIPAL FUNCTION OF THE RADAR BEACON TRANSPONDER IS TO RELAY ANY BCAS RESOLUTION ADVISORY DISPLAYED IN AN AIRCRAFT FOR DISPLAY TO THE RESPONSIBLE AIR TRAFFIC CONTROLLER ON THE GROUND. THIS PROCESS AUTOMATICALLY NOTIFIES THE CONTROLLER OF THE CONFLICT SITUATION AND THE PROBABLE EVASIVE MANEUVER OF THE ACTIVE BCAS AIRCRAFT.

FULL BCAS

LIKE ACTIVE BCAS, FULL BCAS IS AN AIRBORNE SEPARATION ASSURANCE DEVICE IN THE SENSE THAT THE PRINCIPAL ELEMENTS OF THE SYSTEM ARE INSTALLED IN THE AIRCRAFT AND THESE ELEMENTS CAN OPERATE WITHOUT ASSISTANCE FROM GROUND EQUIPMENT. HENCE, THE EQUIPPED AIRCRAFT RECEIVES PROTECTION WHETHER OR NOT IT IS WITHIN RANGE OF GROUND EQUIPMENTS.

WHILE FULL BCAS CAN ACTIVELY INTERROGATE OTHER AIRCRAFT, AS DOES THE ACTIVE BCAS, THE PRINCIPAL ADVANTAGES OF THE FULL BCAS LIE IN ITS PASSIVE SURVEILLANCE MODES AND COMBINATIONS OF PASSIVE AND ACTIVE MODES.

THE PASSIVE MODES LISTEN TO THE INTERROGATIONS TRANSMITTED BY AIR TRAFFIC CONTROL SURVEILLANCE GROUND STATIONS AND TO THE REPLIES OF PROXIMATE AIRCRAFT TRANSPONDERS TO THESE INTERROGATIONS. THROUGH SUITABLE PROCESSING OF THIS INFORMATION ALONG WITH ANCILLARY INFORMATION, IT IS POSSIBLE TO MEASURE ACCURATELY THE RANGE, ALTITUDE, AND BEARING OF PROXIMATE AIRCRAFT. BECAUSE OF THE HIGHLY ACCURATE BEARING DATA AVAILABLE, FULL BCAS CAN

GENERATE HORIZONTAL RESOLUTION ADVISORIES (TURN RIGHT OR TURN LEFT) IN ADDITION TO THE VERTICAL RESOLUTION ADVISORIES AVAILABLE FROM ACTIVE BCAS. A SECOND PRINCIPAL ADVANTAGE OF FULL BCAS WITH RESPECT TO ACTIVE BCAS IS ITS CAPABILITY TO OPERATE RELIABLY IN ALL TRAFFIC DENSITIES.

I SHOULD EMPHASIZE THAT IN AN ENCOUNTER BETWEEN AN AIRCRAFT EQUIPPED WITH A FULL BCAS AND ONE WITH AN ACTIVE BCAS, THE RESOLUTION ADVISORIES GENERATED BY EACH WILL BE FULLY COMPATIBLE, THUS ASSURING A COHERENT FUTURE ENVIRONMENT WHERE A MIX OF ACTIVE AND FULL BCAS EQUIPMENTS MAY CO-EXIST.

ATARS

THE AUTOMATIC TRAFFIC ADVISORY AND RESOLUTION SERVICE (ATARS) USES SURVEILLANCE DATA FROM GROUND-BASED DISCRETE ADDRESS BEACON SYSTEM (DABS) SENSORS. DABS IS A TOTALLY COMPATIBLE UPGRADE OF TODAY'S RADAR BEACON SYSTEM IN THE SENSE THAT DABS EQUIPMENTS WILL OPERATE IN TODAY'S ENVIRONMENT, AND EXISTING RADAR BEACON EQUIPMENTS WILL BE ABLE TO OPERATE IN THE DABS ENVIRONMENT OF THE FUTURE. THE TWO PRINCIPAL CONTRIBUTIONS MADE BY DABS GROUND SENSORS ARE (L) PRECISION SURVEILLANCE DATA THAT IS MUCH MORE RELIABLE THAN THAT AVAILABLE TODAY AND (2) AN AIR-GROUND-AIR DATA LINK CAPABILITY. SINCE EACH AIRCRAFT EQUIPPED WITH A DABS TRANSPONDER HAS ITS OWN DISCRETE IDENTITY CODE OR ADDRESS, "PRIVATE-LINE" COMMUNICATIONS BETWEEN THE AIRCRAFT AND THE GROUND ARE POSSIBLE.

ATARS USES THE PRECISION SURVEILLANCE DATA AVAILABLE FROM THE DABS GROUND SENSOR TO IDENTIFY AIRCRAFT CONFLICTS AND THEN

TRANSMITS APPROPRIATE HORIZONTAL AND/OR VERTICAL RESOLUTION ADVISORIES TO THE AIRCRAFT INVOLVED USING THE DABS DATA LINK. IN A SIMILAR FASHION, ATARS CAN PROVIDE AN AUTOMATIC TRAFFIC ADVISORY SERVICE TO PROPERLY EQUIPPED AIRCRAFT WITHIN THE VIEW OF DABS GROUND STATIONS.

ATARS IS CONSIDERED THE MOST EFFECTIVE APPROACH FOR PROTECTING AGAINST MIDAIR COLLISIONS IN HIGH DENSITY AIRSPACE. BY VIRTURE OF ITS FIXED LOCATION ON THE GROUND AND THE HIGH QUALITY SURVEILLANCE DATA AVAILABLE FROM THE ASSOCIATED DABS SENSOR, ATARS CAN BE PRECISELY ADAPTED TO SPECIFIC SITES TO CONTROL THE INCIDENCE OF NUISANCE ALARMS WHILE PROVIDING COMPREHENSIVE PROTECTION AGAINST COLLISIONS. IT IS EXPECTED THAT THE NUISANCE ALERTS FROM ATARS WILL BE FOR FEWER THAN THOSE FROM EITHER ACTIVE BCAS OR FULL BCAS. IN ADDITION, IN CONTRAST TO BCAS, ATARS REQUIRES RELATIVELY LITTLE EQUIPMENT ON BOARD PROTECTED AIRCRAFT. HENCE, DABS/ATARS GROUND STATIONS IN DENSE TRAFFIC AREAS PROTECT LARGE NUMBERS OF AIRCRAFT WITH ONLY MODEST INVESTMENTS REQUIRED OF USER FOR THE NECESSARY AVIONICS.

CONCLUSION

I HOPE THAT THIS BRIEF DESCRIPTION OF OUR SEPARATION ASSURANCE PROGRAM WILL HELP YOU TO UNDERSTAND ACTIVE BCAS IN THE CONTEXT OF A LARGER SYSTEM.

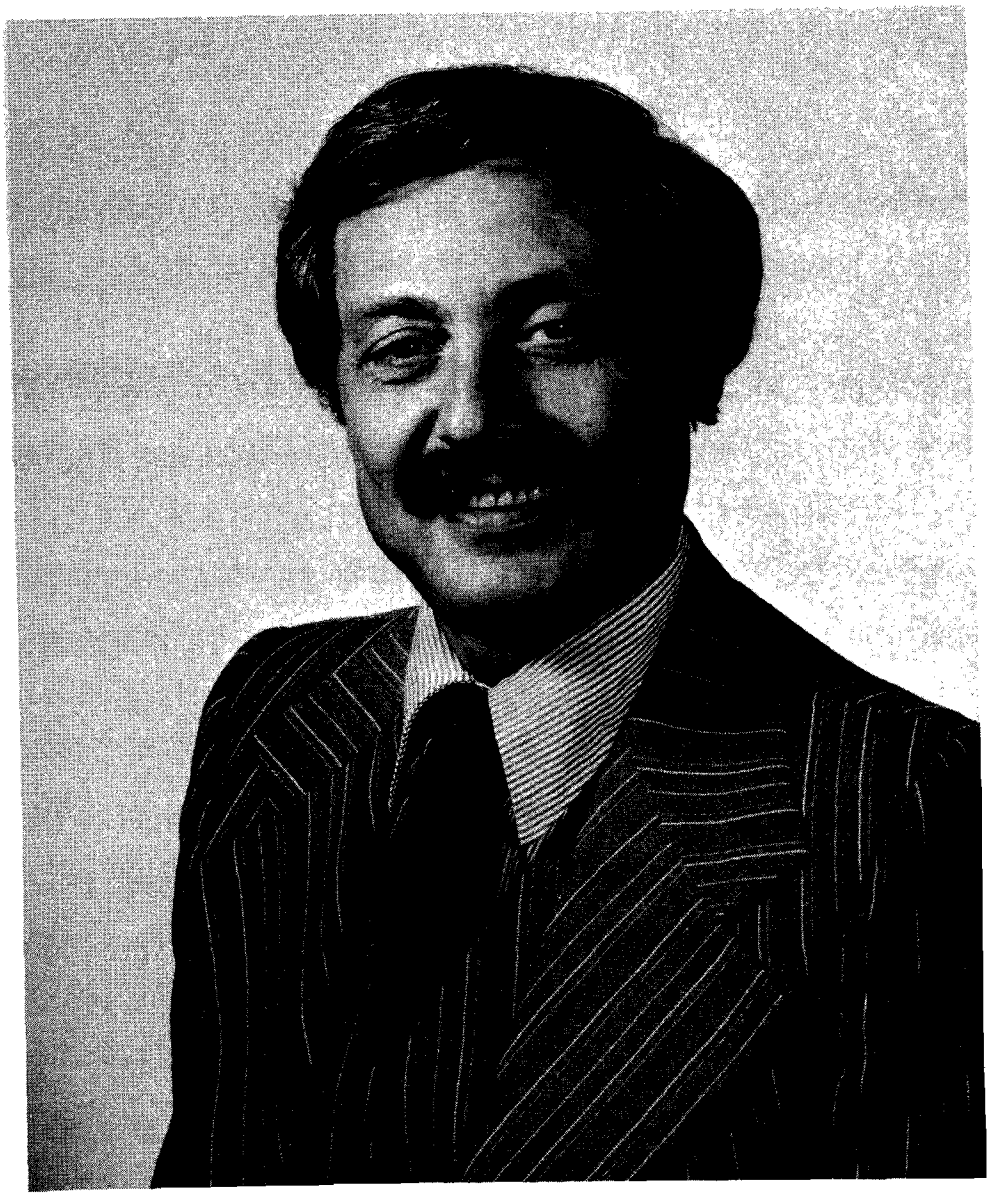
ACTIVE BCAS IS NOT INTENDED TO PROVIDE COLLISION PROTECTION FOR ALL USERS IN ALL AIRSPACE. IN PARTICULAR, WE EXPECT THAT IT WILL NOT OPERATE RELIABLY IN VERY DENSE AIRSPACE SUCH AS THAT

FOUND IN LOS ANGELES TODAY. MOREOVER, THE NECESSARY AVIONICS ARE UNDOUBTEDLY TOO EXPENSIVE TO BE ATTRACTIVE TO MANY GENERAL AVIATION AIRCRAFT OPERATORS.

WE BELIEVE THAT FULL BCAS AND ATARS ARE THE PROPER SOLUTIONS FOR VERY DENSE AIRSPACE, AND THAT LOW-END USERS WHO WANT COLLISION PROTECTION WITH A MINIMUM INVESTMENT IN AVIONICS WILL BENEFIT MOST FROM CONFLICT ALERT, CONFLICT RESOLUTION, AND, LATER, FROM ATARS.

ACTIVE BCAS APPEARS TO BE CAPABLE OF PROVIDNG A VIABLE SEPARATION ASSURANCE SERVICE IN MORE THAN 95% OF TODAY'S DOMESTIC AIRSPACE. MOREOVER, WHILE THE AVIONICS ARE NOT INEXPENSIVE, COSTS APPEAR TO BE WITHIN THE REALM OF REASON FOR SUBSTANTIAL AND IMPORTANT SEGMENTS OF TODAY'S USER COMMUNITY.

THANK YOU



Norman Solat

Chief, Communications and Surveillance Division
Systems Research and Development Service
Federal Aviation Administration

HISTORY AND RATIONALE OF ACTIVE BCAS DEVELOPMENT PROGRAM

GOOD MORNING, LADIES AND GENTLEMEN. WHAT YOU HAVE HEARD SO FAR THIS MORNING FROM AL ALBRECHT AND JIM BISPO IS A PERSPEC-

TIVE OF THE ACTIVE BCAS PROGRAM AS PART OF THE AGENCY'S OVERALL DEDICATION TO SAFETY, AND MORE SPECIFICALLY, AS AN INTEGRAL PART OF A COMPREHENSIVE AIRCRAFT SEPARATION ASSURANCE PROGRAM. MY ROLE THIS MORNING IS TO PROVIDE A TRANSITION TO THE TALKS WHICH FOLLOW--TO LINK THE GENERAL PRINCIPLES OF THESE EARLIER REMARKS WITH THE MORE DETAILED BRIEFINGS WHICH ARE THE MAJOR PART OF THIS 2-DAY MEETING. I WILL ATTEMPT TO PLACE THE FEATURES OF THE ACTIVE BCAS DESIGN INTO THE PERSPECTIVE OF PURPOSE AND FUNCTION--ALSO INDICATING WHICH, IN MY OPINION, ARE THE MORE SALIENT ACCOMPLISHMENTS AND WHERE SOME FURTHER ACCOMPLISHMENTS ARE EXPECTED.

WHEN I LOOK OVER THE AGENDA, IT STRIKES ME THAT A GREAT DEAL OF ATTENTION WILL BE PAID--JUSTIFIABLY--TO THE DETAILS OF THE BCAS DESIGN AS IT EXISTS TODAY, AS THE ITERATIVE PROCESS OF DESIGN AND VERIFICATION NEARS COMPLETION. THIS IS AS IT SHOULD BE. THE DESIGN, AS REPRESENTED IN THE EQUIPMENT AND OTHER DISPLAYS IN THE DISPLAY ROOM, IS WHAT YOU HAVE BEEN INVITED TO EXAMINE. IT IS WHAT HAS BEEN DESCRIBED IN THE ACTIVE BCAS NATIONAL AVIATION STANDARD, RECENTLY PUBLISHED IN THE FEDERAL REGISTER, AND WHAT WE WOULD LIKE YOUR COMMENTS ON.

DURING THIS CONFERENCE WE WILL HEAR THE ENGINEERS' VIEW OF BCAS AS WELL AS OBSERVATIONS FROM OUR OFFICE OF FLIGHT OPERATIONS, TO WHOM WE ENGINEERS ARE ULTIMATELY ANSWERABLE. BEFORE WE GET TO THAT POINT, WE NEED TO DEFINE WHAT ACTIVE BCAS IS SUPPOSED TO DO. IN THE WORLD OF ARCHITECTURE, THERE IS A FAMOUS STATEMENT: "FORM FOLLOWS FUNCTION." WE NEED TO DESCRIBE THE FUNCTION--WHAT BCAS IS SUPPOSED TO DO--BEFORE WE CAN EVALUATE

THE DETAILS OF ITS FORM--ITS DESIGN.

LET US START WITH THE BASICS. WE CAN ALL AGREE THAT ACTIVE BCAS IS A SYSTEM DESIGNED TO AID IN THE PREVENTION OF MIDAIR--AND NEAR MIDAIR--COLLISIONS. THAT MUCH IS SIMPLE. BUT JUST LIKE A CONTRACT, IT BEGINS TO GET MORE COMPLICATED WHEN WE START ADDING THE "WHEREAS" AND THE DETAILS.

FIRST, ACTIVE BCAS IS DESIGNED TO PERFORM THE COLLISION-PREVENTION FUNCTION IN AN ENVIRONMENT WHERE OTHER AIRCRAFT FROM WHICH PROTECTION IS REQUIRED ARE CARRYING A VARIETY OF EQUIPMENTS TO MAKE THEM VISIBLE TO BCAS--ATCRBS (OR SSR) TRANSPONDERS, DABS TRANSPONDERS, OR OTHER BCAS UNITS--WHETHER ACTIVE OR FULL BCAS.

SECOND, ACTIVE BCAS IS DESIGNED TO PERFORM THIS FUNCTION IN THE EN ROUTE AIRSPACE AS WELL AS THE TERMINAL ENVIRONMENT--RECOGNIZING THE PRACTICAL LIMITS ON TRAFFIC DENSITY--UNDER GROUND SURVEILLANCE OR OUTSIDE OF IT, AND FOR AIRCRAFT UNDER INSTRUMENT FLIGHT RULES AS WELL AS VISUAL FLIGHT RULES.

MEETING THESE REQUIREMENTS CONCURRENTLY INEVITABLY LEADS TO A SET OF CAVEATS, OR DESIGN CONSTRAINTS. THE REMAINDER OF THE DESIGN JOB THEN BECOMES MAKING A SERIES OF TRADE-OFFS AMONG THOSE CONSTRAINTS TO EVOLVE THE SYSTEM OF GREATEST VALUE TO THE USERS. THE EXTENT TO WHICH WE HAVE SUCCEEDED IN DOING THAT WILL BECOME APPARENT AS THE AGENDA PROCEEDS.

AS A LEAD-IN TO THE LATER DISCUSSIONS, LET ME TAKE A FEW MINUTES TO DISCUSS THESE REQUIREMENTS IN SOMEWHAT GREATER DETAIL.

FIRST, IT SHOULD BE CLEAR THAT ACTIVE BCAS NEEDS TO "SEE" A

VARIETY OF TARGETS EMINATING SIGNALS OF DIFFERENT TYPES, THEN EXTRACT THOSE SIGNALS FROM AN ENVIRONMENT CONTAINING MANY SUCH SIGNALS, AND DO IT IN SUCH A WAY THAT IT CAN UNAMBIGUOUSLY DETERMINE WHICH OF THOSE SIGNALS IS OF PARTICULAR INTEREST TO IT. THAT IS, IT SHOULD NOT MISS ALARMS, NOR SHOULD IT GENERATE FALSE ALARMS.

AS YOU KNOW, WHILE THIS CAN BE A RELATIVELY SIMPLE TASK WITH ONLY ONE OR TWO TARGETS IN THE AREA, IT BECOMES EXCEEDINGLY DIFFICULT AS THE NUMBER OF TARGETS BECOMES VERY LARGE. TESTING OF THE FIRST ACTIVE BCAS SURVEILLANCE UNIT BY MITRE CORPORATION AND BY THE FAA TECHNICAL CENTER BEGAN IN 1975, AND CONTINUED THROUGH 1978, INCLUDING FLIGHT TESTS AT ATLANTIC CITY, WASHINGTON, D.C., AND LOS ANGELES. THOSE TESTS SHOWED THAT WE WERE ON THE RIGHT TRACK, BUT THAT WE STILL HAD A LONG WAY TO GO. ONE OF THE BIG PROBLEM AREAS WE DETERMINED WAS THAT, DUE PRINCIPALLY TO MULTI-PATH EFFECTS, WE COULDN'T ALWAYS GET RELIABLE TRACKS FOR ATCRBS-EQUIPPED AIRCRAFT WHICH WERE BELOW THE BCAS AIRCRAFT. ALSO, IN HIGH DENSITY AREAS, THE BCAS HAD A TENDENCY TO GENERATE MULTIPLE FALSE TARGETS, CREATING THE POTENTIAL FOR GENERATING FALSE ALARMS

IN 1977, THE LINCOLN LABORATORY BEGAN THE DEVELOPMENT OF THE SECOND GENERATION OF THE ACTIVE BCAS SURVEILLANCE DESIGN, TAKING INTO ACCOUNT WHAT HAD BEEN LEARNED DURING THE EARLIER ACTIVITIES. THE RESULTS OF THAT DEVELOPMENT, WHICH YOU WILL HEAR ABOUT FROM LINCOLN TOMORROW, ARE CONTAINED IN THE BCAS EXPERIMENTAL UNIT, OR BEU. ONE OF WHICH IS IN THE DISPLAY ROOM, AND ONE OF WHICH IS INSTALLED IN THE FAA'S BOEING 727, WHICH YOU CAN WALK THROUGH IF YOU WISH. IN A WORD, THE

PROBLEMS WHICH WERE IDENTIFIED IN THE TESTS OF THE EARLIER FEASIBILITY MODELS HAVE BEEN LARGELY SOLVED; WE BELIEVE OUR FIRST REQUIREMENT HAS BEEN MET.

SECOND, IT SHOULD BE CLEAR THAT THERE'S MORE TO ACTIVE BCAS THAN SURVEILLANCE. ONCE A TARGET IS ACCURATELY AND UNABMIGUOUSLY IDENTIFIED AS A REAL AIRCRAFT, THE LOGIC IN THE BCAS COMPUTER MUST DETERMINE IF THE AIRCRAFT REPRESENTS A POTENTIAL THREAT, AND IF SO, WHAT SHOULD BE DONE TO AVOID IT.

THE MOST DIFFICULT PART, OF COURSE, IS ACCURATELY DETERMINING THE TARGET AS BEING THREATENING. THIS IS BECAUSE OF THE INTENTIONAL CLOSE SPACING OF AIRCRAFT IN TERMINAL AREAS, AND THE TIGHT TIME CONSTRAINTS UNDER WHICH SUCH DECISIONS MUST BE MADE, BOTH OF WHICH ARE EXACERBATED BY OUR IGNORANCE OF THE OTHER AIRCRAFT'S INTENT TO MANEUVER. THE POSSIBILITY OF A NO-WARNING, LAST INSTANT MANEUVER IS IMPOSSIBLE TO DEFEND AGAINST AND WILL FOREVER REMAIN ONE OF THE "CONSTRAINTS" I SPOKE OF PREVIOUSLY.

IN 1967, THE AIR TRANSPORT ASSOCIATION OF AMERICA PUBLISHED ANTC-117 CONTAINING A COLLISION AVOIDANCE LOGIC WHICH PROVIDED THE FOUNDATION UPON WHICH THE CURRENT ACTIVE BCAS LOGIC IS BUILT. TESTING OF THE ANTC-117 LOGIC WAS CARRIED ON THROUGH THE 1970'S. THOSE TESTS INDICATED THAT THERE WERE AN EXCESSIVE NUMBER OF NUISANCE ALARMS GENERATED IN NORMAL TRAFFIC OPERATIONS IN TERMINAL AREAS, AND POINTED TO THE NEED TO CHANGE A NUMBER OF PARAMETERS IN THE LOGIC WHEN IN THE VICINITY OF HIGH DENSITY TERMINALS--A CONCEPT WHICH IS CALLED "DESENSITIZATION."

SINCE 1975, THE MITRE CORPORATION HAS BEEN CONTINUALLY

DEVELOPING THE LOGIC AND THE DESENSITIZATION ALGORITHMS. THAT LOGIC IS RESIDENT IN THE COMPUTER OF THE BEU IN THE DISPLAY ROOM, AND OF COURSE IN THE AIRCRAFT, AND MITRE WILL DESCRIBE THAT LOGIC DURING TOMORROW'S BRIEFING. I BELIEVE IT'S FAIR TO SAY THAT THE PRESENT LOGIC REPRESENTS AN EFFECTIVE TRADEOFF BETWEEN COLLISION PROTECTION AND ALERT RATES IN NORMAL TRAFFIC OPERATIONS.

THIRD, PERHAPS THE MOST IMPORTANT REQUIREMENTS OF BCAS IS WRAPPED UP IN THE SINGLE WORD, "COMPATIBILITY." BCAS MUST DEMONSTRATE ALL FACETS OF THAT MULTI-FACETED WORD IF IT IS TO BE A SUCCESSFUL OPERATING SYSTEM. LET ME TAKE A FEW MINUTES TO AMPLIFY THAT TERM AND DISCUSS SOME OF ITS RAMIFICATIONS.

OBVIOUSLY, BCAS MUST DEMONSTRATE ELECTROMAGNETIC COMPATIBILITY--EMC. BCAS SHARES THE SSR CHANNEL WITH ATCRBS, DABS, AND THE MILITARY IFF SYSTEM, AIMS. MOREOVER, TACAN, DME, AND THE MILITARY JTIDS SYSTEM OPERATE IN ADJACENT BANDS. STUDIES WERE INITIATED IN 1972 TO ASSURE THE COMPATIBLE OPERATION OF THE DABS SYSTEM WITH THOSE SERVICES, AND THOSE STUDIES HAVE BEEN EXTENDED TO INCLUDE ACTIVE BCAS.

RECENT RESULTS FROM THE ELECTROMAGNETIC COMPATIBILTY ANALYSIS CENTER, ECAC, INDICATE THAT BCAS WILL NOT CAUSE DEGRADATION OF THE OPERATION OF EITHER ATCRBS OR DABS GROUND SURVEILLANCE, EVEN IN TRAFFIC DENSITIES THREE TO FOUR TIMES THOSE ENCOUNTERED TODAY IN LOS ANGELES. OTHER RESULTS OF THE FAA'S EMC STUDIES AND TESTS ARE THE SUBJECT OF ONE OF TOMORROW'S BRIEFINGS.

ANOTHER ASPECT OF COMPATIBILITY LIES IN THE ABILITY OF

ACTIVE BCAS TO PERFORM AS PART OF AND WITHOUT DISRUPTION TO A LARGER SYSTEM, THE AIR TRAFFIC CONTROL SYSTEM, WHICH REMAINS THE PRINCIPAL MEANS FOR ASSURING AIRCRAFT SEPARATION. IN NORMAL TRAFFIC OPERATIONS, FREE OF CONFLICTS, BCAS MUST NOT GENERATE NUISANCE ALARMS WHICH DISRUPT THE SAFE AND EFFICIENT FLOW OF TRAFFIC. THIS COMPATIBILITY IS PARTLY ACCOMPLISHED BY MEANS OF AN AIR-TO-GROUND COMMUNICATION LINK, UTILIZING SIGNAL STRUCTURES WITH DEMONSTRATED HIGH RELIABILITY, AND FORMATS COMMON TO THE RECENTLY PUBLISHED NATIONAL AVIATION STANDARD FOR DABS, AND THE BCAS NATIONAL STANDARD.

STILL ANOTHER ASPECT OF ACTIVE BCAS COMPATIBILITY WAS DISCUSSED BRIEFLY BY JIM BISPO--THE COMPATIBILITY OF ACTIVE BCAS WITH THE OTHER ELEMENTS OF THE AIRCRAFT SEPARATION ASSURANCE PROGRAM. ACTIVE BCAS HELPS PROVIDE UNINTERRUPTED COLLISION AVOIDANCE SERVICES AS THE GROUND SYSTEM TRANSITIONS IN <u>TIME</u> FROM TODAY'S ATCRBS INTERROGATORS TO TOMORROW'S DABS SENSORS, AND FOR AIRCRAFT AS THEY TRANSITION <u>GEOGRAPHICALLY</u> FROM AREAS OF NO SURVEILLANCE, THROUGH AREAS OF ATCRBS SURVEILLANCE, TO AREAS WHERE THE PRINCIPAL COLLISION AVOIDANCE SERVICE MAY BE PROVIDED BY ATARS. THESE TIME AND GEOGRAPHIC TRANSITIONS MUST ALSO BE ACCOMPLISHED INDEPENDENTLY OF THE EQUIPAGE OF OTHER AIRCRAFT IN THE VICINITY--WHETHER THEY ARE EQUIPPED WITH ATCRBS, DABS/ATARS, ACTIVE BCAS, OR FULL BCAS. IN SHORT, ACTIVE BCAS, WHICH MAY BE AVAILABLE FOR INSTALLATION AS EARLY AS 1983, WILL BE AROUND FOR A LONG TIME, AND IS DESIGNED TO OPERATE IN A NUMBER OF DIFFERENT ENVIRONMENTS. THE COMPLEXITIES INHERENT IN PROVIDING AND DEMONSTRATING COMPATIBILITY OF THIS TYPE, AND THE MEANS TAKEN TO ACHIEVE IT, ARE THE TOPICS OF SEVERAL OF TOMORROW'S BRIEFINGS.

THERE IS, OF COURSE, ONE MORE ASPECT OF THE COMPATIBILITY REQUIREMENT--COMPATIBILITY WITH FLIGHT OPERATIONS. YOU WILL BE HEARING TODAY AND TOMORROW ABOUT THAT ISSUE FROM THE FAA PEOPLE MOST CONCERNED THAT ACTIVE BCAS DOES INDEED SATISFY ALL THE CRITERIA IMPLIED BY THAT SENSE OF THE WORD COMPATIBILITY. THOSE DISCUSSIONS ARE FROM THE VIEWPOINT OF THE PERSON IN THE COCKPIT, AND WILL DESCRIBE THE STEPS TAKEN TO DATE--AND THOSE STILL TO BE TAKEN--TO ASSURE OURSELVES AND THE USERS THAT THE INTRODUCTION OF ACTIVE BCAS INTO THE NATIONAL AIRSPACE SYSTEM WILL HAVE NOT NEGATIVE SIDE EFFECTS.

FINALLY, I THINK IT GERMANE TO SAY A FEW WORDS ABOUT THE MATURITY OF THE PROGRAM. WE WOULD BE CONCERNED, AS WOULD YOU, IF WE COULD DEMONSTRATE ONLY THAT LABORATORY EQUIPMENT COULD PERFORM THE REQUIRED FUNCTIONS IN A SUITABLE MANNER. THIS IS PARTICULARLY IMPORTANT SINCE, AS I MENTIONED EARLIER, UNITS MAY BE MADE AVAILABLE AS EARLY AS 1983. TO UNDERSTAND WHAT ISSUES OF MANUFACTURABILITY ARE INHERENT IN THE ACTIVE BCAS CONCEPT, THE FAA HAS CONTRACTED SINCE MARCH OF 1980 WITH DALMO VICTOR OPERATIONS OF BELL AEROSPACE TEXTRON, WHOSE DISPLAY IS ALSO IN THE DISPLAY ROOM, AND WHOSE REPRESENTATIVES WILL HAVE THE OPPORTUNITY TO SPEAK TO THAT SUBJECT LATER. THEIR INPUTS INTO THE BCAS PROGRAM HAVE BEEN INVALUABLE. THE UNITS, WHICH ARE TO BE DELIVERED IN MARCH OF 1981 WILL BE USED FOR AN EXTENDED EVALUATION OF BCAS IN IN-SERVICE AIR CARRIER AIRCRAFT. YOU WILL BE HEARING MORE ABOUT THAT PROGRAM, AS WELL.

BY WAY OF SUMMARY, LET ME REITERATE WHAT I BELIEVE ARE SOME SIGNIFICANT ACCOMPLISHMENTS. WHAT HAS BEEN DONE IS TO BUILD, INSTALL AND TEST AN ACTIVE BCAS EXPERIMENTAL UNIT THAT CAN RELIABLY DETECT AND TRACK TARGETS CARRYING ATCRBS OR DABS TRANSPONDERS. IT CAN DO THAT IN RELATIVELY HIGH DENSITY ENVIRONMENTS, AND IN THE PRESENCE OF GARBLE AND MULTIPATH INTERFERENCE. FURTHER, WE HAVE DEMONSTRATED A LOGIC WHICH UTILIZES THESE FIRM TRACKS TO DETECT WHEN OTHER AIRCRAFT MAY BE THREATENING AND RELIABLY RESOLVE THOSE ENCOUNTERS WITH A TIMELY ALARMS DISPLAYED TO THE PILOT. AND WE HAVE ALSO DEMONSTRATED THAT THE SYSTEM WHICH DOES ALL THAT IS WITHIN THE MANUFACTURING STATE-OF-THE-ART.

LEST I GET CARRIED AWAY IN MY ENTHUSIASM, I SHOULD ADD THAT IN NO WAY IS THE JOB COMPLETED YET. OPERATIONAL EVALUATION OF THE BCAS UNITS WILL CONTINUE. AS KEN HUNT WILL DESCRIBE, THERE ARE STEPS YET TO BE TAKEN BEFORE ACTIVE BCAS WILL BE INTRODUCED INTO THE OPERATIONAL ENVIRONMENT.

FROM A TECHNICAL STANDPOINT, IN THE FUTURE WE WILL BE INTRODUCING ENHANCEMENTS TO THE BASIC BCAS, TO MAKE ACTIVE BCAS AS RESPONSIVE AS POSSIBLE TO SPECIALIZED USER NEEDS. ONE OF THOSE ENHANCEMENTS WILL BE THE ADDITION OF A DIRECTIONAL ANTENNA CAPABILITY TO THE BCAS, TO PROVIDE PROXIMITY INFORMATION FOR COCKPIT DISPLAY TO AID THE PILOT IN HIS ACQUISITION AND ASSESSMENT OF THREATENING AIRCRAFT. YOU CAN SEE A SIMULATED DEMONSTRATION OF THIS FEATURE IN THE DISPLAY ROOM.

IN CONCLUSION, I'D LIKE TO ADD MY WELCOME AND THE WELCOME OF ALL OF US IN THE COMMUNICATIONS AND SURVEILLANCE DIVISION TO THOSE ALREADY EXPRESSED BY AL ALBRECHT, JIM BISPO, AND BOB WEDAN. I HOPE THAT THE BRIEFINGS YOU WILL HEAR AND THE DISPLAYS WE'VE PREPARED WILL PROVIDE YOU THE INFORMATION YOU NEED. IF THERE IS ANYTHING ELSE WE CAN DO FOR YOU, PLEASE ASK.

THANK YOU

Kenneth S. Hunt

Director, Office of Flight Operations
Federal Aviation Administration

IMPLEMENTATION OF ACTIVE BCAS

Implementation of Active BCAS

IMPLEMENTATION

OF

ACTIVE BCAS

MR. K. HUNT

GOOD MORNING! I AM PLEASED TO HAVE THIS OPPORTUNITY TO DISCUSS WITH YOU OUR EXPERIENCE WITH THE ACTIVE BCAS AND TO TALK FOR A FEW MOMENTS ABOUT THE IMPLEMENTATION OF THIS CAPABILITY.

WE ARE PLEASED THAT THE ACTIVE BCAS PROGRAM IS PROGRESSING AS WELL AS IT IS. THE SYSTEM SHOWS PROMISE - WE ARE ENCOURAGED BY WHAT WE HAVE SEEN SO FAR AND EXPECT THAT WE WILL BE ABLE TO IMPLEMENT THE ACTIVE BCAS AS A BACKUP COLLISION AVOIDANCE SYSTEM IN THE NEAR FUTURE. THERE IS A LOT OF WORK YET TO BE COMPLETED, HOWEVER.

WE ARE PLEASED THAT WE HAVE THE EXPERTISE AND DEDICATION WITHIN THE AGENCY THAT WE HAVE SEEN DISPLAYED BY OUR TECHNICAL PEOPLE IN THE DEVELOPMENT OF ACTIVE BCAS. WE ARE FORTUNATE THAT WE HAVE HAD THE SUPPORT OF SOME OF THE FINEST MINDS IN THE INDUSTRY TODAY IN THE WORK OF LINCOLN LABORATORIES OF MIT, OF THE MITRE CORPORATION, AND OF MANY OTHER FINE ORGANIZATIONS. AS YOU KNOW, THESE PEOPLE HAVE DEVELOPED AN EXPERIMENTAL SYSTEM THAT HAS BEEN DEMONSTRATED, IN A LIMITED OPERATIONAL DEMONSTRATION, TO HAVE THE CAPABILITY OF PROVIDING CONFLICT RESOLUTION SERVICE IN AN OPERATIONAL ENVIRONMENT WITHOUT INTERFERING WITH THE NORMAL OPERATION OF THE AIRPLANE OR ITS CREW. THIS IS, IN MY VIEW, A MAJOR STEP IN THE DEVELOPMENT AND IMPLEMENTATION OF A COLLISION AVOIDANCE CAPABILITY.

Active BCAS Operational Requirements

- Detect Collision Threats in All Weather Conditions
- Provide Timely Advisories to Pilot
- Compatible with Conventional ATC and its Evolution
- Reliable Protection in All Airspace
- Acceptably Low Level of Unwanted Alarms
- Resolve Multiple-Aircraft Encounters
- Protection Available to First Equipped Users
- Affordable to Broad Spectrum of NAS Users

THE OPERATING SERVICES OF THE FAA IN COOPERATION WITH THE AVIATION COMMUNITY HAVE ESTABLISHED THE OPERATING REQUIREMENTS FOR A COLLISION AVOIDANCE SYSTEM.

- THE SYSTEM MUST DETECT ALL POTENTIAL MIDAIR COLLISIONS WITH OTHER AIRCRAFT IN ALL WEATHER CONDITIONS.

- THE SYSTEM MUST PROVIDE TIMELY RESOLUTION ADVISORIES TO THE PILOT

- OPERATION MUST BE COMPATIBLE WITH THE EXISTING ATC SYSTEM AND WITH PLANNED EVOLUTION OF THE SYSTEM

- RELIABLE PROTECTION MUST BE PROVIDED THROUGHOUT NAVIGABLE AIRSPACE, INCLUDING AIRSPACE NOT COVERED BY PRIMARY OR SECONDARY RADAR SYSTEMS

- THE SYSTEM MUST OPERATE WITH AN ACCEPTABLY LOW LEVEL OF UNWANTED ALARMS

- THE SYSTEM SHOULD BE CAPABLE OF HANDLING ENCOUNTERS INVOLVING MULTIPLE AIRCRAFT IN AREAS WITH LARGE NUMBERS OF AIRCRAFT WITHOUT SATURATION OF THE OPERATING FREQUENCIES

- SERVICES SHOULD BE AVAILABLE TO THE FIRST USERS OF THE EQUIPMENT AND SHOULD NOT REQUIRE COOPERATIVE MANEUVERS OF OTHER AIRCRAFT

- AFFORDABLE AND COMPATIBLE COLLISION AVOIDANCE SYSTEM OPTIONS SHOULD BE PROVIDED FOR A BROAD SPECTRUM OF NATIONAL AIRSPACE SYSTEM USERS

WE RECOGNIZE THAT IT IS ESSENTIAL THAT EQUIPMENT PROVIDING AT LEAST A MINIMUM LEVEL OF SATISFACTORY COLLISION AVOIDANCE INFORMATION MUST BE MADE AVAILABLE TO THE AVIATION COMMUNITY AT THE EARLIEST POSSIBLE DATE. WE HAVE BEEN AT THIS TASK FOR A NUMBER OF YEARS - WITH THE SOLUTION NOW NEAR AT HAND WE MUST PROCEED AS RAPIDLY AS WE CAN TO IMPLEMENTATION.

AT THE SAME TIME, I CAUTION YOU TO RECOGNIZE THAT SUBSTANTIAL WORK REMAINS BEFORE WE CAN FINALLY IMPLEMENT ACTIVE BCAS.

IN GENERAL TERMS, THE WORK REMAINING FALLS INTO THESE AREAS.

WE ARE WORKING WITH OUR RESEARCH AND DEVELOPMENT PEOPLE TO IDENTIFY THOSE ELEMENTS OF A COLLISION AVOIDANCE SYSTEM THAT ARE ESSENTIAL FOR A MINIMUM LEVEL OF SATISFACTORY PERFORMANCE. IS IT NECESSARY, FOR EXAMPLE, TO PROVIDE VERTICAL SPEED LIMITS IN ADDITION TO NEGATIVE ADVISORIES SUCH AS "DON'T DESCEND" OR "DON'T CLIMB" AND POSITIVE ADVISORIES TO "CLIMB" OR "DESCEND." IF WE DO REQUIRE THAT SUCH INFORMATION BE PROVIDED, HOW SHOULD

Work Remaining to Implement Active BCAS

- Identify Minimum Display Elements
- Evaluate Usefulness of Traffic Proximity Information
- Evaluate Cockpit Workload Issues
- Establish Operational Procedures
- Identify Satisfactory Desensitization Scheme
- Demonstrate Satisfactory Operational Performance

IT BE USED? SHOULD WE REQUIRE IN OUR PROCEDURES FOR THE USE OF ACTIVE BCAS THAT A PILOT ALWAYS RESPOND IMMEDIATELY TO A POSITIVE ADVISORY BUT USE OTHER ADVISORIES IN SOME DIFFERENT FASHION?

WE ARE STILL WORKING TO DEVELOP THE CAPABILITY TO DISPLAY BEARING TO THE THREAT AS IT IS PERCEIVED BY ACTIVE BCAS. ONCE DEVELOPED, THIS CAPABILITY WOULD UNDOUBTEDLY ENHANCE THE PERFORMANCE OF ACTIVE BCAS OR A COLLISION AVOIDANCE SYSTEM AGAINST BOTH ALTITUDE ENCODING AND NON-ALTITUDE ENCODING TRANSPONDER EQUIPPED AIRCRAFT. THE USEFULNESS OF SUCH INFORMATION IN THE COCKPIT MUST BE EXPLORED, HOWEVER, TO INSURE THAT WE DO NOT INTRODUCE UNNECESSARY LEVELS OF SOPHISTICATION.

IF THE CAPABILITY TO DETECT AND DISPLAY BEARING TO THE TARGET IS ADDED TO ACTIVE BCAS, WE THEN INTRODUCE YET ANOTHER CAPABILITY - THAT OF PROVIDING TRAFFIC PROXIMITY INFORMATION TO THE PILOT. IF WE DECIDE TO IMPLEMENT SOME FORM OF TRAFFIC ADVISORY INFORMATION AS A PART OF OR IN SUPPORT OF ACTIVE BCAS, WE MUST DEVELOP AND AGREE TO THE PROCEDURES FOR THE USE OF SUCH INFORMATION.

WE ARE HOPEFUL THAT WE CAN WORK OUT A SATISFACTORY METHOD TO DISPLAY LIMITED TRAFFIC PROXIMITY ADVISORIES IN SUPPORT OF ACTIVE BCAS. THIS CAPABILITY WILL HOPEFULLY AFFORD US SOME MEASURE OF PROTECTION AGAINST TARGETS THAT DO NOT HAVE ALTITUDE ENCODING TRANSPONDERS. IT MAY ALSO GREATLY ENHANCE THE CONFIDENCE OF THE AIRCREW IN ACTIVE BCAS AS A SYSTEM TO WHICH HE CAN RESPOND IMMEDIATELY WHEN HE MUST DO SO TO AVERT A COLLISION.

THE DESENSITIZATION ISSUE MUST STILL BE WORKED OUT. WE MUST PERFECT A WAY TO DESENSITIZE THE SYSTEM AS WE ENTER THE TERMINAL AREA TO REDUCE THE NUMBER OF UNWANTED ALARMS WHICH AFFECT COCKPIT WORKLOAD AND PILOT CONFIDENCE. WHETHER WE DO THIS MANUALLY WITH A SWITCH IN THE COCKPIT, OR AUTOMATICALLY THROUGH THE USE OF A DEVICE ON THE GROUND IN THE TERMINAL AREA, OR WITH SWITCHES TIED PERHAPS TO THE LANDING GEAR AND FLAPS OR RADAR ALTIMETER, HAS YET TO BE WORKED OUT.

FINALLY, HAVING WORKED THROUGH THESE ISSUES WE MUST DEMONSTRATE THE OVERALL SYSTEM PERFORMANCE WE ARE LOOKING FOR IN THE REAL WORLD OPERATING ENVIRONMENT BEFORE WE CAN ARRIVE AT THE FINAL DECISION TO IMPLEMENT.

ONE FURTHER THOUGHT IN THIS AREA OF RESEARCH AND DEVELOPMENT. AS YOU HAVE HEARD ALREADY, THE COLLISION AVOIDANCE CONCEPT WE ARE DEVELOPING REQUIRES THE IMPLEMENTATION BOTH OF ATARS AND ACTIVE BCAS TO ACHIEVE THE PROTECTION WE ARE LOOKING FOR. WE IN THE OPERATIONAL SIDE OF THE FAA FEEL IT IS ESSENTIAL THAT WE CONTINUE THE DEVELOPMENT OF THE FULL BCAS. NOT ONLY WILL SPINOFF FROM THIS PROGRAM UNDOUBTEDLY CONTINUE TO ENHANCE ACTIVE BCAS, BUT MORE IMPORTANTLY, FULL BCAS WILL PROVIDE THE DESIRED LEVEL OF PROTECTION IN THE BUSIER TERMINAL AREAS FOR COMMERCIAL TRANSPORT AIRCRAFT IN THE EVENT IMPLEMENTATION OF ATARS IS DELAYED FOR WHATEVER REASONS - WHETHER THEY BE TECHNICAL OR ECONOMIC.

SO MUCH FOR THIS REVIEW OF THE R & D PROGRAM FOR ACTIVE BCAS. LET ME CHANGE THE TOPIC TO A MORE GENERAL ONE - THAT OF THE TYPICAL AVIONICS CERTIFICATION AND IMPLEMENTATION PROCESS. MANY OF YOU WORK IN THIS AREA EVERYDAY AND ARE INTIMATELY FAMILIAR WITH IT. SOME HAVE ASKED, HOWEVER, THAT I BRIEFLY DESCRIBE THE PROCESS BY WHICH AVIONICS LIKE ACTIVE BCAS ARE IMPLEMENTED.

AS MOST OF YOU ARE AWARE, THE DESIRED PERFORMANCE REQUIREMENTS FOR ELECTRONIC SYSTEMS TO BE INSTALLED IN CIVIL TRANSPORT AIRCRAFT TODAY ARE USUALLY DEVELOPED BY COMMITTEE IN A FORUM CALLED THE RADIO TECHNICAL COMMISSION FOR AERONAUTICS - THE RTCA. WORKING WITHIN SPECIAL COMMITTEES ESTABLISHED BY THE RTCA, REPRESENTATIVES OF ALL INTERESTED PARTIES, INCLUDING THE USERS, MANUFACTURERS, AND THE GOVERNMENT CREATE A DOCUMENT FOR EACH SYSTEM OF INTEREST THAT SPECIFIES THE MINIMUM OPERATIONAL PERFORMANCE REQUIREMENTS OR "MOPS." BECAUSE ALL PARTIES ARE REPRESENTED, THIS DOCUMENT USUALLY REPRESENTS A SET OF COMPROMISES THAT REFLECT THE INDUSTRY'S INTERPRETATION OF MINIMUM DESIRABLE TECHNICAL AND OPERATIONAL PERFORMANCE AS CONSTRAINED BY MANUFACTURING LIMITATIONS AND THE REALITIES OF PROBABLE COSTS TO THE USERS.

AS THE USERS' REQUIREMENTS FOR A PARTICULAR AIRBORNE ELECTRONICS SYSTEM BECOME APPARENT, THE FAA WILL DEVELOP A TECHNICAL STANDARD ORDER, OR "TSO," FOR USE AS A REFERENCE BY THE COMMUNITY IN THE ACQUISITION AND IMPLEMENTATION OF SUCH A SYSTEM. THE MOPS MAY BE USED IN PART BY THE FAA

Avionics Certification and Implementation

- RTCA Minimum Operational Performance Standard (MOPS)
- FAA Technical Standard Order (TSO)
- Notice of Proposed Rule Making (NPRM)
- Federal Aviation Regulations (FAR)
- Supplemental Type Certificate (STC)
- Training Requirements
- Internal FAA Directives
- Advisory Circulars
- Operations Specifications

AS A REFERENCE FOR THE TECHNICAL PERFORMANCE REQUIREMENTS OF A SYSTEM IN PREPARING THE TSO.

WHERE IT IS DECIDED THAT REGULATORY ACTION BY THE GOVERNMENT IS APPROPRIATE IN THE IMPLEMENTATION OF SOME PARTICULAR CAPABILITY, A SPECIFIC REGULATORY PROJECT IS THEN ESTABLISHED WITHIN THE FAA AUTHORIZING THE EXPENDITURE OF RESOURCES TO DEVELOP THE APPROPRIATE RULES AND AMENDMENTS. TO COMPLY WITH THE PUBLIC LAW, A NOTICE OF PROPOSED RULE MAKING IS PUBLISHED IN THE FEDERAL REGISTER OUTLINING THE PROPOSAL AND ITS BACKGROUND AND SOLICITING PUBLIC COMMENT. THESE COMMENTS ARE THEN ANALYZED AND CAREFULLY CONSIDERED IN THE DEVELOPMENT OF ANY FEDERAL REGULATIONS OR AMENDMENTS THAT MIGHT RESULT. WHERE IT IS APPROPRIATE, AIRWORTHINESS RULES RELATED TO THE IMPLEMENTATION OF AIRBORNE EQUIPMENT WILL OFTEN REFER TO AN APPROPRIATE TSO IN STATING THE REQUIRED OPERATIONAL OR TECHNICAL PARAMETERS.

THERE ARE, OF COURSE, MANY CIRCUMSTANCES WHERE RULEMAKING IS NOT ANTICIPATED, BUT WHERE AN OPERATOR MAY WISH TO INSTALL AND OPERATE AIRBORNE EQUIPMENT OF SOME SORT. THAT OPERATOR MUST OBTAIN AUTHORIZATION FROM THE FAA TO INSTALL AND OPERATE THAT EQUIPMENT IF IT HAS NOT BEEN CERTIFICATED EARLIER AS A PART OF THE AIRCRAFT. IN THIS EVENT, THE OPERATOR MUST OBTAIN A SUPPLEMENTAL TYPE CERTIFICATE OR FIELD APPROVAL FOR THAT SPECIFIC PIECE OF EQUIPMENT. THIS REQUIRES THAT THE OPERATOR, OFTEN IN COOPERATION WITH THE MANUFACTURER, PROVIDE SUFFICIENT PROOF TO THE FAA

THAT THE DEVICE PERFORMS ITS INTENDED FUNCTION AND THAT IT DOES NOT INTERFERE WITH SAFETY OF FLIGHT.

THE FAA OFTEN REQUIRES THAT IN SUPPORT OF THE IMPLEMENTATION OF A NEW SYSTEM OR CAPABILITY, APPROPRIATE TRAINING BE PROVIDED BY THE OPERATORS. MODIFICATIONS TO AN OPERATOR'S TRAINING PROGRAMS ARE IMPLEMENTED THROUGH THE FAA'S PRINCIPAL OPERATIONS, AVIONICS, AND MAINTENANCE INSPECTORS FOR THE CARRIERS AND THROUGH THE SAFETY PROGRAMS OF THE GENERAL AVIATION DISTRICT OFFICES. SUCH MODIFICATIONS ARE SUPPORTED BY WRITTEN DIRECTIVES TO THE RESPONSIBLE FAA OFFICES IN THE FIELD FROM THE APPROPRIATE HEADQUARTERS FUNCTION.

AS A PART OF THE IMPLEMENTATION PROCESS OF A NEW CAPABILITY, THE FAA OFTEN PUBLISHES ADVISORY CIRCULARS WHICH MAY TAKE THE FORM OF GUIDANCE TO FAA PERSONNEL AND THE AVIATION PUBLIC FOR THE CERTIFICATION AND USE OF NEW EQUIPMENT OR MAY BE DIRECTED MORE AT THE OPERATOR IN THE FORM OF ADDITIONAL INFORMATION. AS EXPERIENCE WITH A PARTICULAR SYSTEM GROWS, THESE ADVISORY CIRUCLARS ARE OFTEN UPDATED.

THE TIME REQUIRED FOR THIS IMPLEMENTATION PROCESS TO TAKE PLACE VARIES GREATLY ACCORDING TO THE NATURE OF THE SYSTEM OR CAPABILITY IN QUESTION AND TO THE PRESSURES, BOTH INTERNAL AND EXTERNAL, ON THE AVIATION COMMUNITY FOR ANY CHANGE. IN THE CASE OF AREA NAVIGATION, IT IS TAKING MANY YEARS. THE GROUND PROXIMITY WARNING SYSTEM, ON THE OTHER HAND, WAS IMPLEMENTED QUICKLY AND WE ARE STILL WORKING OUT THE DETAILS.

AS A RULE, IT SEEMS THAT IT TAKES ONE TO TWO YEARS FOR THE RTCA TO DEVELOP A MOPS TO THE POINT THAT IT CAN FIRST BE PUBLISHED. THE RULEMAKING PROCESS, IF WARRANTED, CAN BE INITIATED IN PARALLEL WITH THE DEVELOPMENT OF A TSO. IN SOME CASES THE AVIATION COMMUNITY'S INTEREST IN A NEW SYSTEM IS SUCH THAT THE DEVELOPMENT OF THE MOPS AND THE RESEARCH NECESSARY TO SUPPORT RULEMAKING AND IMPLEMENTATION ARE ACCELERATED. SUCH IS THE CASE FOR ACTIVE BCAS. (SLIDE 5) IT IS OUR HOPE THAT THE REMAINING RESEARCH AND DEVELOPMENT, THE DEVELOPMENT OF THE MOPS BY INDUSTRY, AND THE REGULATORY ACTION ANTICIPATED BY THE FAA CAN PROCEED IN PARALLEL SO AS TO PERMIT IMPLEMENTATION OF THE FIRST ACTIVE BCAS UNITS IN 1983. AS I THINK YOU WILL AGREE, THIS IS AN EXTREMELY DEMANDING SCHEDULE. THERE IS A GREAT DEAL OF WORK REMAINING, GENTLEMEN.

IT IS IMPORTANT THAT WE RECOGNIZE, IN PARTICULAR, THAT OPTIMIZATION OF DISPLAYS, AND OF THEIR LOCATION IN THE COCKPIT, MUST BE COMPLETED BY INDUSTRY. LIKEWISE, THE PROCEDURES FOR THE USE OF THESE DISPLAYS MUST BE DEVELOPED BEFORE WE CAN IMPLEMENT THIS SYSTEM.

Possible Implementation Scenario for Active BCAS

2/81 First Meeting of RTCA Special Committee for MOPS

2/82 RTCA Minimum Operational Performance Standard

8/82 Airworthiness Rules and Amendments Published

CY 83 Certified Avionics Available

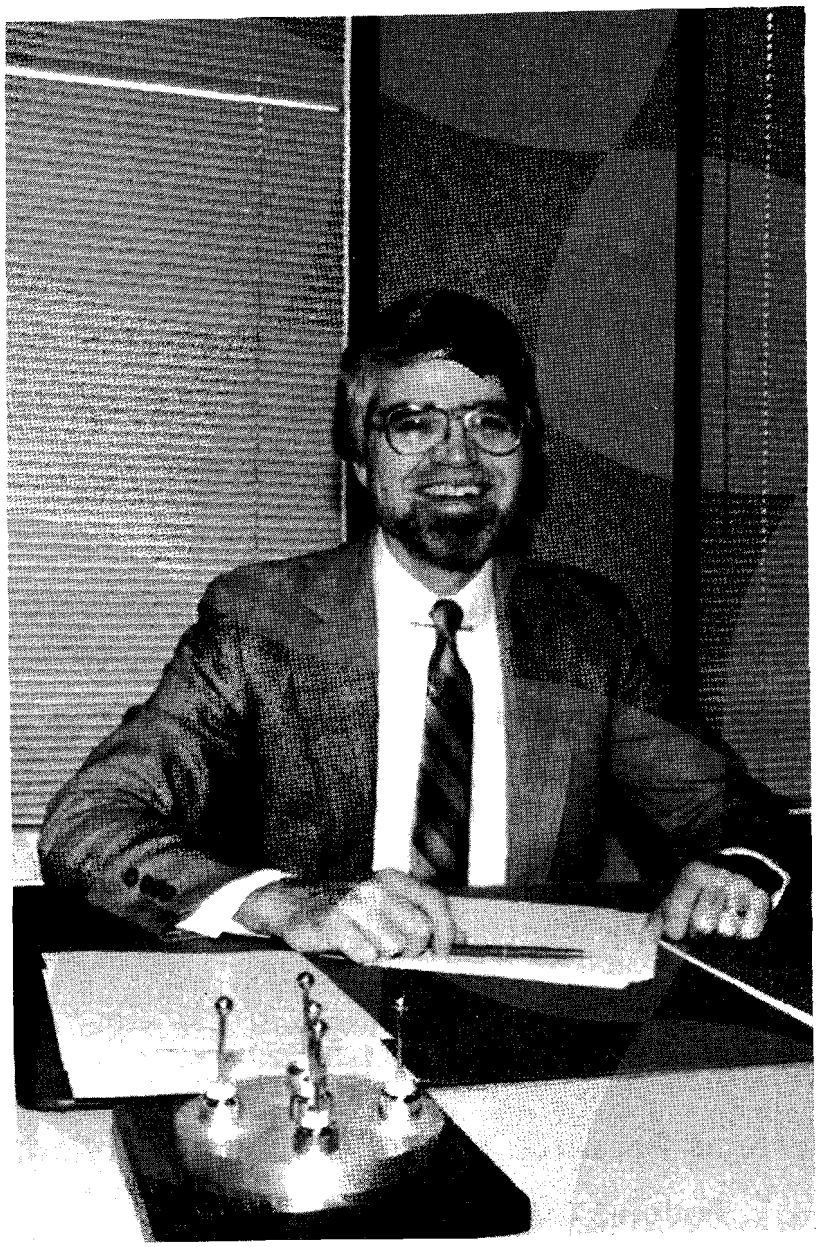
CY 84 RBX Units Commissioned (If Necessary)

IN SUMMARY, TO ACHIEVE THE OBJECTIVE, WE MUST FIRST COMPLETE THE VALIDATION OF THE ACTIVE BCAS CONCEPT. DOCUMENTATION OF THE ONGOING R&D EFFORT MUST BE PROVIDED TO THE OPERATIONAL SERVICES AND BE FOUND TO SUPPORT THE IMPLEMENTATION OF ACTIVE BCAS. THE AGENCY MUST INCLUDE IN ITS R&D THE EVALUATION OF THE CONTRIBUTIONS OF ANGLE OF ARRIVAL INFORMATION AND OF TRAFFIC PROXIMITY INFORMATION TO THE IMPLEMENTABILITY OF ACTIVE BCAS.

WE MUST ALSO COMPLETE THE OPERATIONAL TESTS AND EVALUATIONS NECESSARY TO ASSURE OURSELVES THAT WE CAN IN FACT IMPLEMENT ACTIVE BCAS, AND TO PROVIDE THE INFORMATION NECESSARY TO PROCEED WITH THE CERTIFICATION AND IMPLEMENTATION OF ACTIVE BCAS.

AS YOU WILL SEE AND HEAR AT THIS CONFERENCE, THE DEVELOPMENT OF A USEFUL COLLISION AVOIDANCE SYSTEM IS IN HAND. WE IN THE FAA ARE PARTICULARLY CONCERNED, HOWEVER, THAT WE AS A COMMUNITY MUST RECOGNIZE THE VERY GREAT EFFORT YET REQUIRED TO IMPLEMENT A SATISFACTORY COLLISION AVOIDANCE SYSTEM IN A TIMELY FASHION. IT IS IMPORTANT THAT INDUSTRY RECOGNIZE THE ISSUES THAT REMAIN TO BE RESOLVED. WE INVITE YOU TO PARTICIPATE IN THE APPROPRIATE FORUMS TO ASSIST IN COMPLETING THE WORK REMAINING.

THANK YOU VERY MUCH



Dr. Clyde Miller

Chief, Separation Systems Branch
Communications and Surveillance Division
Systems Research and Development Service
Federal Aviation Administration

TECHNICAL PERFORMANCE OF ACTIVE BCAS

Technical Performance of Active BCAS

January 1981

Systems Research and Development Service

Federal Aviation Administration

TECHNICAL PERFORMANCE OF ACTIVE BCAS

DR. CLYDE A. MILLER

I. TECHNICAL PERFORMANCE OF ACTIVE BCAS

THE PURPOSE OF MY TALK IS TO DESCRIBE THE TECHNICAL PERFORMANCE OF ACTIVE BCAS AS WE KNOW IT TODAY. THE DISCUSSION FOCUSES ON PERFORMANCE IN QUANTITATIVE ENGINEERING TERMS AS DIFFERENTIATED FROM THE OPERATIONAL POINT OF VIEW WHICH IS THE SUBJECT OF THE NEXT TALK.

THROUGHOUT 1980, THE FEDERAL AVIATION ADMINISTRATION'S PROGRAM FOR THE DEVELOPMENT OF ACTIVE BCAS HAS INTENSIVELY EVALUATED THE PERFORMANCE OF THIS CONCEPT. THESE EVALUATIONS WERE A CONTINUATION OF SIMILAR AND RELATED EFFORTS THAT WERE INITIATED IN THE MID 1970'S TO ASSESS THE PERFORMANCE OF THE FIRST GENERATION ACTIVE BCAS EQUIPMENTS DESIGNED BY MITRE CORPORATION. THE EQUIPMENTS EVALUATED DURING L980 WERE BASED ON A SECOND GENERATION ACTIVE BCAS DESIGN PROVIDED IN PART BY MASSACHUSETTS INSTITUTE OF TECHNOLOGY LINCOLN LABORATORY AND IN PART BY MITRE CORPORATION.

WHILE OUR EVALUATIONS ARE NOT YET COMPLETE, IT IS POSSIBLE, BASED ON OUR WORK THUS FAR, TO PROVIDE A REASONABLY COMPREHENSIVE DESCRIPTION OF ACTIVE BCAS PERFORMANCE. FROM THE PERSPECTIVE OF THE ENGINEERING DEVELOPMENT COMMUNITY WITHIN THE FEDERAL AVIATION ADMINISTRATION, THE PERFORMANCE PICTURE WHICH HAS EMERGED IS VERY ENCOURAGING, AND WE HAVE REASON TO BELIEVE THAT THE AGENCY IS WELL ON ITS WAY TO PROVIDING THE FIRST ELEMENT OF A NATIONALLY STANDARDIZED AIRBORNE COLLISION AVOIDANCE CAPABILITY.

Measures of Technical Performance

- **Protection (Separation) in Hazardous Encounters**
- **Alert Rate in Normal Traffic**

2. MEASURES OF TECHNICAL PERFORMANCE

THE PRINCIPAL MEASURES OF TECHNICAL PERFORMANCE THAT ARE GERMANE TO MY TALK ARE THE ABILITY OF ACTIVE BCAS TO PROVIDE SAFE SEPARATION IN HAZARDOUS MIDAIR ENCOUNTERS, AND THE RATE AT WHICH ACTIVE BCAS GENERATES ALERTS IN NORMAL TRAFFIC OPERATIONS.

FOR ALL PRACTICAL PURPOSES, ACTIVE BCAS IS A BACK-SEAT DRIVER. IT MONITORS THE POSITIONS OF AIRCRAFT IN THE VICINITY OF THE BCAS-EQUIPPED AIRCRAFT, AND GENERATES PILOT ALERTS, WHICH RECOMMEND AIRCRAFT MANEUVERS FOR CONFLICT RESOLUTION, WHENEVER A HAZARDOUS ENCOUNTER IS DETECTED. ANY BACK-SEAT DRIVER THAT IS TO BE VALUED AND APPRECIATED BY PILOTS AND AIR TRAFFIC CONTROLLERS MUST PROVIDE A VIABLE TRADEOFF BETWEEN ITS ABILITY TO RESOLVE HAZARDOUS ENCOUNTERS AND ITS TENDENCY TO GENERATE ALERTS IN TRAFFIC FREE OF REAL CONFLICTS.

MY TALK IS LARGELY A DISCUSSION OF THE STATUS OF OUR ACTIVE BCAS DESIGN IN TERMS OF THE BALANCE THAT HAS BEEN ACHIEVED BETWEEN COLLISION PROTECTION AND ALERT RATES.

3. OBJECTIVES OF TECHNICAL PERFORMANCE EVALUATIONS

THE OBJECTIVES OF THE TECHNICAL EVALUATIONS THAT I WILL DISCUSS HAVE BEEN THREE-FOLD. AS A FIRST STEP, THE EVALUATIONS ARE UNDERTAKEN TO ASSESS THE PERFORMANCE OF ACTIVE BCAS IN THE TERMS THAT I HAVE DESCRIBED. THESE ASSESSMENTS LEAD TO THE IDENTIFICATION OF SHORTFALLS - ASPECTS OF PERFORMANCE THAT ARE CANDIDATES FOR IMPROVEMENTS. THESE SHORTFALLS, IN TURN, STIMULATE DESIGN MODIFICATIONS WHICH ARE THEN SUBJECTED TO NEW EVALUATIONS.

Objectives of Technical Performance Evaluations

- Assess System Performance
- Identify Performance Shortfalls
- Evaluate System Modifications

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THE CYCLE OF PERFORMANCE ASSESSMENTS, FOLLOWED BY DESIGN ENHANCEMENTS, FOLLOWED BY NEW ASSESSMENTS IS ONGOING IN THE ACTIVE BCAS PROGRAM. IT BEGAN WITH THE EARLY FEASIBILITY EQUIPMENTS AT MITRE CORPORATION, CONTINUES IN OUR EVALUATIONS OF THE LINCOLN LABORATORY EQUIPMENTS, AND WILL NOT END UNTIL WE HAVE COMPLETED OUR EVALUATIONS OF THE DALMO VICTOR EQUIPMENTS ON IN-SERVICE AIR CARRIER AIRCRAFT UNDER THE GUIDANCE OF ARINC RESEARCH CORPORATION.

4. PERFORMANCE EVALUATION TECHNIQUES (FLIGHT TEST)

THE TWO PRINCIPAL TECHNIQUES THAT HAVE BEEN EMPLOYED IN EVALUATING ACTIVE BCAS ARE FLIGHT TESTING AND COMPUTER SIMULATION STUDIES. FLIGHT TESTING, WHILE EXPENSIVE AND TIME COMSUMING, PROVIDES AN OPPORTUNITY TO ASSESS PERFORMANCE IN THE REAL-WORLD ENVIRONMENT.

TWO DISTINCTLY DIFFERENT TYPES OF FLIGHT TESTS HAVE BEEN CONDUCTED IN THE 225 HOURS OF TESTING TO DATE. INTENTIONAL CLOSE ENCOUNTER FLIGHTS INVOLVE FLYING TEST AIRCRAFT ON COLLISION OR NEAR-COLLISION COURSES IN ORDER TO DETERMINE THE EXTENT TO WHICH ACTIVE BCAS CAN RESOLVE THESE HAZARDOUS CONFLICTS. LITERRALLY HUNDREDS OF CLOSE ENCOUNTERS HAVE BEEN FLOWN AT THE FAA TECHNICAL CENTER IN ATLANTIC CITY, NEW JERSEY. ADDITIONAL ENCOUNTERS HAVE BEEN FLOWN IN THE LOS ANGELES, WASHINGTON AND NEW YORK HUBS IN ORDER TO ASCERTAIN WHETHER OR NOT THE SIGNAL INTERFERENCE CHARACTERISTIC OF THOSE ENVIRONMENTS DEGRADES THE ABILITY OF ACTIVE BCAS TO PROVIDE RESOLUTIONS.

Performance Evaluation Techniques

Flight Tests

- Intentional Close Encounters:
  - FAA Technical Center
  - Natural Environments
    - Los Angeles
    - Washington, D.C.
    - New York
- Flights in Normal Traffic
  - FAA Test Aircraft
  - Operational Air Carrier Aircraft

TEST FLIGHTS ARE ALSO CONDUCTED IN NORMAL TRAFFIC--TRAFFIC PRESUMABLY FREE OF CONFLICTS. THE OBJECTIVE HERE IS TO ASSESS THE ALERT RATE IN SUCH ENVIRONMENTS, AND TO UNDERSTAND THE OPERATIONAL CIRCUMSTANCES THAT LEAD TO BCAS ALERTS. I WILL DESCRIBE SOME RESULTS FROM A 126-HOUR TOUR OF THE DOMESTIC AIRSPACE CONDUCTED BY THE TECHNICAL CENTER'S BOEING 727 TEST AIRCRAFT. OUR PROGRAM FOR EVALUATING THE DALMO VICTOR ACTIVE BCAS UNITS ON IN-SERVICE AIR CARRIER AIRCRAFT WILL PROVIDE A WEALTH OF ADDITIONAL INFORMATION IN THIS AREA.

5. PERFORMANCE EVALUATION TECHNIQUES (SIMULATION STUDIES)

COMPUTER SIMULATION IS RELATIVELY INEXPENSIVE, AND PROVIDES AN OPPORTUNITY TO EXHAUSTIVELY STUDY SPECIFIC ASPECTS OF SYSTEM OPERATION UNDER CONTROLLED CONDITIONS. MOREOVER, IT IS STRAIGHTFORWARD TO SIMULATE SITUATIONS IMPOSSIBLE TO ESTABLISH IN THE REAL WORLD. FOR EXAMPLE, WE HAVE SIMULATED THE OPERATION OF THE ENTIRE HOUSTON HUB AIRSPACE UNDER THE CONDITION THAT ALL OF THE AIRCRAFT IN THAT AIRSPACE ARE EQUIPPED WITH ACTIVE BCAS.

OUR SIMULATION STUDIES HAVE BEEN OF TWO TYPES--NON-REAL TIME SIMULATIONS IN WHICH THERE IS NO MAN IN THE LOOP, AND REAL TIME SIMULATIONS THAT HAVE INCLUDED HUMAN OPERATORS--EITHER PILOTS OR AIR TRAFFIC CONTROLLERS.

THE MONTE CARLO NON-REAL TIME SIMULATIONS ARE USED TO ANALYZE THE ABILITY OF ACTIVE BCAS TO RESOLVE ENCOUNTERS INVOLVING ONE OR TWO INTRUDERS. WE HAVE USED THIS TECHNIQUE TO

Performance Evaluation Techniques

Simulation Tests

- Non-Real Time (Unmanned):
  - Monte Carlo:
    - 15 Midairs
    - Hypothetical Encounters
  - Analysis of ARTS Data:
    - Houston
    - Philadelphia, Washington (Broste)
- Real Time (Manned):
  - Controller Interface
  - Pilot Interface (Morgenstern)

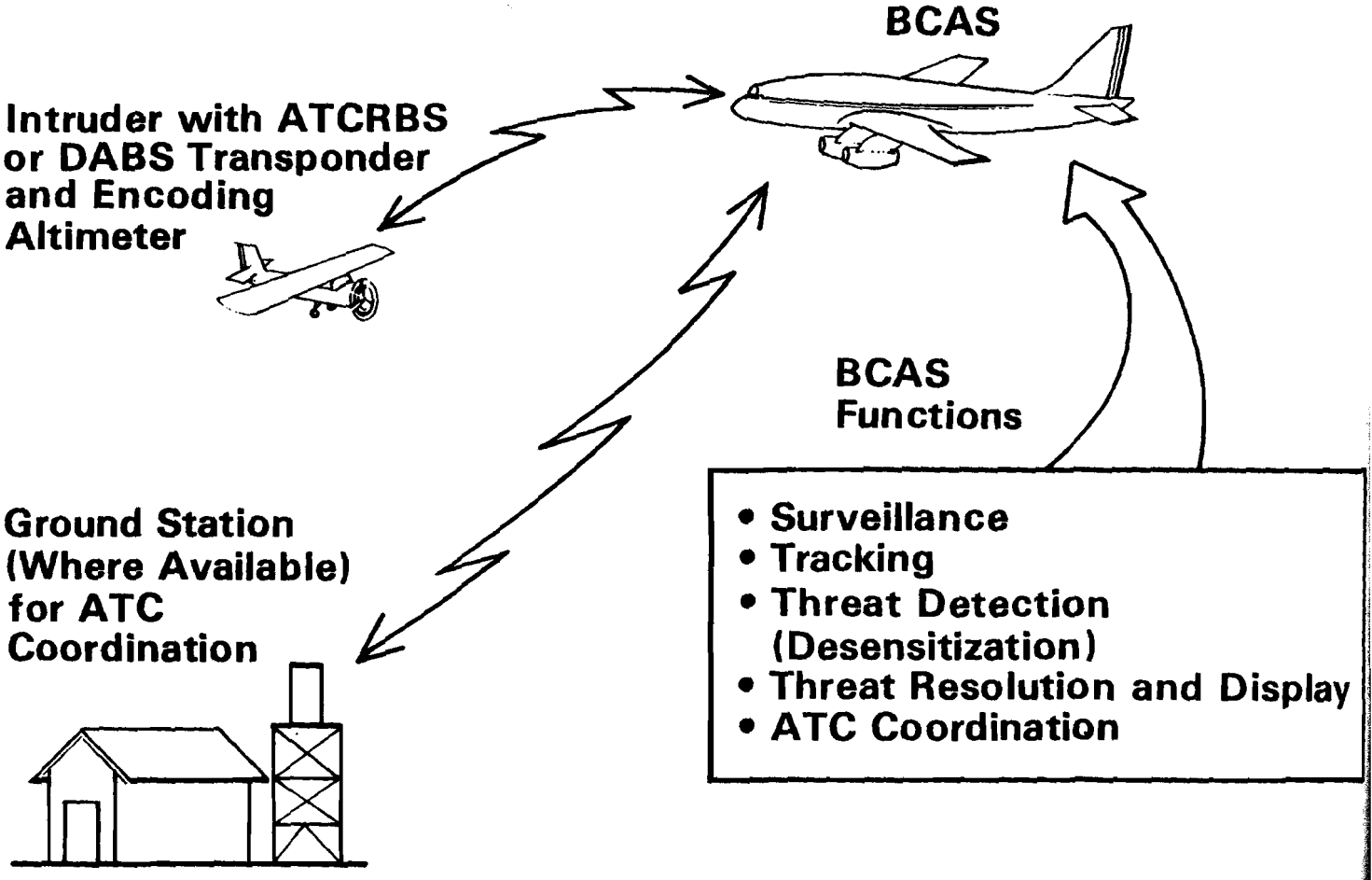
5

ASSESS THE PROTECTION THAT BCAS WOULD HAVE PROVIDED IN 15 ACTUAL MIDAIR COLLISIONS INVOLVING AIR CARRIER AIRCRAFT. IN ADDITION, THE RESOLUTION PERFORMANCE OF ACTIVE BCAS HAS BEEN EVALUATED IN MORE THAN 5000 HYPOTHETICAL ENCOUNTERS SIMULATED AT THE TECHNICAL CENTER.

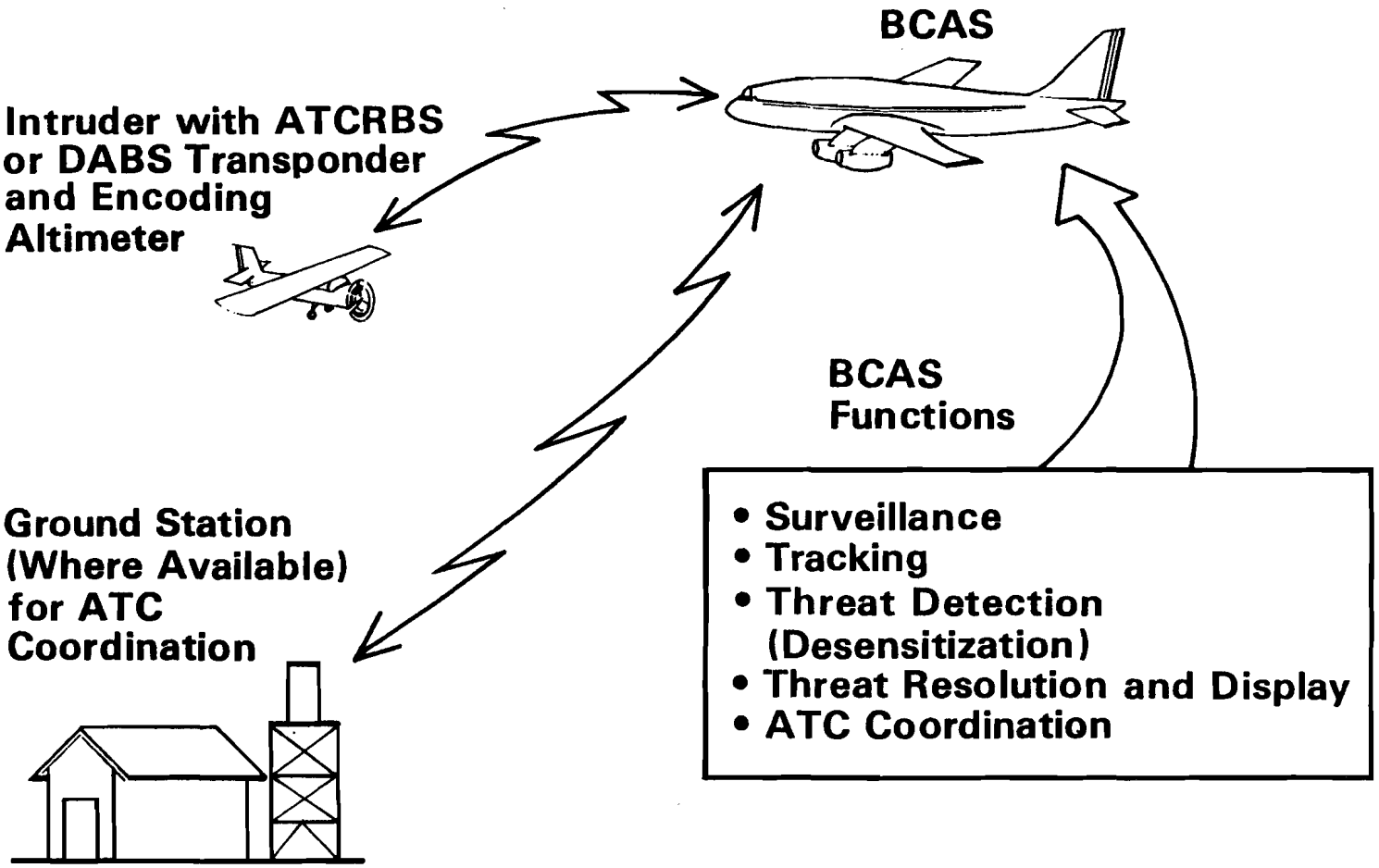
NON-REAL TIME SIMULATION HAS ALSO BEEN USED TO ANALYZE BCAS ALERTS IN TODAY'S TRAFFIC ENVIRONMENT. THE EXISTING AIR TRAFFIC CONTROL SYSTEM UTILIZES ARTS GROUND COMPUTERS THAT RECEIVE SURVEILLANCE DATA FROM RADARS, AND PROCESS THESE DATA FOR DISPLAY TO AIR TRAFFIC CONTROLLERS. IT IS POSSIBLE TO EXTRACT THESE SURVEILLANCE DATA ON MAGNETIC TAPE, AND THEN TO ANALYZE BCAS ALERTS UNDER THE CONDITION THAT ALL OF THE AIRCRAFT REPRESENTED BY THE SURVEILLANCE DATA ARE BCAS EQUIPPED. SUCH STUDIES HAVE BEEN CONDUCTED USING ARTS DATA FROM HOUSTON, PHILADELPHIA AND WASHINGTON, D.C. I WILL DESCRIBE SOME OF THE RESULTS OF THE HOUSTON STUDY. THE PHILADELPHIA AND WASHINGTON, D.C. RESULTS ARE SOMEWHAT DATED, BUT ARE AVAILABLE IN THE BROSTE REPORT LISTED IN YOUR BIBLIOGRAPHY FOR THOSE THAT MAY BE INTERESTED.

OUR REAL TIME SIMULATIONS OF THE CONTROLLER INTERFACE WITH ACTIVE BCAS HAVE BEEN CONDUCTED AT THE FAA TECHNICAL CENTER. HERE THE COMPUTER GENERATES A CONTROLLER DISPLAY OF SIMULATED TERMINAL AREA TRAFFIC WHICH REALISTICALLY RESPONDS TO CLEARANCES ISSUED BY THE CONTROLLERS. THE OPERATION OF ACTIVE

Active BCAS Concept



Active BCAS Concept



BCAS IS ACCURATELY PORTRAYED SO THAT THE RATE OF ALERTS, AND THE CIRCUMSTANCES UNDER WHICH ALERTS OCCUR CAN BE ANALYZED. I WILL DESCRIBE SOME RESULTS FROM A SIMULATION OF THE KNOXVILLE AIRSPACE.

FINALLY, WE HAVE USED THE UNITED AIRLINES BOEING 727 SIMULATOR AT DENVER TO STUDY THE IMPACT OF ACTIVE BCAS ON FLIGHT CREWS. THIS STUDY IS DESCRIBED BY THE MORGENSTERN REPORT IN YOUR BIBLIOGRAPHY AS WELL AS THE ARINC RESEARCH CORPORATION VIDEO TAPE AVAILABLE FOR VIEWING IN THE EXHIBIT ROOM.

6. ACTIVE BCAS CONCEPT

BEFORE DESCRIBING THE RESULTS OF OUR TECHNICAL EVALUATIONS, I NEED TO SAY A FEW THINGS ABOUT THE OPERATION OF ACTIVE BCAS. ACTIVE BCAS IS INTENDED TO PROVIDE A VIABLE SEPARATION ASSURANCE SERVICE IN LOW AND MEDIUM DENSITY AIRSPACE, THAT IS, IN DENSITIES IMPLYING 6 TO 9 AIRCRAFT WITHIN 10 NMI OF THE ACTIVE BCAS AIRCRAFT, OR SAID ANOTHER WAY, IN DENSITIES OF 0.02 TO 0.03 AIRCRAFT PER SQUARE NAUTICAL MILE.

IN ORDER TO PROVIDE SEPARATION ASSURANCE, THE ACTIVE BCAS AIRBORNE EQUIPMENT MUST PERFORM FIVE DISTINCT FUNCTIONS. THE FIRST OF THESE IS SURVEILLANCE, OR DETERMINING THE RANGES AND ALTITUDES OF NEARBY AIRCRAFT. SURVEILLANCE IS ACCOMPLISHED BY TRANSMITTING RADIO SIGNALS WHICH ELICIT REPLIES FROM EITHER THE ATCRBS AIR TRAFFIC CONTROL TRANSPONDER CURRENTLY CARRIED ON LARGE NUMBERS OF DOMESTIC AIRCRAFTS OR FROM THE DABS TRANSPONDER

PLANNED FOR THE FUTURE. GIVEN RANGE AND ALTITUDE DATA ON PROXIMATE AIRCRAFT, THE TRACKING FUNCTION TRACKS, OR EXTRAPOLATES, THIS INFORMATION SO THAT THE FUTURE POSITIONS OF THESE AIRCRAFT CAN BE ESTIMATED. THE TRACKED POSITIONS OF PROXIMATE AIRCRAFT ARE SCANNED BY THE THREAT DETECTION FUNCTION TO DETERMINE WHICH AIRCRAFT ARE POTENTIAL COLLISION THREATS. THE THREAT RESOLUTION FUNCTION THEN SELECTS AND DISPLAYS A RESOLUTION ADVISORY, OR RECOMMENDED MANEUVER, FOR RESOLVING THESE COLLISION THREATS. FINALLY, THE AIR TRAFFIC CONTROL COORDINATION FUNCTION ASSURES THAT ANY RESOLUTION ADVISORY DISPLAYED TO THE PILOT CAN BE TRANSMITTED TO THE GROUND FOR DISPLAY TO THE APPROPRIATE AIR TRAFFIC CONTROLLER.

THE THREAT DETECTION FUNCTION REQUIRES ADDITIONAL EXPLANATION. IN THE SPARSE HIGH ALTITUDE AIRSPACE, AN AIRCRAFT THAT IS WITHIN 30 SECONDS OF THE POSITION OF THE BCAS AIRCRAFT MIGHT BE CONSIDERED A COLLISION THREAT. NORMAL SEPARATIONS IN THIS AIRSPACE ARE LARGE ENOUGH THAT A 30-SECOND THREAT CRITERION WILL GENERATE VERY FEW DISTRACTING ALERTS. HOWEVER, IN RELATIVELY DENSE TERMINAL TRAFFIC, THE 30-SECOND CRITERION CAN BE EXPECTED TO GENERATE A LARGE NUMBER OF NUISANCE ALERTS. HENCE, IN DENSE TERMINAL TRAFFIC, IT IS NECESSARY TO REDUCE THE SENSITIVITY OF THE THREAT DETECTION FUNCTION SO THAT, FOR EXAMPLE, ALERTS ARE GENERATED ONLY FOR THOSE AIRCRAFT WITHIN 20 SECONDS OF THE BCAS AIRCRAFT POSITION. WHILE THIS DESCRIPTION OVER-SIMPLIFIES THE LOGIC USED BY THE THREAT DETECTION FUNCTION, IT POINTS OUT THE NEED TO DESENSITIZE ACTIVE BCAS TO MAKE

Protection Performance: Non-Real Time Simulations (Billman, 80-125)

- **Scope** — Approximately 5000 Single-Intruder Encounters
- **Assumptions** — Error-Free Surveillance
- **Results**
  - Adequate Separation in Straight-Line Encounters
  - Abrupt Vertical Accelerations by Unequipped Intruders Degrade Protection
  - Abrupt Horizontal Accelerations by Intruders are Less Troublesome

IT MORE TOLERANT OF PROXIMATE AIRCRAFT WHEN THE BCAS AIRCRAFT FLIES INTO MORE DENSE AIRSPACE. THE U. S. NATIONAL AVIATION STANDARD FOR ACTIVE BCAS DEFINES SEVEN DISTINCT LEVELS OF SENSITIVITY WHICH CAN BE SELECTED AUTOMATICALLY UNDER GROUND CONTROL, AUTOMATICALLY BASED ON OWN AIRCRAFT PARAMETERS SUCH AS RADAR ALTITUDE, OR MANUALLY BY THE PILOT.

FINALLY, I SHOULD MENTION THAT ACTIVE BCAS HAS THE ABILITY TO DISPLAY PROXIMITY WARNING INFORMATION IN THE COCKPIT IN THE FORM OF THE RANGE, ALTITUDE, AND BEARING OF EACH NEARBY AIRCRAFT. THIS INFORMATION DOES NOT, IN ITSELF, TELL THE PILOT HOW TO AVOID COLLISIONS BUT IT DOES ALERT THE PILOT TO NEARBY AIRCRAFT THEREBY DISCOURAGING PILOT MANEUVERS THAT CAN RESULT IN CONFLICTS.

7. PROTECTION PERFORMANCE: NON-REAL TIME SIMULATION (BILLMAN)

I WILL BEGIN THE DESCRIPTION OF ACTIVE BCAS PERFORMANCE BY DISCUSSING ITS ABILITY TO RESOLVE HAZARDOUS ENCOUNTERS. ONE TECHNICAL CENTER MONTE CARLO SIMULATION STUDY ANALYZED THE ABILITY OF ACTIVE BCAS TO RESOLVE 5000 SINGLE-INTRUDER ENCOUNTERS. IN THIS STUDY, IT WAS ASSUMED THAT THE SURVEILLANCE SYSTEM WORKED PERFECTLY IN ORDER TO FOCUS ON THE TRACKING, THREAT DETECTION AND THREAT RESOLUTION FUNCTIONS.

ENCOUNTERS SIMULATED INCLUDED AIRCRAFT CLIMBING AND DESCENDING AT CONSTANT VERTICAL RATES RANGING FROM 500 FPM TO 4000 FPM. IN ADDITION, ENCOUNTERS INVOLVING HORIZONTAL AND VERTICAL TURNS WERE EVALUATED.

Protection Performance: Non-Real Time Simulation (Zarrelli)

- **Scope** — Analysis of 15 Midairs:
  - Randomized Initial Conditions
  - Surveillance Errors (Range and Altitude)
  - Randomized Aircraft Response Parameters
- **Assumptions** — BCAS Desensitized Per Location of Collision
- **Results** — With Both Aircraft Equipped and No Random Effects, 13 Midairs Resolved:
  - St Louis Midair too Close to Airport
  - Carmel, NY Midair Had Abrupt Vertical Maneuver

  — With Intruder Unequipped and Random Effects, Some Encounters Not Resolved:
  - Vertical Maneuvers by Intruder
  - Vertical Tracker Errors
  - Surveillance Errors (Altitude)

RESOLUTION OF ENCOUNTERS INVOLVING FIXED CLIMB/DESCENT RATES WAS UNIFORMILY SATISFACTORY. ACTIVE BCAS GENERATED RESOLUTION ADVISORIES IN TIME TO PROVIDE ADEQUATE VERTICAL SEPARATION AT THE TIME OF CLOSEST APPROACH.

SOME ENCOUNTERS INVOLVING ABRUPT VERTICAL MANEUVERS BY UNEQUIPPED INTRUDERS CLOSE BY IN ALTITUDE WERE NOT ADEQUATELY RESOLVED. SUCH ENCOUNTERS PROVIDE INADEQUATE TIME FOR BCAS RESOLUTION. I WILL SHOW YOU AN EXAMPLE IN A MINUTE.

ENCOUNTERS INVOLVING ABRUPT HORIZONTAL MANEUVERS ARE LESS TROUBLESOME THAN THOSE WITH VERTICAL MANEUVERS BECAUSE THE INITIAL SEPARATIONS ARE GENERALLY LARGE IN THE HORIZONTAL PLANE. BCAS THEREFORE, HAS MORE TIME TO PROVIDE RESOLUTION.

THE RESULTS OF THIS STUDY WITH REGARD TO RESOLUTION OF ENCOUNTERS WITH FIXED CLIMB AND DESCENT RATES WERE VERY ENCOURAGING. THE LIMITATIONS WITH REGARD TO INTRUDERS MANEUVERING IN THE VERTICAL DIRECTION PROMPTED US TO IMPROVE THE DESIGN OF OUR VERTICAL TRACKER.

8. PROTECTION PERFORMANCE: NON-REAL TIME SIMULATION (ZARRELLI)

THE ZARRELLI MONTE CARLO SIMULATION STUDY ANALYZED THE ABILITY OF ACTIVE BCAS TO RESOLVE 15 ACTUAL MIDAIR COLLISIONS UNDER CONDITIONS THAT INCLUDED ERRORS IN SURVEILLANCE DATA AND VARIATIONS IN THE ACCELERATIONS AND VERTICAL RATES USED BY THE ACTIVE BCAS AIRCRAFT IN RESPONDING TO RESOLUTION ADVISORIES. IN THE STUDY OF EACH ACCIDENT, THE BCAS THREAT DETECTION FUNCTION WAS DESENSITIZED IN ACCORDANCE WITH THE DISTANCE OF

THE COLLISION FROM THE NEAREST TERMINAL AND THE DESENSITIZATION RULES FORMULATED BY THE ZARRELLI HOUSTON STUDY FOR CONTROLLING ALERT RATES. (I WILL TELL YOU ABOUT THE HOUSTON STUDY IN A FEW MINUTES.) THOSE COLLISIONS WHICH OCCURRED CLOSE TO TERMINALS WERE SIMULATED WITH A DESENSITIZED THREAT DETECTION FUNCTION WHILE THOSE THAT OCCURRED IN SPARSE EN ROUTE AIRSPACE WERE ANALYZED WITH THE THREAT DETECTION FUNCTION AT FULL SENSITIVITY.

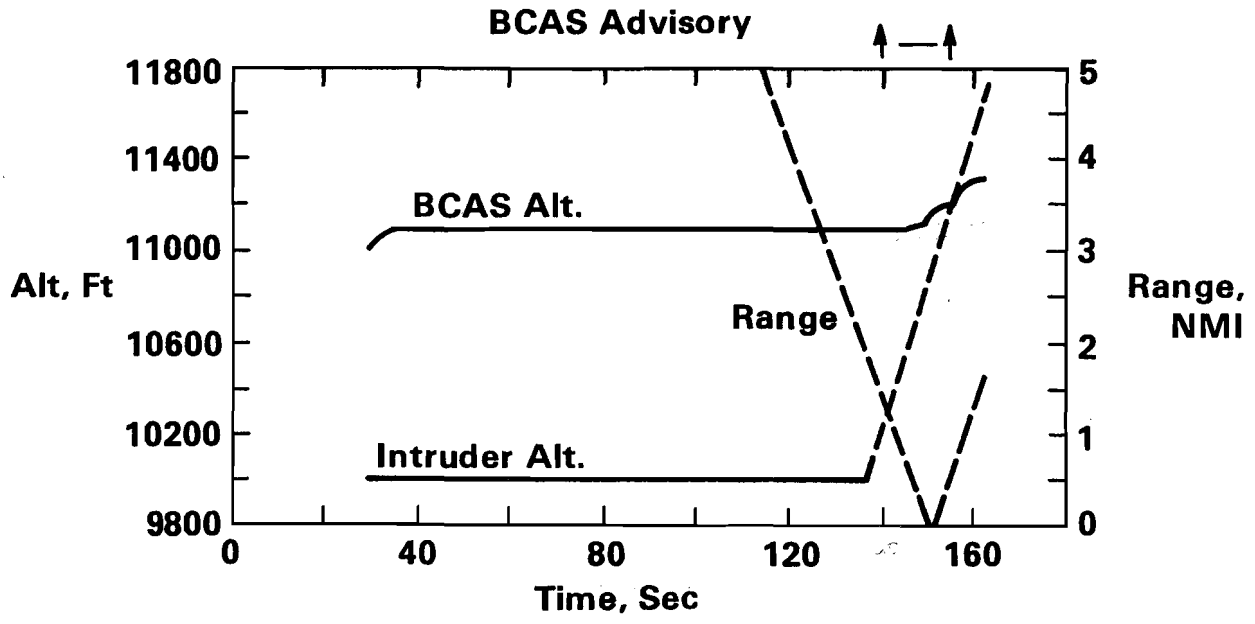
THE ST LOUIS MIDAIR OCCURRED SO CLOSE TO THE AIRPORT THAT THE HOUSTON DESENSITIZATION RULES WOULD HAVE INHIBITED BCAS RESOLUTION. IF BCAS HAD NOT BEEN INHIBITED, AND BOTH AIRCRAFT INVOLVED IN THE ACCIDENT HAD BEEN EQUIPPED WITH BCAS UNITS NOT DEGRADED BY RANDOM EFFECTS, BCAS WOULD HAVE PROVIDED RESOLUTION WITH 250 FEET OF VERTICAL SEAPARTION AT CLOSEST APPROACH.

THE CARMEL, NY MIDAIR INVOLVED AN ABRUPT VERTICAL MANEUVER BY THE INTRUDER 12 SECONDS PRIOR TO THE COLLISION. THIS ACCIDENT WAS NOT RESOLVABLE BY ANY PRACTICAL COLLISION AVOIDANCE SYSTEM AS I WILL SHOW YOU IN A MOMENT.

THE REMAINING 13 MIDAIR COLLISIONS WOULD HAVE BEEN PREVENTED BY ACTIVE BCAS HAD BOTH AIRCRAFT BEEN EQUIPPED WITH UNITS NOT DEGRADED BY RANDOM EFFECTS. THE MINIMUM VERTICAL SEPARATION AT CLOSEST APPROACH WOULD HAVE BEEN 260 FEET.

IF IT IS ASSUMED THAT ONLY ONE OF THE AIRCRAFT IN EACH ENCOUNTER WAS EQUIPPED WITH BCAS, AND THE RANDOM EFFECTS WERE OPERATIVE, THE PROBABILITY OF RESOLVING THE 13 MIDAIRS IS 95%. THAT IS, THERE IS A 5% CHANCE THAT THE SEPARATION AT CLOSEST APPROACH WOULD HAVE BEEN LESS THAN 100 FEET AT THE SAME TIME THE HORIZONTAL SEPARATION WAS LESS THAN 1000 FEET.

Intruder Vertical Maneuver — Carmel, N.Y. Midair (Zarrelli)



Conclude: 12 Seconds From Intruder Pull-up to Impact, Insufficient for BCAS Resolution.

II

THE PRINCIPAL FACTORS THAT CONTRIBUTED TO RESOLUTION DIFFICULTIES WERE VERTICALLY MANEUVERING INTRUDERS, LESS THAN OPTIMAL VERTICAL TRACKER PERFORMANCE AND ALTITUDE ERRORS IN SURVEILLANCE DATA.

9. INTRUDER VERTICAL MANEUVER

THIS SLIDE SHOWS A GRAPH OF THE CARMEL MIDAIR COLLISION UNDER THE ASSUMPTION THAT ONLY ONE AIRCRAFT IS EQUIPPED WITH ACTIVE BCAS. THE ALTITUDES OF THE BCAS AND INTRUDER AIRCRAFT CAN BE READ FROM THE VERTICAL SCALE ON THE LEFT SIDE OF THE CHART WHILE THE RANGE OF THE INTRUDER FROM THE BCAS AIRCRAFT CAN BE READ FROM THE SCALE ON THE RIGHT. THE HORIZONTAL AXIS SHOWS TIME.

ON THE GRAPH, THE COLLISION OCCURS WHERE THE RANGE GOES TO ZERO AT A TIME OF 150 SECONDS. AT 138 SECONDS, 12 SECONDS PRIOR TO THE COLLISION, THE INTRUDER ABRUPTLY INITIATES A CLIMB OF 4,000 FPM FROM AN ALTITUDE 1100 FEET BELOW THE BCAS AIRCRAFT. TWO SECONDS LATER AT 140 SECONDS ON THE GRAPH, BCAS GENERATES A CLIMB ADVISORY AND THE BCAS AIRCRAFT, AFTER A PILOT DELAY OF 5 SECONDS OR SO, BEGINS ITS CLIMB AT A TIME OF 145 SECONDS. THE 5 SECONDS AVAILABLE TO THE BCAS AIRCRAFT TO MANEUVER OUT OF THE WAY IS INSUFFICIENT TO RESOLVE THE CONFLICT.

THE CARMEL ACCIDENT IS A CASE OF INSUFFICIENT TIME BEING AVAILABLE FOR RESOLUTION. IT IS INTERESTING TO NOTE THAT HAD THE INTRUDER BEEN EQUIPPED WITH AN ACTIVE BCAS UNIT THAT INCLUDED A PROXIMITY WARNING FUNCTION IN ACCORDANCE WITH OUR

Protection Performance: Flight Tests With Intentional Encounters (Preliminary Data)

- Scope — 240 BCAS Unit Encounters:

Airspace	BCAS Sorties			
	Unequipped Intruders		BCAS Intruders	
	ATCRBS	DABS	ATCRBS	DABS
Atlantic City	105	24	7	6
Washington, DC	5	0	0	0
New York	16★	16	0	0
Los Angeles	16★	0	16	0

★ Diversity ATCRBS Transponders

- Assumptions — None

I2

CURRENT DESIGN, THE INTRUDER WOULD HAVE HAD THE POSITION OF THE HIGHER ALTITUDE AIRCRAFT ON HIS DISPLAY, AND MAY HAVE KNOWN BETTER THAN TO INITIATE THE VERTICAL MANEUVER WHICH CAUSED THE ACCIDENT.

I0. PROTECTION PERFORMANCE: FLIGHT TESTS (I OF 2)

CONTINUING WITH OUR EVALUATIONS OF THE PROTECTION PERFORMANCE OF ACTIVE BCAS, THIS SLIDE SHOWS THE SCOPE OF THE ENCOUNTER FLIGHT TESTING TO DATE. SINCE FEBRUARY OF LAST YEAR, THE TECHNICAL CENTER HAS CONDUCTED 370 ENCOUNTER FLIGHTS OF WHICH THE 240 FLOWN SINCE JULY PROVIDE A DATA BASE OF CURRENT RESULTS. MOST OF THESE ENCOUNTERS WERE A MATTER OF FLYING A BCAS TEST AIRCRAFT AGAINST A SINGLE INTRUDER EQUIPPED EITHER WITH AN ATCRBS TRANSPONDER OR WITH A DABS TRANSPONDER. IN SOME OF THE ENCOUNTERS, THERE WERE TWO BCAS TEST AIRCRAFT OPERATING INDEPENDENTLY AND EQUIPPED WITH ONE OR THE OTHER TYPE OF TRANSPONDER. THE FLIGHTS WITH TWO BCAS TEST AIRCRAFT PROVIDED AN OPPORTUNITY TO MAKE TWO TEST RUNS WITH A SINGLE ENCOUNTER FLIGHT.

2 indep BCAS

THE TEST FLIGHTS IN THE ATLANTIC CITY AREA HAVE INCLUDED A VARIETY OF ENCOUNTER GEOMETRIES TO INCLUDE HORIZONTALLY AND VERTICALLY MANEUVERING INTRUDERS AS WELL AS ENCOUNTERS WITH VARIOUS FIXED RATES OF CLIMB AND DESCENT. FORTY-EIGHT OF THE ATLANTIC CITY ENCOUNTERS WERE THREE-AIRCRAFT CONFLICTS WITH BCAS PROVIDING RESOLUTION FOR TWO SIMULTANEOUS INTRUDERS.

Protection Performance: Flight Tests With Intentional Encounters (Preliminary Data)

- Results — Resolution Advisories in Correct Directions

  — Alert Times:

Airspace	BCAS Sorties			
	Unequipped Intruders		BCAS Intruders	
	ATCRBS	DABS	ATCRBS	DABS
Atlantic City	All Alerts Timely			
Washington, DC	Timely	--	--	--
New York	Timely	★	--	--
Los Angeles	3/16 Late	--	★	--

★ Analyses Incomplete

I3

THE FLIGHT TESTS IN THE LOS ANGELES AND NEW YORK HUBS ENCOUNTERED LOCAL TRAFFIC DENSITIES IN EXCESS OF THOSE FOR WHICH ACTIVE BCAS IS DESIGNED. DENSITIES AS HIGH AS 0.04 AIRCRAFT PER SQUARE NAUTICAL MILE, WHICH CORRESPONDS TO I2 AIRCRAFT WITHIN A IO NMI RADIUS, WERE ENCOUNTERED. AT THE SAME TIME, FRUIT RATES EXCESSED 25,000 REPLIES PER SECOND.

ONE CORRECTION IS REQUIRED TO THIS SLIDE. THE ASTERICK ON THE I6 NEW YORK ATCRBS ENCOUNTERS SHOULD BE DELETED. THESE ENCOUNTERS WERE CONDUCTED WITH THE INTRUDER EQUIPPED WITH A STANDARD ATCRBS TRANSPONDER WITH ONLY A BOTTOM-MOUNTED ANTENNA.

II. PROTECTION PEFORMANCE: FLIGHT TESTS (2 OF 2)

OUR ANALYZES OF THESE ENCOUNTER FLIGHTS ARE NOT COMPLETE. HOWEVER, FROM THE DATA THAT HAS BEEN ANALYZED, AND FROM THE OBSERVATION OF THE EQUIPMENT DURING THE TEST FLIGHTS, IT APPEARS AS THOUGH RESOLUTION ADVISORIES WERE RECEIVED AT THE PROPER TIMES IN THE ENCOUNTERS, AND THAT THESE ADVISORIES INDICATED THE CORRECT DIRECTIONS FOR THE BCAS AIRCRAFT TO MOVE IN ORDER TO RESOLVE THE ENCOUNTERS.

AT THE MOMENT, THE LOS ANGELES TESTS PROVIDE THE ONLY EXCEPTION TO THIS GENERAL CONCLUSION. IN THE DENSE LOS ANGELES AIRSPACE, THERE WERE THREE INSTANCES OF LATE ALARMS DURING THE I6 ENCOUNTERS WITH ATCRBS INTRUDERS. ONE OF THESE ALARMS OCCURRED I5 SECONDS LATE (AT IO SECONDS PRIOR TO CLOSEST

Protection Performance: Flight Tests in Normal Traffic (Tornese)

- **Scope**
  - 37 Hour Evaluation at 28 Airports in 18 Cities
  - 89 Hours En Route
- **Assumptions**
  - None
- **Results**
  - 11 Unplanned Alerts Above 500 Ft AGL
  - 10 Advisories in Correct Direction
  - 1 Advisory Ineffective; Corrected by New Vertical Tracker

APPROACH INSTEAD OF AT 25 SECONDS) AND TWO ALARMS OCCURRED 6 SECONDS LATE. THESE LATE ALARMS MAY REPRESENT A CHARACTERISTIC DEGRADATION OF ACTIVE BCAS PERFORMANCE IN DENSE AIRSPACE OF THE TYPE FOUND IN LOS ANGELES TODAY. ADDITIONAL TESTING IN THE LOS ANGELES AREA WILL BE CONDUCTED DURING I98L.

WE WERE PLEASANTLY SURPRISED WITH THE PRELIMINARY RESULTS FROM THE NEW YORK AREA WHICH INDICATED TIMELY ALERTS IN THAT DENSE AIRSPACE. WE HAD EXPECTED TO SEE SOME DEGRADATION OF ACTIVE BCAS PERFORMANCE SIMILAR TO THE LOS ANGELES RESULTS.

A CORRECTION IS REQUIRED TO THIS SLIDE ALSO. THE ASTERIK OPPOSITE NEW YORK IN THE DABS COLUMN SHOULD BE DELETED AND THE WORK "TIMELY" SUBSTITUTED. OUR ANALYSIS OF DABS ALERTS IN THE NEW YORK AIRSPACE INDICATES THAT ALL ALERTS WERE RECEIVED ON TIME.

I2. PROTECTION PERFORMANCE: FLIGHT TESTS IN NORMAL TRAFFIC

THE LAST WORD ON PROTECTION PERFORMANCE COMES FROM A I26-HOUR TOUR OF THE DOMESTIC AIRSPACE FLOWN IN THE TECHNICAL CENTER BOEING 727 TEST AIRCRAFT THAT IS AVAILABLE FOR YOUR INSPECTION THIS AFTERNOON. THIS TOUR PROVIDED 37 HOURS OF OPERATION IN SOME OF THE MOST DENSE AIRSPACE AVAILABLE, TO INCLUDE LOS ANGELES, NEW YORK, CHICAGO, ATLANTA, SAN FRANCISCO, WASHINGTON, D.C., DALLAS AND DENVER.

DURING THE TOUR, II UNPLANNED ALERTS WERE RECORDED WHILE THE BCAS AIRCRAFT WAS MORE THAN 500 FEET ABOVE GROUND LEVEL. IN IO OF THESE II ENCOUNTERS, THE RESOLUTION ADVISORY WAS IN

Alert Rates: Non-Real Time Simulations (Zarrelli)

- **Scope** – Analysis of 65 Hours of Peak Houston Area Mode C Traffic (1600 A/C-Hrs of ARTS Data)

- **Assumptions**
  - All Aircraft BCAS Equipped
  - BCAS Desensitized Per Prescribed Maps

- **Results**
  - 64 Climb/Descend Alerts in 65 Hours
  - Per Aircraft Alerts 1 in 12 Hours:
    - 1 in 19 Hours for ATC Code A/C
    - 1 in 4 Hours for VFR Code A/C

THE CORRECT DIRECTION FOR RESOLVING THE CONFLICT. IN ONE ENCOUNTER, WHICH INVOLVED A VERTICALLY MANEUVERING INTRUDER, THE RESOLUTION ADVISORY WOULD NOT HAVE CAUSED THE BCAS AIRCRAFT TO MOVE AWAY FROM THE INTRUDER. WHEN THIS ENCOUNTER WAS REEVALUATED USING A NEWLY DEVELOPED VERTICAL TRACKER DESIGN, THE RESOLUTION ADVISORY DID PROVIDE EFFECTIVE RESOLUTION.

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MY SUMMARY OF THESE PROTECTION RESULTS IS AS FOLLOWS:

(I) WE CAN BE CONFIDENT OF OUR ABILITY TO RESOLVE ENCOUNTERS IN WHICH THE INTRUDER IS NOT MANEUVERING IN THE VERTICAL PLANE. THIS PERFORMANCE HAS BEEN DEMONSTRATED BOTH BY SIMULATION AND BY FLIGHT TEST.

level-overs

(2) VERTICALLY MANEUVERING INTRUDERS ARE MORE DIFFICULT TO RESOLVE, AND WE NEED TO EVALUATE AND REFINE OUR NEW VERTICAL TRACKER DESIGN IN ORDER TO OPTIMIZE PERFORMANCE IN THIS AREA.

(3) IN TERMS OF THE ACTUAL MIDAIR COLLISIONS THAT WE HAVE ANALYZED, WITH CARMEL AND ST LOUIS ASIDE, ACTIVE BCAS IS 95% EFFECTIVE IN PROVIDING RESOLUTION.

I3. ALERT RATES: NON-REAL TIME SIMULATIONS

TURNING NOW TO ALERT RATES, I MENTIONED EARLIER A ZARRELLI STUDY OF HOUSTON HUB TRAFFIC. THIS STUDY ANALYZED 65 HOURS OF MODE C TRAFFIC RECORDED, FOR THE MOST PART, DURING PEAK TRAFFIC PERIODS. ALTOGETHER, THE I600 AIRCRAFT HOURS OF DATA CORRESPOND TO AN AVERAGE OF 25 AIRCRAFT WITHIN 50 NMI OF THE HOUSTON RADAR. THE SIMULATION ASSUMED THAT ALL AIRCRAFT WERE EQUIPPED WITH ACTIVE BCAS.

Alert Rates: Real Time Simulation (Adkins)

- **Scope** — 16 Hour ATC Simulation of Knoxville Terminal (280 A/C-Hrs of Data)
- **Assumptions**
  - 1985 Traffic (0.02 A/C Per Sq NMI)
  - IFR/VFR Mix with Overflights
  - All Aircraft BCAS Equipped
  - Dated Version of Logic
- **Results**
  - 12 Alerts in 16 Hours
  - Per Aircraft Alerts 1 in 11 Hours
  - Air Carrier Alerts 1 in 42 Operations

I6

THE OBJECTIVE OF THE STUDY WAS TO DEFINE SPECIFIC DESENSITIZATION RULES, OR MAPS, TO BE APPLIED TO THE THREE PRINCIPAL AIRPORTS IN THE HUB IN ORDER TO EFFECTIVELY CONTROL THE BCAS ALERT RATE IN THE DENSE REGIONS OF HOUSTON AIRSPACE WITHOUT UNNECESSARILY DEPRIVING BCAS AIRCRAFT OF THEIR COLLISION PROTECTION. THE EXTENT TO WHICH BCAS RETAINED AN ABILITY TO PROTECT AGAINST COLLISIONS IS REFLECTED IN THE ANALYSIS OF THE I5 ACTUAL MIDAIR COLLISIONS THAT I DISCUSSED EARLIER.

WITH ALL AIRCRAFT IN THE HOUSTON HUB BCAS EQUIPPED, AND OPERATING IN ACCORDANCE WITH THE SPECIFIED DESENSITIZATION MAPS, THERE WERE 64 ALERTS, IN THE 65 HOURS OF DATA, INSTRUCTING PILOTS TO EITHER CLIMB OR TO DESCEND. ON THE AVERAGE, AN AIRCRAFT WOULD RECEIVE ONE SUCH ALERT IN I2 HOURS OF OPERATION IN THE PEAK-HOUR HOUSTON AIRSPACE. AN IFR AIRCRAFT WITH A DISCRETE ATC CODE WOULD RECEIVE ONE ALERT EVERY I9 HOURS. IF THE AVERAGE IFR AIRCRAFT SPENDS 20 MINUTES IN THE HOUSTON AIRSPACE IN THE COURSE OF AN ARRIVAL OR DEPARTURE, THE IFR ALERT RATE CAN BE STATED AS I ADVISORY TO CLIMB OR DESCEND IN EVERY 57 OPERATIONS IN THE PEAK-HOUR HOUSTON AIRSPACE.

I4. ALERT RATES: REAL TIME SIMULATION

A SECOND ELEMENT OF ALERT RATE DATA COMES FROM A SIMULATION OF THE KNOXVILLE TERMINAL ENVIRONMENT WHEREIN AIR TRAFFIC CONTROLLERS CONTROLLED TRAFFIC IN REAL TIME ON COMPUTER

Alert Rates: Flight Tests in Normal Traffic (Tornese)

- Scope
  - 37 Hour Evaluation at 28 Airports in 18 Cities
  - 89 Hours En Route
- Assumptions
  - Desensitization Not "Optimized"
- Results
  - All Alerts Associated with Real Aircraft
  - 11 Unplanned Alerts Above 500 Ft AGL:
    - 1 Alert in 89 Hours En Route
    - 10 Alerts in 37 Hours of Close-in Terminal Operations
  - No Alerts in Some Dense Terminal Areas:
    - Chicago O'Hare
    - Atlanta
    - Los Angeles
    - Washington, D.C.

I7

GENERATED DISPLAYS. THE TRAFFIC VOLUME WAS PURPOSELY INCREASED TO PROVIDE THE 0.02 AIRCRAFT PER SQUARE NAUTICAL DENSITY ASSOCIATED WITH ACTIVE BCAS OPERATION. AS IN THE HOUSTON SIMULATION, IT WAS ASSUMED THAT ALL AIRCRAFT WERE BCAS EQUIPPED.

THE I6 HOURS OF SIMULATION PRODUCED I2 ALERTS THAT REQUIRED MODIFICATION OF AIRCRAFT FLIGHT PATHS, AND ANOTHER I9 ALERTS THAT DID NOT REQUIRE FLIGHT PATH DEVIATIONS. AIR CARRIER AIRCRAFT IN THIS STUDY RECEIVED I ALERT REQUIRING A FLIGHT PATH DEVIATION IN EVERY 42 OPERATIONS IN THE KNOXVILLE PEAK-HOUR TRAFFIC ENVIRONMENT.

I5. ALERT RATES: FLIGHT TESTS IN NORMAL TRAFFIC

THE FINAL BIT OF DATA ON ALERT RATES COMES FROM THE I26-HOUR TOUR OF THE DOMESTIC AIRSPACE THAT I DESCRIBED EARLIER. THESE FLIGHTS WERE NOT CONDUCTED WITH DESENSITIZATION RULES CAREFULLY TAILORED TO THE INDIVIDUAL TERMINAL AREAS. IN FACT, SOME FLIGHTS WERE MADE INTO DENSE TERMINAL ENVIRONMENTS WITH THE SENSITIVITY LEVEL PURPOSELY SET HIGH IN ORDER TO SEE WHAT THE RESULTS WOULD BE. HENCE, THE TERMINAL AREA ALERT RATES SUGGESTED BY THESE RESULTS ARE NOT REPRESENTATIVE OF AN OPERATIONAL SYSTEM.

NONETHELESS, SOME INTERESTING RESULTS ARE AVAILABLE FROM THE TOUR. IN THE 89 HOURS OF OPERATION IN EN ROUTE AIRSPACE, THERE WAS ONLY L ALERT WHICH SUGGESTS A VERY LOW ALERT RATE IN THIS REGIME AS WE HAD EXPECTED. A SECOND INTERESTING

OBSERVATION IS THAT THERE WERE NO ALERTS AT CHICAGO O'HARE, ATLANTA AND LOS ANGELES, THE THREE BUSIEST AIR CARRIER AIRPORTS IN THE NATION, WHILE DENVER, WHICH RANKS NINTH, PROVIDED FOUR ALERTS. THERE IS AN IMPLICATION THAT THE ALERT RATE DEPENDS AS MUCH ON THE STRUCTURE OF THE TRAFFIC FLOW AS ON THE TOTAL VOLUME OF TRAFFIC.

TO SUMMARIZE OUR ALERT RATE STUDIES, THE HOUSTON AND KNOXVILLE RESULTS INDICATE THAT IFR TRAFFIC MIGHT EXPRIENCE I ALERT IN EVERY 50 PEAK-HOUR OPERATIONS WHEN BCAS SENSITIVITY LEVELS ARE ESTABLISHED AS NOW ENVISIONED. VFR AIRCRAFT EQUIPPED WITH ACTIVE BCAS WOULD EXPERIENCE A SUBSTANTIALLY HIGH ALERT RATE.

A QUESTION REMAINS AS TO WHETHER THIS ALERT RATE IS TOO HIGH OR TOO LOW - TOO LOW IN THE SENSE THAT MORE DESENSITIZATION IS BEING USED THAN IS NECESSARY. SOME EFFORT HAS BEEN APPLIED TO ASSESS THE IMPACTS OF ACTIVE BCAS ALERTS ON AIR TRAFFIC CONTROLLERS AND FLIGHT CREWS. THE CONTROLLERS WHO PARTICIPATED IN THE KNOXVILLE SIMULATION FELT THAT THE ACTIVE BCAS ALERTS THEY EXPERIENCED HAD NO ADVERSE IMPACT ON THE ATC ENVIRONMENT OR THEIR CONTROL PROCEDURES. MOREOVER, PILOTS WHO PARTICIPATED IN THE ARINC RESEARCH SIMULATION STUDY AT UNITED DID NOT ALWAYS OBJECT TO, AND SOMETIMES APPRECIATED, ALERTS THAT REINFORCED WHAT THEY ALREADY KNEW ABOUT THEIR ENVIRONMENT. A SIMILAR PHENOMENON OCCURRED DURING OUR I26-HOUR TOUR IN THE BOEING 727. OF THE SEVEN ALERTS THAT WOULD HAVE

Summary

- Technical Evaluations Have Been Extensive
- Collision Protection Appears Effective
- Alarm Rate in Normal Traffic Appears Reasonable
- Evaluations Will Continue Into 1982

I9

REQUIRED DEVIATIONS FROM THE EXISTING FLIGHT PATH, TWO REINFORCED EXISTING ATC INSTRUCTIONS. WHILE IT IS CLEAR THAT NOT ALL ALERTS ARE GOOD ALERTS, IT IS ALSO CLEAR THAT NOT ALL ALERTS ARE BAD ALERTS.

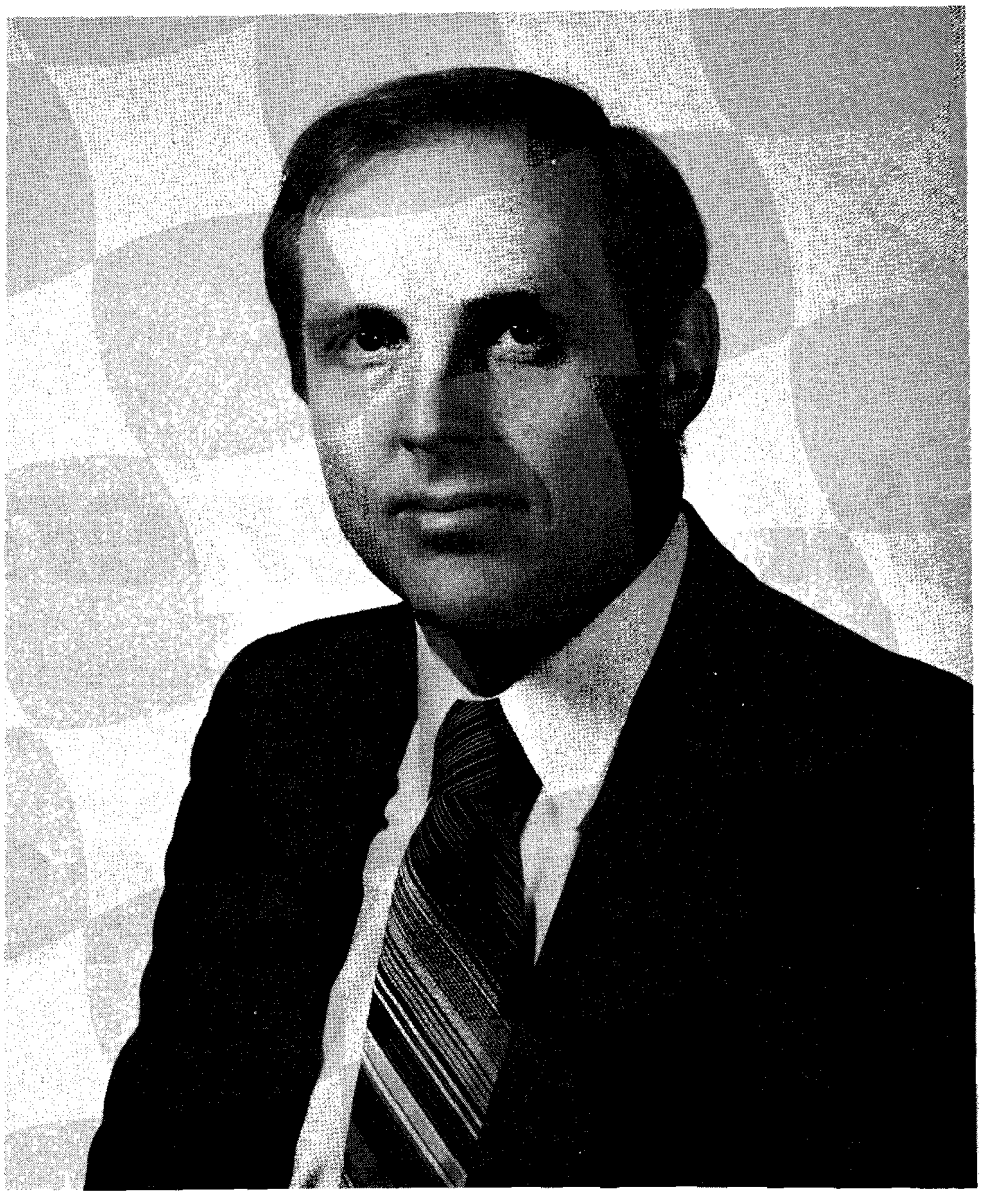
THIS SUMMER WE WILL BE CONDUCTING ANOTHER TOUR OF THE DOMESTIC AIRSPACE. THE FOCUS OF THIS ACTIVITY WILL BE A REFINED ASSESSMENT OF ALERT RATES THAT WILL INCLUDE ANALYZES OF THE IMPACTS OF ALERTS ON FLIGHT CREWS. THIS WORK, AND THE IN-SERVICE EVALUATION USING THE DALMO VICTOR UNITS, WILL BETTER DEFINE THE DESENSITIZATION RULES APPROPRIATE FOR OPERATIONAL UNITS.

I6. SUMMARY

IT IS FAIR TO SAY THAT OUR TECHNICAL EVALUATIONS OF ACTIVE BCAS HAVE BEEN EXTENSIVE. RESULTS TO DATE INDICATE THAT A HIGH LEVEL OF PROTECTION FROM MIDAIR COLLISIONS CAN BE PROVIDED. IN TERMS OF THE I3 ACTUAL MIDAIR COLLISIONS THAT I DISCUSSED, ACTIVE BCAS IS 95% EFFECTIVE IN PROVIDING RESOLUTION. IN ADDITION, THE ALERT RATE APPEARS TO BE WITHIN REASONABLE BOUNDS. THE KNOXVILLE AND HOUSTON STUDIES INDICATE THAT I FLIGHT PATH DEVIATION MIGHT OCCUR IN EVERY 50 AIR CARRIER OPERATIONS DURING PEAK-HOUR TRAFFIC. MOREOVER, KNOXVILLE RESULTS SUGGEST THAT THESE ALERTS WOULD HAVE LITTLE OR NO IMPACT ON ATC OPERATIONS.

20

AND FINALLY, I WILL FINISH AS I STARTED BY TELLING YOU THAT OUR EVALUATIONS OF ACTIVE BCAS ARE NOT COMPLETED. THIS SUMMER WE WILL BE FLYING AN ENHANCED VERSION OF ACTIVE BCAS THAT INCLUDES A PROXIMITY WARNING CAPABILITY. WE WILL LEARN MORE ABOUT ALERT RATES, MORE ABOUT DESENSITIZATION, AND MORE ABOUT THE IMPACT OF ACTIVE BCAS ON FLIGHT CREWS. THIS WORK WILL BE FOLLOWED BY THE EVALUATION OF ACTIVE BCAS ON IN-SERVICE AIR CARRIER AIRCRAFT, AN ACTIVITY SCHEDULED TO CONTINUE INTO THE EARLY PART OF 1982.



Malcolm A. Burgess

Flight Technical Programs Branch
Office of Flight Operations
Federal Aviation Administration

OPERATIONAL PERFORMANCE OF ACTIVE BCAS

Flight Experience With Active BCAS

FLIGHT EXPERIENCE

WITH

ACTIVE BCAS

MR. M. BURGESS

GOOD AFTERNOON

I HAVE RECENTLY PARTICIPATED AS A PILOT OF THE FAA BOEING 727 FLIGHT TEST AIRCRAFT IN TESTS OF THE ACTIVE BCAS EXPERIMENTAL SYSTEM IN AN OPERATIONAL ENVIRONMENT. I WOULD LIKE TO PROVIDE FOR YOU AN OVERVIEW OF THAT WORK AND OUTLINE FOR YOU WHERE WE, IN THE OFFICE OF FLIGHT OPERATIONS OF THE FAA, FEEL THE ACTIVE BCAS PROGRAM IS TODAY WITH RESPECT TO IMPLEMENTATION.

THE OBJECTIVE OF THE SERIES OF FLIGHTS I WILL DESCRIBE WAS TO PROVIDE A FIRST LOOK - A VERY PRELIMINARY EVALUATION - OF ACTIVE BCAS PERFORMANCE IN AN OPERATIONAL ENVIRONMENT. THIS WAS A LOOK AT ACTIVE BCAS AS IT WAS AVAILABLE IN THE FORM OF THE BASIC EXPERIMENTAL UNIT PROVIDED BY MIT LINCOLN LABORATORY. IT WAS OUR INTENT TO (1) CONFIRM THAT THE ACTIVE BCAS CONCEPT AND THE SUPPORTING ALGORITHMS WERE ON THE RIGHT TRACK, AND (2) TO IDENTIFY ISSUES REQUIRING FURTHER ATTENTION BEFORE ACTIVE BCAS COULD BE IMPLEMENTED.

Objectives of Preliminary Operational Evaluation of Active BCAS

- Confirm Active BCAS Concept and Algorithms on Right Track
- Identify Issues Requiring Further Attention Before Implementation

I WOULD CAUTION YOU IN THE USE OF THE RESULTS OF THESE TESTS. THESE TESTS CANNOT TAKE THE PLACE OF MORE DEFINITIVE ENGINEERING FLIGHT TESTS OF THE ACTIVE BCAS LOGIC AND OF ITS ALGORITHMS USING PLANNED ENCOUNTERS. ONE CANNOT SAFELY EXPLORE MANY OF THE DETAILS OF THE LOGIC IN A VERY LIMITED TEST SUCH AS THE ONE WE CONDUCTED.

LIKEWISE, THE VERY LIMITED NATURE OF OUR TESTS WOULD NOT PERMIT ONE TO MAKE ANY DEFINITIVE DETERMINATION OF MISSED ALARM OR FALSE ALARM RATES. OUR LIMITED EXPOSURE TO THE TRAFFIC OF THE TERMINAL AREAS IN WHICH WE FLEW WAS INSUFFICIENT TO SUPPORT ANY STATISTICAL STUDY OF SYSTEM PERFORMANCE.

WE HAVE FLOWN THE ACTIVE BCAS EXPERIMENTAL UNIT INTO 28 MAJOR AIRPORTS IN THESE MAJOR TERMINAL AREAS. I WAS AN ACTIVE PARTICIPANT IN THE FLIGHT CONDUCTED IN 13 OF THESE TERMINAL AREAS. WE FLEW AN AVERAGE OF 6 APPROACHES IN EACH OF THE TERMINAL AREAS TO EITHER A FULL STOP LANDING OR TO A VERY LOW APPROACH AND GO-AROUND. IN EACH TERMINAL AREA WE ENDEAVORED TO PERFORM THE APPROACHES AND LANDINGS DURING THE PEAK TRAFFIC PERIODS-AND IN SUCH A MANNER AS TO DUPLICATE AS CLOSELY AS WE COULD THE NORMAL ARRIVAL AND DEPARTURE TRAFFIC PATTERNS OF THE AIR CARRIERS. AT THE SAME TIME WE FLEW THE NORMAL APPROACHES AND DEPARTURES THAT ARE KNOWN TO HAVE THE HIGHEST EXPOSURE TO THE MORE COMPLEX ARRIVAL AND DEPARTURE TRAFFIC STREAMS. ALTHOUGH AT SOME LOCATIONS WE DID PERFORM LOW APPROACHES WITH TRANSITION TO TYPICAL DEPARTURE ROUTES, WE DID NOT PERFORM DELIBERATE BLUNDERS OR OTHERWISE SETUP UNUSUAL SITUATIONS THAT SOMETIMES OCCUR IN THE COURSE OF NORMAL OPERATIONS.

Terminal Areas In Which Active BCAS Flown

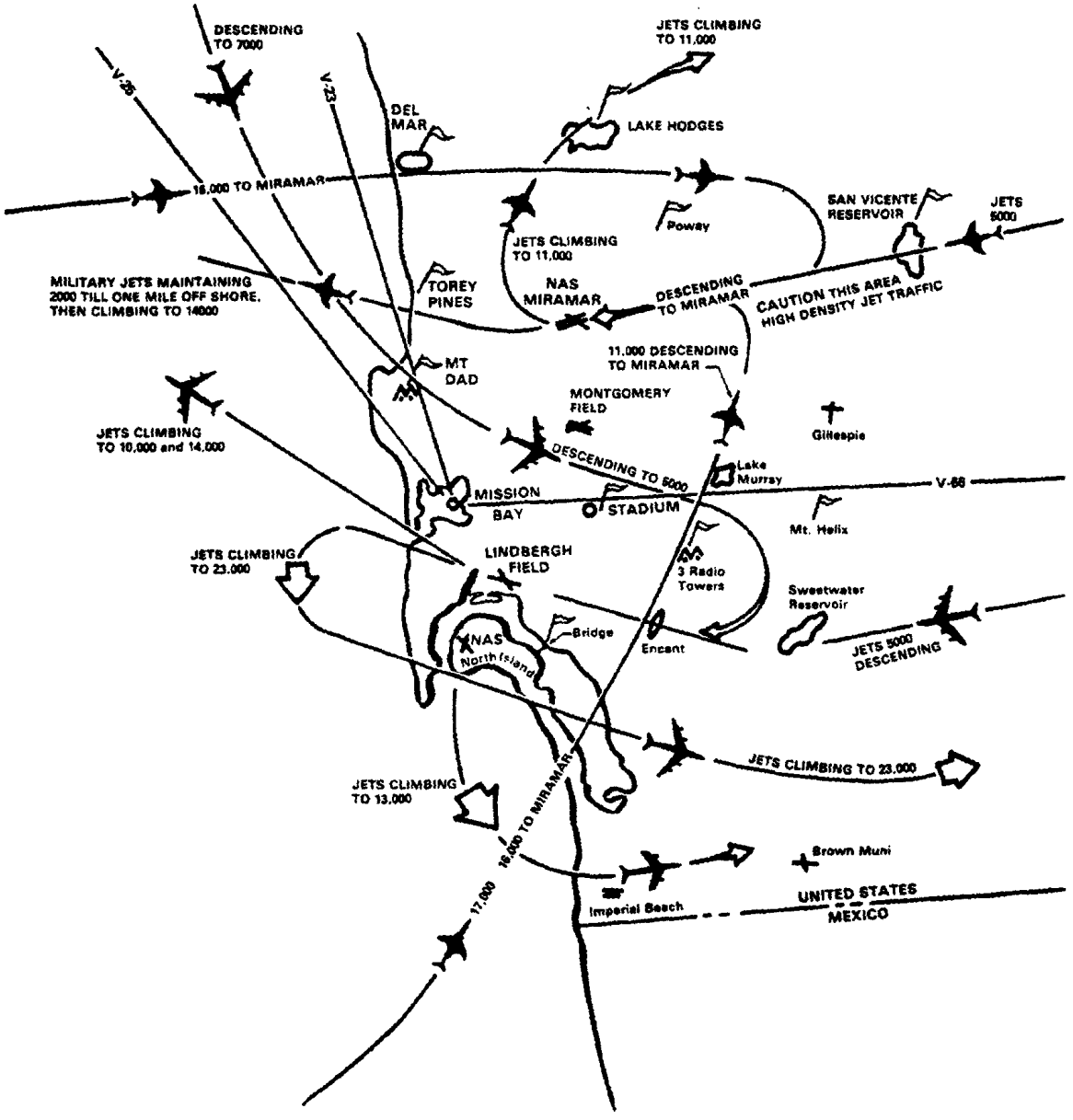
Dallas/Fort Worth
Houston
Denver
Salt Lake City
Los Angeles
San Diego
Seattle
San Francisco/Oakland

Washington
Baltimore
New York
Atlanta
Miami
Kansas City
Chicago
Philadelphia

PRIOR TO FLIGHT IN EACH OF THE TERMINAL AREAS, WE SAT DOWN IN A PLANNING SESSION WITH THE TOWER SUPERVISORS, APPROACH CONTROL SUPERVISOR, AND AIR TRAFFIC CONTROL OPERATIONS AND PROCEDURES SPECIALISTS TO ESTABLISH A COURSE OF ACTION. WE DESCRIBED FOR THESE PEOPLE THE OBJECTIVES OF OUR TESTS AND THE CHARACTERISTICS OF ACTIVE BCAS THAT WERE OF INTEREST TO THEM. (SLIDE 4) THEY, IN TURN, DESCRIBED FOR US THE ARRIVAL AND DEPARTURE TRAFFIC CHARACTERISTICS OF THEIR PARTICULAR TERMINAL AREAS AND IDENTIFIED AREAS WHERE THEY FELT, ON THE BASIS OF THEIR EXPERIENCE, A COLLISION AVOIDANCE SYSTEM SHOULD BE TESTED. USING DIAGRAMS SIMILAR TO THE ONE SHOWN, WE DISCUSSED TYPICAL ALTITUDE SEPARATIONS AND AIRSPEEDS USED IN ARRIVALS AND DEPARTURES IN THAT AREA AS THEY MIGHT AFFECT THE ACTIVE BCAS. WE LOOKED, FOR EXAMPLE, AT THE PROCEDURES AND ROUTES USED TO MERGE TRAFFIC FROM DIFFERENT DIRECTIONS INTO THE VARIOUS FEEDER FIXES AND THEN AT THE WAY ARRIVALS FROM DIFFERENT FIXES ARE VECTORED TO THE RUNWAY. WE WERE PARTICULARLY INTERESTED, FOR EXAMPLE, IN SIMULTANEOUS APPROACHES IN VMC TO PARALLEL RUNWAYS WHERE THEY EXIST. WE LOOKED AT THE CHARACTERISTICS OF GENERAL AVIATION AND MILITARY TRAFFIC IN THE AREAS AND AT HOW THIS TRAFFIC IS SEPARATED FROM ARRIVING AND DEPARTING AIR CARRIER TRAFFIC. WE ALSO DISCUSSED TYPICAL PEAK TRAFFIC PERIODS TO ENSURE WE WERE IN THE AREAS OF INTEREST AT THE TIME OF HIGHEST TRAFFIC COUNTS.

FINALLY, AFTER WE FELT WE WERE SUFFICIENTLY FAMILIAR WITH THE TERMINAL AREA TRAFFIC CHARACTERISTICS, WE PROCEEDED TO ESTABLISH A SEQUENCE OF EVENTS BY WHICH WE COULD OPTIMIZE OUR LIMITED FLIGHT TIME IN THE AREA WITH RESPECT TO EXPOSURE OF THE ACTIVE BCAS SYSTEM TO THE MORE DEMANDING AREAS OF NORMAL OPERATIONS. WE WORKED OUT THE DETAILS OF ANY ATC CONSTRAINTS WE HAD TO OBSERVE, SUCH AS RESTRICTIONS ON MULTIPLE FULL STOP LANDINGS AND ON DEPARTURES OR LOW APPROACHES, AND ANY OTHER PROCEDURES NECESSARY TO SEQUENCE US WITH OTHER TRAFFIC.

Area and Normal IFR Traffic Flow



I WOULD LIKE TO ADD AT THIS POINT THAT THE COOPERATION AND SUPPORT PROVIDED US BY AIR TRAFFIC CONTROL WAS EXCELLENT. INVARIABLY THE SUPERVISORS, SPECIALISTS, AND CONTROLLERS WENT OUT OF THEIR WAY TO ACCOMMODATE US WHILE CONDUCTING THEIR NORMAL OPERATIONS IN A VERY PROFESSIONAL AND SAFE MANNER.

OUR AGREEMENT WITH AIR TRAFFIC CONTROL WAS THAT WE WERE TO BE PROVIDED NORMAL SEPARATION FROM OTHER TRAFFIC AT ALL TIMES IN COMPLETE ACCORD WITH ESTABLISHED PROCEDURES. WE ATTEMPTED TO FOLLOW THE NORMAL AIR CARRIER ARRIVAL AND DEPARTURE PROCEDURES AT ALL TIMES FROM TYPICAL ARRIVAL FIXES TO THE RUNWAY THRESHOLD AND FROM DEPARTURE OF THE RUNWAY TO SOME POINT ALONG THE DEPARTURE ROUTE CLEAR OF THE TERMINAL AREA.

OUR CREW IN THE COCKPIT CONSISTED OF A FULL-TIME FLIGHT ENGINEER PROVIDED BY THE FAA TECHNICAL CENTER, A SAFETY PILOT IN THE COPILOT'S POSITION PROVIDED BY THE FAA TECHNICAL CENTER, AND EITHER MYSELF OR ANOTHER FAA FLIGHT STANDARDS PILOT IN THE PILOT'S POSITION. THE TWO SAFETY PILOTS, BY THE WAY, WERE THE FAA PILOTS WHO ARE CONDUCTING THE ENGINEERING FLIGHT TESTS OF ACTIVE BCAS AT THE FAA TECHNICAL CENTER IN THE BOEING 727. TWO OF THE FLIGHT STANDARDS PILOTS WERE PROVIDED BY THE FAA AIRCRAFT EVALUATION GROUPS OF THE NORTHWEST AND WESTERN FAA REGIONS. A THIRD PILOT PARTICIPATING IN THE FLIGHTS WAS AN ENGINEERING TEST PILOT FROM THE SOUTHERN FAA REGION. THE CHIEF OF THE FLIGHT TECHNICAL PROGRAMS BRANCH OF THE OFFICE OF FLIGHT OPERATIONS OF FAA HEADQUARTERS ALSO PARTICIPATED. I FLEW APPROXIMATELY 25% OF THE APPROACHES THAT WERE FLOWN AND PARTICIPATED AS

AN OBSERVER IN THE JUMP SEAT IN MOST OF THE OTHER APPROACHES FLOWN. WE CONDUCTED APPROXIMATELY 129 APPROACHES AND DEPARTURES ALTOGETHER.

WE WERE SUPPORTED ON THE GROUND BY AN AIR TRAFFIC CONTROL SPECIALIST PROVIDED BY THE FAA TECHNICAL CENTER WHO WAS PRESENT AT ALL TIMES IN THE ATC FACILITY TO ASSURE OF NO CONFUSION IN THE FACILITY DURING OUR FLIGHT ACTIVITY. THIS TASK ALSO INCLUDED THE EVALUATION OF ANY INTERFACE WITH AIR TRAFFIC CONTROL THAT MAY BE REQUIRED FOR THE IMPLEMENTATION OF ACTIVE BCAS. WE WERE ALSO SUPPORTED IN FLIGHT BY A TEAM OF ENGINEERING SPECIALISTS FROM THE FAA TECHNICAL CENTER WHO PLANNED AND COORDINATED THESE FLIGHTS AND WHO OPERATED THE TEST INSTRUMENTATION ON BOARD THE AIRCRAFT.

THIS WAS THE ACTIVE BCAS BEU . . . .

IN ADDITION TO THE DATA COLLECTION AND TEST INSTRUMENTATION ON BOARD THE AIRCRAFT, WE WERE PROVIDED WITH THREE SEPARATE ACTIVE BCAS DISPLAYS. THE PRIMARY DISPLAY OF CONFLICT RESOLUTION ADVISORIES WAS SUPERIMPOSED ON THE PILOT'S INSTANTANEOUS VERTICAL SPEED INDICATOR - OR "IVSI." THE CRT DISPLAY OF ADDITIONAL TRAFFIC INFORMATION WAS LOCATED . . . .

THIS DISPLAY CONSISTED OF TWO ARROW-SHAPED CUTOUTS IN THE CENTER OF THE INSTRUMENT WHICH WOULD ILLUMINATE IN RED TO PROVIDE A POSITIVE ADVISORY TO CLIMB OR DESCEND. THE UPPER AND LOWER HALVES OF THE VERTICAL SPEED INDICATOR FACE

WERE ALSO MODIFIED WITH CUTOUTS TO PROVIDE "EYEBROWS" THAT ILLUMINATED IN YELLOW TO PROVIDE ADVISORIES TO "DON'T CLIMB," INDICATED BY ILLUMINATION OF UPPER EYEBROWS, AND "DON'T DESCEND," INDICATED BY ILLUMINATION OF THE LOWER EYEBROWS. AS YOU MAY BE ABLE TO DISTINGUISH FROM THE SLIDE, THE UPPER AND LOWER EYEBROWS WERE ALSO SEGMENTED SO THAT SELECTED SEGMENTS COULD BE ILLUMINATED TO PROVIDE VERTICAL SPEED LIMIT ADVISORIES. ILLUMINATION OF THE LOWER SEGMENT, FOR EXAMPLE, FROM THE MINUS 500 FEET PER MINUTE MARK ON THE IVSI ON AROUND TO THE 3 O'CLOCK POSITION, INDICATED "DON'T DESCEND AT A RATE GREATER THAN 500 FEET PER MINUTE." THE DISPLAY WE USED WOULD PROVIDE 500, 1,000, AND 2,000 FEET PER MINUTE LIMITS IN CLIMB AND DESCENT.

THE FIRST ADVISORY TO BE DISPLAYED ON THIS DEVICE IN AN ENCOUNTER WOULD ALSO TRIGGER AN AUDIO ALARM DISTINCT FROM ANY OTHER IN THE COCKPIT WHICH WOULD SOUND CONTINUOUSLY AS LONG AS AN ADVISORY OF ANY KIND WAS DISPLAYED. THIS, THEN, WAS OUR PRIMARY ACTIVE BCAS DISPLAY. ONCE AGAIN, THERE WERE 3 CATEGORIES OR DISPLAYS - THE POSITIVE ADVISORY, THE NEGATIVE ADVISORY, AND THE VERTICAL SPEED LIMITS.

WE ALSO INSTALLED A SECOND DISPLAY WHICH WE CALLED AN "ADDITIONAL TRAFFIC INFORMATION DISPLAY." IT CONSISTED OF A MODIFIED BENDIX COLOR WEATHER RADAR DISPLAY AND WAS MOUNTED TO THE RIGHT OF THE NORMAL WEATHER RADAR DISPLAY JUST TO THE LEFT OF THE COPILOT'S KNEE. WE INSTALLED THIS DISPLAY TO (1) ASSIST THE CREW IN DETERMINING THE RANGE AND ALTITUDE OF ANY THREAT FOR WHICH AN ADVISORY WAS DISPLAYED ON THE IVSI, AND (2) TO PROVIDE SOME PRELIMINARY INSIGHT INTO HOW USEFUL SOME OF THE ADDITIONAL INFORMATION AVAILABLE WITHIN THE ACTIVE BCAS

Active BCAS Operational Evaluation Results

184 Hours of Instrumented Flight
18 Terminal Areas/28 Airports

Acquisition Range Generally Greater Than 11 Miles

18 Valid Target of Opportunity Alerts

- 4 False Alarms
  - — Wiring Error (Connection to RDR Alt. Omitted)
  - — Partial Transmitter Failure
  - — Altitude Sensing Logic Error
  - — Intermittent Air Data Computer Malfunction
- 2 Missed/Late Alarms
  - — Transponder Problem
  - — Unknown

SIGNAL PROCESSOR MIGHT BE TO THE CREW. AS YOU CAN SEE FROM THE SLIDE, THE ADDITIONAL TRAFFIC INFORMATION DISPLAY PRESENTED, IN TABULAR FORM, TRACK NUMBERS FOR UP TO 8 OF THE CLOSEST OF THE 50 TRACKS THAT COULD BE PROCESSED BY THE SYSTEM. IT ALSO DISPLAYED RANGE, RANGE RATE, AND RELATIVE ALTITUDE TO THE THREAT FOR EACH OF THE TRACKS. THIS INFORMATION WAS UPDATED ONCE EVERY 4 SECONDS. WHEN AN ADVISORY WAS DISPLAYED ON THE IVSI, THE TRACK INFORMATION FOR THE THREAT CAUSING THE ADVISORY WAS DISPLAYED ON THE ADDITIONAL TRAFFIC INFORMATION DISPLAY IN RED TO ASSIST IN ITS ASSIMILATION BY THE CREW.

A REAL TIME DISPLAY OF TRACK INFORMATION WAS ALSO PROVIDED IN THE PASSENGER CABIN AS PART OF THE TEST INSTRUMENTATION PACKAGE. ALTHOUGH NOT OF USE TO THE CREW, THIS DEVICE DISPLAYED THE TRACK RANGE AND ALTITUDE GRAPHICALLY FOR THE TECHNICAL OBSERVERS ON BOARD OF ALL TARGETS SEEN BY THE ACTIVE BCAS WITHIN $\pm$ 5,000 FEET IN ALTITUDE AND WITHIN 12 MILES RANGE.

THE RESULTS OF THIS PRELIMINARY EVALUATION WERE SIGNIFICANT. THREAT ACQUISITION WAS EXCELLENT, WHEN THE EQUIPMENT WAS WORKING PROPERLY, AND OCCURRED AT RANGES GENERALLY OF GREATER THAN 11 MILES. THE ALARMS PROVIDED AGAINST THE 18 TARGETS OF OPPORTUNITY THAT OCCURRED DURING OUR FLYING WERE VALID AND PROVIDED USEFUL CONFLICT RESOLUTION ADVISORIES.

THERE WERE, AS YOU WOULD EXPECT IN ANY PRELIMINARY TESTS OF ELECTRONICS OF THIS NATURE, 4 EQUIPMENT MALFUNCTIONS THAT CAUSED FALSE ALARMS. INADVERTANT DAMAGE TO THE CONNECTION BETWEEN THE RADAR ALTIMETER AND THE BCAS MADE IT IMPOSSIBLE FOR THE SYSTEM TO DISPLAY POSITIVE DESCEND ADVISORIES DURING SEVERAL OF THE FLIGHTS UNTIL DISCOVERED AND FIXED IN LOS ANGELES. A PARTIAL FAILURE OF THE BCAS TRANSMITTER CAUSED MULTIPLE FALSE ADVISORIES AT ONE POINT IN THE SEATTLE TERMINAL AREA. THE FAILURE WAS APPARENTLY OF A SWITCH RELATED TO THE WHISPER/SHOUT CIRCUITRY OF THE TRANSMITTER AND LED TO A SEQUENCE OF ADVISORIES ON THE IVSI THAT CAUSED US ALL CONSTERNATION IN THE COCKPIT UNTIL WE REALIZED FROM THE INFORMATION DISPLAYED ON THE ADDITIONAL TRAFFIC INFORMATION DISPLAY THAT NEITHER OF THE TWO TRACKS TRIGGERING THE IVSI WERE REASONABLE. A GRAPHICAL DISPLAY OF THE INFORMATION WE HAD ON THE ADDITIONAL TRAFFIC INFORMATION DISPLAY, AND THE ADDITION OF BEARING TO THE TARGET, WOULD HAVE ENABLED US TO REACH THAT CONCLUSION FAR SOONER.

AN OMISSION IN THE ALTITUDE SENSING LOGIC OF THE BCAS LED TO FALSE ALARMS AT ALTITUDE ON TWO OCCASIONS WHILE EN ROUTE FROM ONE TERMINAL AREA TO ANOTHER. AGAIN, THE AIRSPEED AND ALTITUDE INFORMATION ON THE ADDITIONAL TRAFFIC INFORMATION DISPLAY, COUPLED WITH THE TRAFFIC ADVISORY INFORMATION PROVIDED BY ATC, ENABLED US TO RECOGNIZE THE FALSE ADVISORIES WHEN THEY OCCURRED.

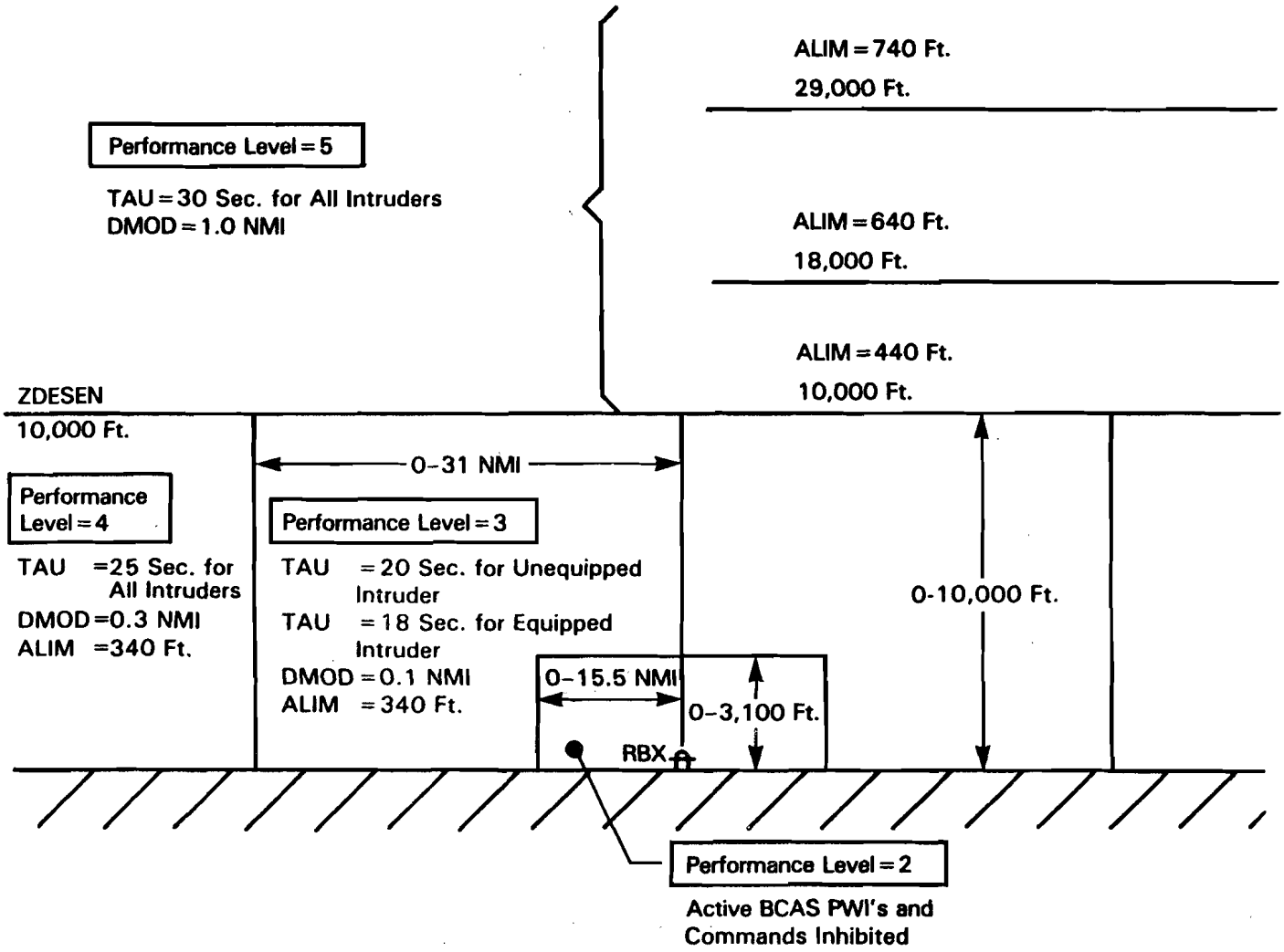
AND WHILE IN THE MIAMI AREA, AN INTERMITTENT MALFUNCTION IN THE OUTPUT OF THE AIRCRAFT'S AIR DATA COMPUTER LED TO THE OMISSION OF A FEW BITS OF ALTITUDE DATA AND TO AN ERRONEOUS ALARM BY THE BCAS. THESE INTERMITTENT AND SPORADIC MALFUNCTIONS OCCURRED COINCIDENTALLY WITH OUR FLIGHT THROUGH SOME RAIN SHOWERS AND CAUSED US TO WONDER FOR AWHILE WHAT THE CAUSE WAS.

THERE WERE TWO INSTANCES WHERE THE BCAS EITHER PROVIDED VERY LATE ADVISORIES OR NO ADVISORY AT ALL WHEN THERE WERE, IN FACT, CONFLICTS WITH OTHER AIRCRAFT. IN THE FIRST CASE, THE PROBLEM WAS RESOLVED WITH THE SUBSTITUTION OF ANOTHER TRANSPONDER IN OUR AIRCRAFT. IN THE SECOND CASE, A PROBLEM WITH THE TRANSPONDER IN OUR AIRCRAFT THAT HAS NOT YET BEEN RESOLVED, CAUSED US TO BE UNABLE TO ESTABLISH A TRACK ON THE TARGET AIRCRAFT WHILE TRACKING ALL OTHER SURROUNDING AIRCRAFT WITHIN RANGE OF THE SYSTEM. THE TARGET AIRCRAFT IN THIS INSTANCE WAS AN FAA CONVAIR 580 EQUIPPED WITH BCAS AND WAS PARTICIPATING WITH US IN SOME PLANNED ENCOUNTER WORK PERFORMED IN THE LOS ANGELES BASIN DURING OUR STAY THERE.

I MENTION THESE PROBLEM AREAS WE HAD NOT BECAUSE I FEEL THEY DETRACT FROM THE OVERALL VERY SUCCESSFUL PERFORMANCE OF THE ACTIVE BCAS BUT BECAUSE WE LEARNED A LOT FROM THEM. IT IS VERY IMPORTANT, WE FOUND, THAT IN THE FINAL DESIGN A SELF TEST FEATURE BE INCORPORATED AS A PART OF ANY BCAS AVIONICS. IT IS VERY IMPORTANT THAT IN THE FINAL DESIGN ANY FAILURE MODE IN THE BCAS BE HANDLED SUCH THAT NO CONFLICT RESOLUTION ADVISORY BE PROVIDED TO THE PILOT RATHER THAN INCORRECT ADVISORIES. RELIABILITY IS OBVIOUSLY GOING TO BE A MAJOR FACTOR IN THE IMPLEMENTATION OF A COMPLEX SYSTEM LIKE ACTIVE BCAS.

THERE IS ONE FURTHER RESULT THAT I WOULD LIKE TO CALL TO YOUR ATTENTION. IT WAS EVIDENT IN NEARLY EVERY FLIGHT THAT WE MUST FIND A WAY TO DESENSITIZE ACTIVE BCAS AS WE APPROACH AN AIRFIELD. FOR THE PURPOSE OF OUR FLIGHT WE SIMPLY MANUALLY SELECTED VARIOUS SENSITIZATION LEVELS. WE USED, FOR THE MOST PART, THE DESENSITIZATION SCHEME DEVELOPED AS A RESULT OF THE MITRE CORPORATION TRAFFIC

Active BCAS Performance Level Zones and Significant Parameters



STUDIES OF THE HOUSTON TERMINAL AREA. WE FOUND THAT WE COULD OPERATE IN ALMOST ALL OF THE TERMINAL AREAS WITH THE SENSITIVITY LEVELS PROVIDED, BUT THAT AS WE APPROACHED TO WITHIN BETWEEN 1/2 TO 1 1/2 NAUTICAL MILES OF AN AIRPORT, TRANSPONDER ACTIVITY ON THE SURFACE WOULD CAUSE ADVISORIES TO BE DISPLAYED THAT WERE UNWANTED - AND THAT CAUSED AN UNACCEPTABLE LEVEL OF DISTRACTION IN THE COCKPIT DURING THE PERIOD OF HIGHEST CREW WORKLOAD OF THE FLIGHT. SUCH ADVISORIES BECAME EVEN MORE DISTRACTING AND CONFUSING WHEN THEY OCCURRED DURING A LOW APPROACH OR DURING THE PHASE OF DEPARTURE JUST AFTER LIFT OFF.

A MAJOR CONCLUSION OF OUR SHORT LOOK IS THAT WE FEEL THE ACTIVE BCAS CONCEPT, AS IT WAS PROVIDED TO US IN THE FORM OF THE LINCOLN LABORATORY BASIC EXPERIMENTAL UNIT, CAN BE MADE TO WORK. THERE ARE UNDOUBTEDLY SOME COMPROMISES TO BE MADE IN ARRIVING AT A FINAL SET OF ALGORITHMS FOR THE LOGIC, BUT BASICALLY, THEY WORKED.

IT WAS CLEAR THAT WE HAVE YET TO DECIDE WHAT ELEMENTS OF INFORMATION MUST BE INCLUDED IN AN ACCEPTABLE DISPLAY. ARE VERTICAL SPEED LIMITS ESSENTIAL, FOR EXAMPLE? IS BEARING TO THE TARGET ESSENTIAL OR "NICE TO HAVE?" IS TRAFFIC PROXIMITY INFORMATION ESSENTIAL TO IMPLEMENTATION OF ACTIVE BCAS?
IF SO, WHAT INFORMATION SHOULD BE INCLUDED IN A TRAFFIC PROXIMITY WARNING DISPLAY? AND HOW SHOULD SUCH INFORMATION BE USED?

WE THINK IT IS HIGHLY LIKELY THAT, AS A MINIMUM, BEARING TO THE TARGET SHOULD BE ADDED TO THE DISPLAY, IF IT CAN BE OBTAINED. BEYOND THIS, WE FEEL THAT THE INCORPORATION OF ADDITIONAL TRAFFIC PROXIMITY INFORMATION SUCH AS RANGE, RANGE RATE, AND ABSOLUTE ALTITUDE, WILL GREATLY ENHANCE THE PILOT'S ABILITY TO AVOID,

Conclusion of Preliminary Operational Tests of Active BCAS

- Active BCAS Concept Can Be Implemented
- Major Issues Remaining Before Implementation
- Determine Minimum Display Elements
- Determine Usefulness of Traffic Proximity Information
- Establish Densitization Scheme
- Resolve Possible Shielding Problem
- Validate Active BCAS Altimetry Assumptions
- Establish Procedures for Use

IN THE FIRST PLACE, SITUATIONS THAT COULD LEAD TO THE DISPLAY OF CONFLICT ADVISORIES TO WHICH THE CREW MUST REACT. TRAFFIC PROXIMITY INFORMATION, IF PROPERLY DISPLAYED, MIGHT ASSIST THE CREW IN EVALUATING THE CATEGORY OF ADVISORIES THAT FALL IN THE REALM OF TRAFFIC WARNINGS, AND WOULD BETTER PREPARE THE CREW TO RESPOND TO POSITIVE CONFLICT RESOLUTION ADVISORIES TO WHICH THE PILOT MUST REACT QUICKLY TO AVERT A COLLISION. IT IS CLEAR, HOWEVER, THAT TRAFFIC PROXIMITY INFORMATION MUST NOT BE USED TO DESCRIBE WHAT TO DO WITH THIS LATTER CATEGORY OF COMMANDS. WHERE A CONFLICT HAS REACHED THE POINT THAT CAUSES THE ACTIVE BCAS TO DISPLAY A POSITIVE CONFICT RESOLUTION ADVISORY, THERE IS NO TIME FOR PILOT EVALUATION OF A TRAFFIC PROXIMITY DISPLAY.

IT IS CLEAR THAT AS IT EXISTED IN OUR TESTS THE ACTIVE BCAS LOGIC AND PILOT DISPLAY DID NOT ADEQUATELY DISTINGUISH BETWEEN NEGATIVE TRAFFIC ADVISORIES AND VERTICAL SPEED LIMITS THAT ARE TRULY ADVISORY ONLY IN NATURE AND THOSE TO WHICH A PILOT MUST RESPOND IMMEDIATELY TO AVERT A COLLISION.

WE HAVE CONCLUDED THAT SOME FORM OF DESENSITIZATION OF ACTIVE BCAS MUST BE PROVIDED WHETHER IT BE A MANUAL SWITCH IN THE COCKPIT OR A SCHEME TIED TO THE LANDING GEAR SWITCHES, FLAP SWITCHES, AND TO THE RADAR ALTIMETER IF AVAILABLE. IF RELIABILITY OF SUCH SCHEMES PROVE TO BE TOO LOW, THEN PERHAPS A TRANSPONDER ON THE AIRPORT SURFACE MUST BE USED TO ACHIEVE THE NECESSARY DESENSITIZATION.

IT IS POSSIBLE THAT PROPELLER SHIELDING, OR AIRCRAFT SHIELDING, MAY PROVE TO BE A MORE SIGNIFICANT OPERATIONAL PROBLEM THAN ANTICIPATED SO FAR. WE SAW POSSIBLE EVIDENCE OF THIS IN OUR FLIGHTS.

FINALLY, WE HAVE CONCLUDED THAT IF ACTIVE BCAS CAN BE DESIGNED TO PROVIDE TRAFFIC PROXIMITY INFORMATION ON AIRCRAFT NOT EQUIPPED WITH ALTITUDE ENCODING TRANSPONDERS, AND IF THIS INFORMATION CAN BE USED SAFELY IN THE COCKPIT, WE WILL SUBSTANTIALLY IMPROVE THE USEFULNESS OF ACTIVE BCAS.

IN RESOLVING ALL OF THE ISSUES I'VE DISCUSSED WE MUST REMEMBER THERE WILL UNDOUBTEDLY BE DIFFERENT SOLUTIONS FOR EACH OF THE SEVERAL CATEGORIES OF AIR CARRIER AND GENERAL AVIATION AIRCRAFT. IT MAY NOT BE FEASIBLE, FOR EXAMPLE, TO REQUIRE MULTIPLE ANGLE-OF-ARRIVAL SENSING ANTENNAS ON SMALLER GENERAL AVIATION AIRCRAFT, FOR ECONOMIC REASONS AMONG OTHERS.

WE LOOK FORWARD TO THE PARTICIPATION OF MANY OF YOU IN THE WORK THAT YET REMAINS TO ACHIEVE THE IMPLEMENTATION OF ACTIVE BCAS. THERE IS MUCH TO BE DONE BY YOU IN INDUSTRY TO OPTIMIZE ACTIVE BCAS PERFORMANCE, ITS DISPLAYS, AND THE PROCEDURES FOR ITS USE.

THANK YOU VERY MUCH.

THE FEDERAL AVIATION ADMINISTRATION

AIRCRAFT SEPARATION ASSURANCE PROGRAM

Introduction

The objective of the Aircraft Separation Assurance Program is to provide a backup to the conventional ground-based air traffic control system for the purpose of reducing the risk of midair collisions. The program has received the generous and highly valuable assistance of the users and industry. This cooperative and iterative process has resulted in a sound approach to a complex problem.

A System Approach to Aircraft Separation Assurance

The Federal Aviation Administration's program for separation assurance embraces five principal system elements, each focused on a somewhat different combination of airspace regime and user, and each with a somewhat different schedule for development and implementation. Individual elements have been or will be implemented as fully integrated components of the National Airspace System when developmental testing and operational evaluations demonstrate adequate levels of effectiveness. This strategy provides steadily increasing protection from midair collisions for an expanding segment of airspace users, over a larger portion of the airspace, as implementation progresses.

The five elements of the Separation Assurance Program are: (1) Conflict Alert, (2) Conflict Resolution, (3) a limited capability beacon collision avoidance system known as Active BCAS, (4) a full capability BCAS known as Full BCAS, and (5) the Automatic Traffic Advisory and Resolution Service (ATARS).

Conflict Alert

Conflict Alert is currently implemented in the ground-based air traffic control computers associated with the en route airspace as well as the 62 major terminal areas serviced by ARTS III automation equipments. This function warns controllers that violations of separation minima are likely to occur and indicates to controllers which aircraft are in conflict. In response to the alert, a controller may issue appropriate instructions to the aircraft involved if such instructions are warranted.

In the en route case, the look-ahead time is two minutes, as shown in Figure 1. The ground computer system has defined a suitable protection volume around the upper aircraft and has projected that in two minutes the lower aircraft will be within this volume. The Conflict Alert program will provide an indication to the controller in the form of a flashing data block and a Conflict Alert message on the display.

Conflict Alert for Enroute

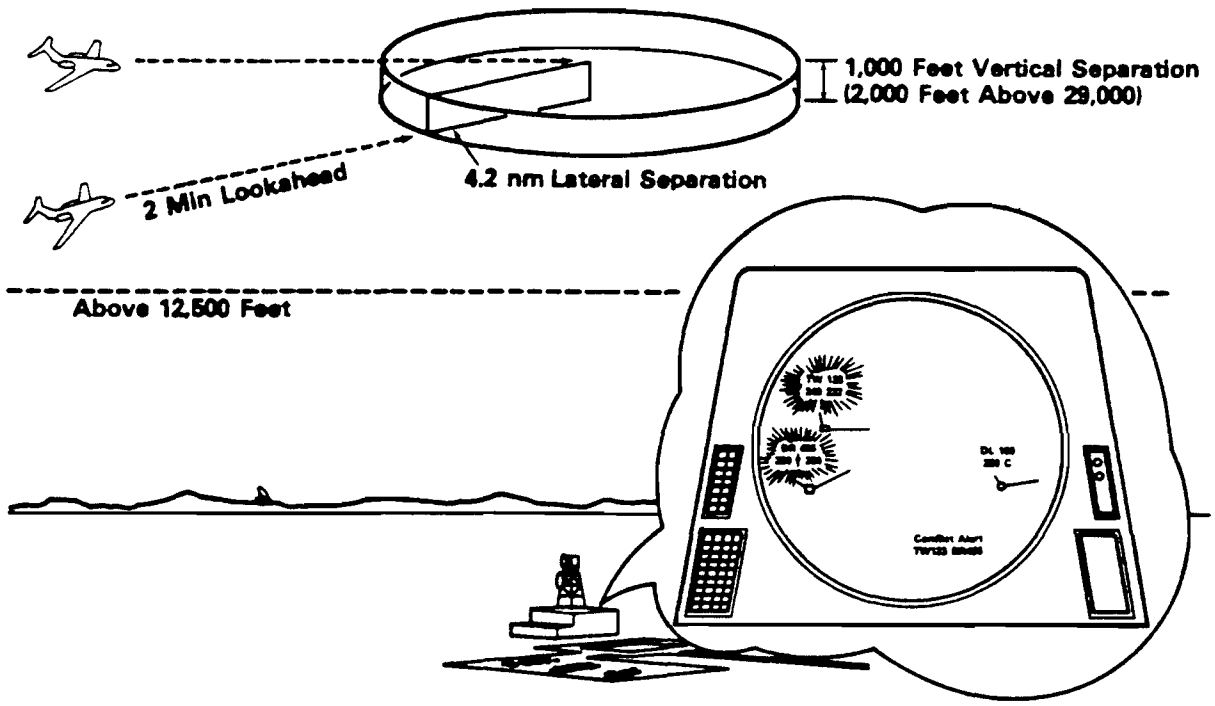


Figure 1

Conflict Resolution

Conflict Resolution is an extension of Conflict Alert that is under development for en route airspace. This automation feature is designed to advise controllers of candidate instructions for resolving conflicts displayed by the Conflict Alert function. In terminal areas, the controller alert feature of ATARS will perform this function.

As opposed to Conflict Alert and Conflict Resolution , the remaining developments in the Aircraft Separation Assurance Program, BCAS and ATARS, provide information directly and automatically to the cockpit, rather than only to the controller. These systems differ among themselves in the source and the extent of the information provided.

Active BCAS

The first, and conceptually the simplest, of these systems is Active BCAS. It operates by interrogating the transponders in other aircraft in the same manner as does a ground radar interrogator as depicted in Figure 2. Information

relating to range, range rate, altitude, and altitude rate of proximate aircraft is derived from the replies to these interrogations. When the on-board Active BCAS computer recognizes the existence of a collision threat, it generates a vertical resolution advisory (climb or descend) and delivers it to the cockpit display. Active BCAS is expected to provide reliable collision protection in low and medium density airspace.

Active BCAS Concept

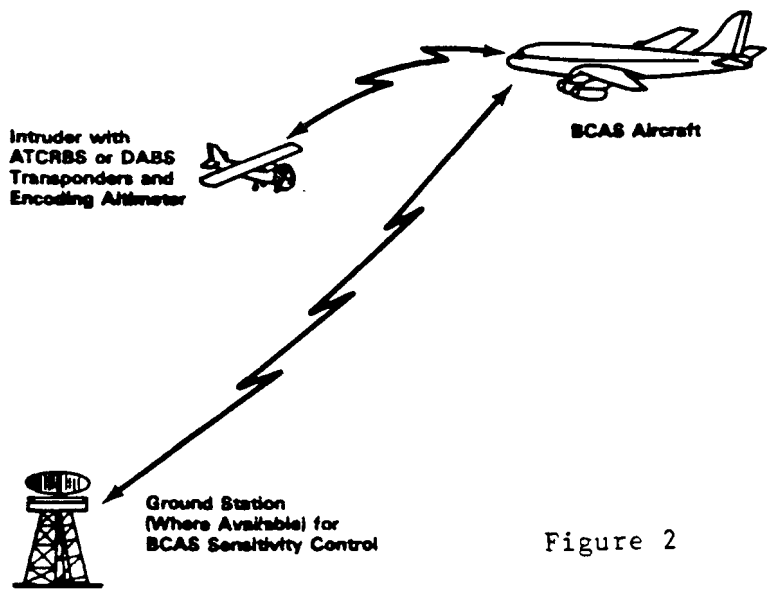


Figure 2

Active BCAS airborne equipments are capable of operating without ground equipments. However, in relatively dense terminal areas, it is anticipated that a ground station called a Radar Beacon Transponder (RBX) will be provided for coordinating Active BCAS with the conventional air traffic control system. The function of the Radar Beacon Transponder is to relay any BCAS resolution advisory displayed in an aircraft to the responsible air traffic controller on the ground. This process automatically notifies the controller of the conflict situation and the probable evasive maneuver of the Active BCAS aircraft. In addition, the Radar Beacon Transponder automatically modifies the threat logic parameters in the airborne BCAS equipment in order to control the alert rate as the BCAS aircraft moves into dense terminal airspace.

Active BCAS will provide protection against aircraft equipped with the current altitude-encoding transponder, and against those equipped with the future DABS transponder, also with altitude encoding. For encounters between two or more aircraft with Active BCAS equipment, it is essential that the maneuver resolution advisories provided to the pilot of each aircraft be coordinated, to insure that avoidance maneuvers are mutually compatible. This BCAS-to-BCAS coordination is accomplished via the BCAS air-to-air data link capability using standardized DABS messages.

In addition to resolution advisories, Active BCAS airborne equipments are capable of displaying traffic advisories providing intruder range, altitude and coarse bearing information.

Full BCAS

Like Active BCAS, Full BCAS (Figure 3) is an airborne separation assurance device in the sense that the principal elements of the system are installed in the aircraft and these elements can operate without assistance from ground equipments. Hence, the equipped aircraft receives protection whether or not it is within range of ground equipments.

While Full BCAS can actively interrogate other aircraft, as does the Active BCAS, the principal advantages of the Full BCAS lie in its passive modes and combinations of passive and active modes.

The passive modes listen to the interrogations transmitted by air traffic control surveillance ground stations and to the replies of proximate aircraft transponders to these interrogations. Through suitable processing of this information along with ancillary information, it is possible to measure accurately the range, altitude, and bearing of proximate aircraft. Because of the highly accurate bearing data available, Full BCAS can generate horizontal resolution advisories (turn right or turn left) in addition to the vertical resolution advisories available from Active BCAS. A second principal advantage of Full BCAS with respect to Active BCAS is its capability to operate reliably in all traffic densities.

Full BCAS Concept

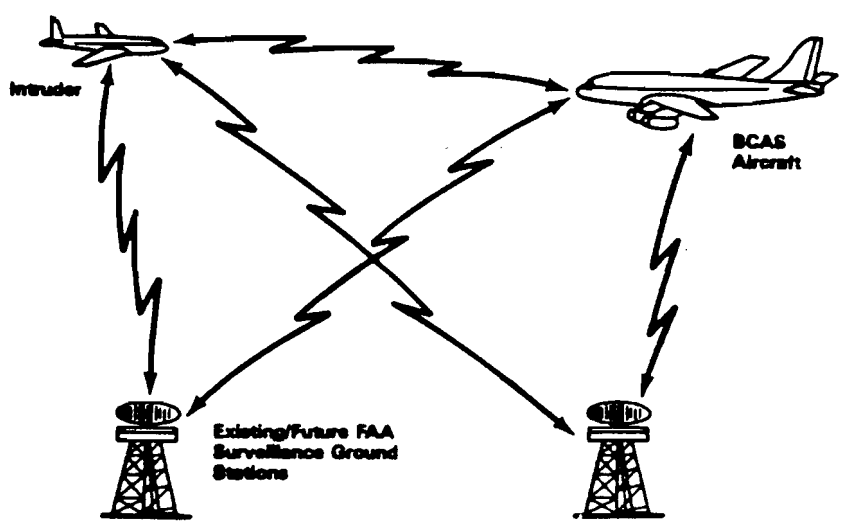


Figure 3

Full BCAS will provide protection against aircraft equipped with today's altitude encoding transponder, and will provide traffic advisories concerning aircraft having transponders without altitude encoders. It will also provide protection against aircraft equipped with DABS transponders. As with Active BCAS, it will coordinate its resolution advisories with other BCAS-equipped aircraft via its air-to-air data link using standardized DABS messages. It should be emphasized that in an encounter between an aircraft equipped with a Full BCAS and one with an Active BCAS, the resolution advisories generated by each will be fully compatible, thus assuring a coherent future environment where a mix of Active and Full BCAS equipments may co-exist.

ATARS

The ground-based Automatic Traffic Advisory and Resolution Service (ATARS) uses surveillance data from Discrete Address Beacon System (DABS) secondary surveillance radar (or beacon radar) sensors. DABS is a totally compatible upgrade of today's Air Traffic Control Radar Beacon System (ATCRBS). The two principal contributions made by DABS ground sensors are (1) precision surveillance data that is highly reliable and (2) an air-ground-air data link capability. Since each aircraft equipped with a DABS transponder has its own discrete identity code or address, "private-line" communications between the aircraft and the ground are possible. ATARS uses the precision surveillance data available from the DABS ground sensor to identify aircraft conflicts and then transmits appropriate horizontal and/or vertical resolution advisories to the aircraft involved using the DABS data link. In a similar fashion, ATARS can provide an automatic traffic advisory service to properly equipped aircraft within view of DABS ground stations. Figure 4 depicts this concept of operation.

DABS/ATARS Concept

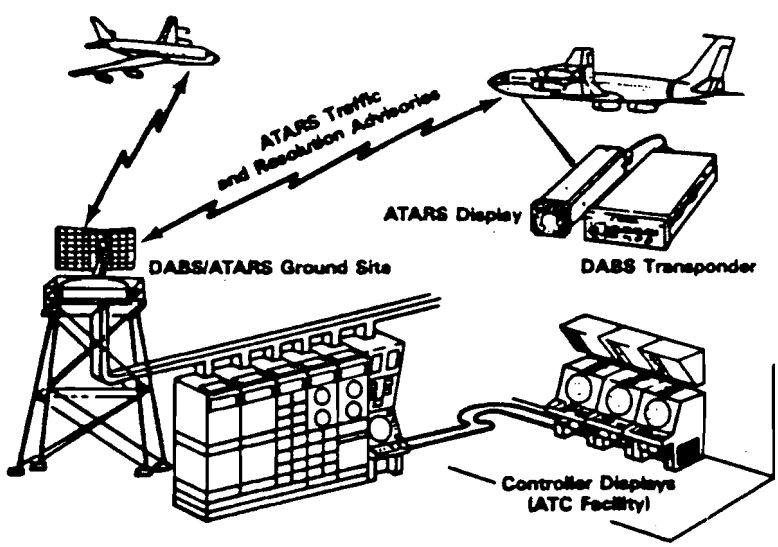


Figure 4

For suitably equipped aircraft, resolution advisories are provided against all other aircraft that have altitude reporting transponders of any type, and traffic advisories may be provided for any transponder-equipped aircraft. As shown in the Figure 4, to receive ATARS service, an aircraft must carry a DABS transponder with an altitude encoding capability, and an ATARS display. The ground portion of the ATARS system consists of the DABS sensor, the ATARS computers, and equipment to interface with the air traffic control facilities serving the airspace covered by the DABS sensor.

ATARS aircraft receive traffic advisories regarding both proximate aircraft and those which constitute a potential threat. In the case of proximate aircraft, the information displayed is intended to aid the pilot in visual acquisition. When an aircraft poses a threat, ATARS displays additional information to aid in evaluating the threat so that the pilot may initiate action to avoid a conflict. In a threat situation, when the computer-projected separation becomes less than the threshold established for that region of airspace, one or both of the aircraft receive a resolution advisory at a predetermined time (approximately 20-30 seconds) before the estimated time of closest approach.

ATARS coordinates with the air traffic control system. Whenever a threat advisory is issued to a controlled aircraft, ATARS can send a corresponding controller alert message to the air traffic control facility responsible for that aircraft.

ATARS is considered the most effective approach for protecting against midair collisions in high density airspace. By virture of its fixed location on the ground and the high quality surveillance data available from the associated DABS sensor, ATARS can be precisely adapted to specific sites to control the incidence of nuisance alarms while providing comprehensive protection against collisions. It is expected that the nuisance alerts from ATARS will be far fewer than those from either Active BCAS or Full BCAS. In addition, in contrast to BCAS, ATARS requires relatively little equipment on board protected aircraft. Hence DABS/ATARS ground stations in dense traffic areas protect large numbers of aircraft with only modest investments required of users for the necessary avionics.

ACTIVE BCAS DESCRIPTION

The Active Beacon Collision Avoidance System (BCAS) is a major element of the Federal Aviation Administration's Aircraft Separation Assurance Program. The BCAS equipment in the equipped aircraft interrogates the air traffic control transponders on board aircraft in its vicinity and listens for the transponder replies. By suitable computer processing of these replies, the airborne BCAS equipment determines the ranges and relative altitudes of proximate aircraft, determines which aircraft represent potential collision threats and displays maneuver advisories to the pilot for resolving any potential threat.

Active BCAS will provide a backup separation assurance service for the existing air traffic control system in low and medium density airspace to include airspace not under surveillance by ground-based radars. It is designed to resolve reliably collision and near-miss encounters in such airspace without producing unwanted alarms in encounters for which the collision risk does not warrant escape maneuvers.

Operational Description

Active BCAS is most readily understood by visualizing its operation in flight. When the equipped aircraft is airborne, the BCAS equipment is continually transmitting interrogation signals. These interrogations are received by the air traffic control transponders carried by all air carriers, virtually all military aircraft, and many general aviation aircraft. In reply to the BCAS interrogation, the transponder transmits a signal which reports its altitude. From the round-trip time between the transmission of the interrogation and the receipt of the reply, the airborne BCAS equipment computes the range to the transponder. Using these two-way radio transmissions, the Active BCAS equipment continually monitors the ranges and altitudes of proximate aircraft.

If the BCAS computer threat detection logic determines that the range and altitude data from a proximate aircraft indicate that a collision or near-miss encounter is likely, the computer threat resolution logic determines the least disruptive vertical maneuver that will ensure the escape of the BCAS aircraft. The least disruptive maneuver is that maneuver which ensures adequate vertical separation while causing the least deviation of the BCAS aircraft from its current vertical trajectory. The maneuver advisory (or resolution advisory) displayed to the pilot can be in several forms to include limit advisories (e.g., limit descent rate to 1000 ft/min), maintain advisories (e.g., maintain climb rate of at least 500 ft/min), negative advisories (e.g., do not descend), and positive advisories (e.g., climb).

Active BCAS has the capability to interface with the ground-based air traffic control system. Through communications with a ground unit called the Radar Beacon Transponder, the parameters of the threat detection logic can be varied as the BCAS-equipped aircraft enters more dense airspace. These parameter

changes ensure that the increasing aircraft density does not induce a high rate of unwanted alarms. At the same time, the BCAS aircraft retains an adequate level of protection from midair collisions. In addition, the ground-based Radar Beacon Transponder provides a communication link whereby any resolution advisory displayed to a pilot can be downlinked and displayed to the appropriate air traffic controller.

System Elements

Active BCAS is designed to operate in a broad spectrum of environments ranging from medium density airspace under surveillance of automated air traffic control systems (e.g., today's Washington, D.C., and Philadelphia environments) to sparse airspace where there is no radar surveillance (e.g., oceanic airspace). The principal elements of the overall system are:

Airborne BCAS Equipment. The equipped aircraft carries BCAS surveillance electronics, the BCAS computer, and associated displays and aircraft interfaces. This equipment is capable of operating without degradation in airspace where there is no associated ground equipment installed.

DABS Transponder with Altitude Encoder. The equipped aircraft carries the Discrete Address Beacon System (DABS) air traffic control transponder in place of the ATCRBS transponder currently in use. The DABS transponder performs the functions of existing transponders and provides a private-line communications link that airborne BCAS equipments use in resolving encounters between equipped aircraft. The DABS transponder is also used in BCAS communications with the ground Radar Beacon Transponder. BCAS is capable of resolving encounters with aircraft equipped with DABS transponders as well as with aircraft equipped with the existing ATCRBS transponders.

ATCRBS Transponder with Altitude Encoder. The Air Traffic Control Radar Beacon System (ATCRBS) transponder is the existing transponder in use throughout the world. The altitude encoder is the existing equipment that converts the barometric altitude of the aircraft into the electrical message transmitted in transponder replies.

Radar Beacon Transponder (RBX). As described earlier, the ground-based Radar Beacon Transponder provides the interface between airborne BCAS equipments and the existing air traffic control system. It provides communications that modify BCAS threat detection logic parameters in relatively dense airspace in order to control the unwanted alarm rate. In addition, it permits resolution advisories displayed to pilots to be relayed to ground air traffic control facilities for display to appropriate controllers.

DABS/ATARS Ground Equipment. The Discrete Address Beacon System (DABS) employs a precision ground-based secondary surveillance radar sensor which provides high quality surveillance data for air traffic control as well as a ground-air-ground data link capability. The high quality surveillance data and the data link support a ground-based separation assurance service called the Automatic Traffic Advisory and Resolution Service (ATARS). Here, the threat detection and resolution functions are performed on the ground with resolution advisories relayed to pilots over the DABS data link. When, in the future, BCAS aircraft operate in the coverage volumes of DABS/ATARS ground stations, the designs of BCAS and ATARS assure that all encounters are resolved unambiguously whether BCAS provides the resolution or resolution comes from ATARS. In addition, in such airspace, the DABS/ATARS ground station will perform the functions of the RBX.

System Growth

Active BCAS has been designed to assure its effectiveness and utility in diverse and changing environments. The Federal Aviation Administration is developing two features which will provide for growth to meet expanded needs.

Angle-of-Arrival Measurement. This enhancement will enable airborne equipments to determine the approximate bearings of threat aircraft and to display this information to the pilot. Threat bearing data improves pilot situation awareness and aids visual recognition. This information, in turn, improves the pilot's ability to respond to BCAS resolution advisories.

Surveillance of Aircraft Without Altitude Encoders. Some aircraft are equipped with air traffic control transponders but do not have altitude encoders. The enhancement to Active BCAS to provide surveillance of such aircraft, together with the angle-of-arrival enhancement, will enable the ranges and bearings of these aircraft to be displayed to the pilot, thereby increasing the opportunity for visual recognition. Since threat altitude is unknown, BCAS cannot provide resolution advisories in encounters with such aircraft.

SUMMARY OF ACTIVE BCAS TEST AND EVALUATION RESULTS

Systems Research and Development Service
Federal Aviation Administration

January 1981

Throughout 1980, the Federal Aviation Administration's program for the development of Active Beacon Collision Avoidance System (BCAS) has intensively evaluated the performance of this concept. These evaluations were a continuation of related efforts initiated in the mid 1970's to assess the performance of the early feasibility models. While all aspects of the Active BCAS design have not been finalized and while our evaluations are therefore not yet complete, our work thus far provides a reasonably comprehensive description of Active BCAS performance.

Flight Tests

More than 225 hours of flight time have been accumulated on engineering model equipments since February 1980. This testing included in excess of 370 in-flight encounters between test aircraft on intentional collision or near-collision courses. Based on preliminary analyses of the 240 encounters flown since July 1980, it appears as though Active BCAS consistently selected the correct resolution advisory sense (climb or descend) and that the advisories were displayed to the test pilots at the correct times. In the dense Los Angeles airspace, there were three instances of late alarms of the correct sense. These late alarms may represent a characteristic degradation of Active BCAS performance in very dense airspace of the type found in Los Angeles today. Additional testing in the Los Angeles area will be conducted during 1981.

In addition to the encounter flight tests, a 126-hour tour of the domestic airspace has been conducted during which the Active BCAS test aircraft operated as a normal air carrier aircraft at 28 airports in 18 cities. This tour produced 11 Active BCAS alerts recorded in chance encounters above 500 feet AGL. These encounters have provided insight into the circumstances under which Active BCAS alerts can occur in normal traffic operations. The alert rate during these tests was higher than will be experienced by operational systems due to the manner in which the experimental Active BCAS equipment was operated.

These two distinctly different flight test series were designed to assess the two principal attributes of Active BCAS--its ability to effectively resolve hazardous midair encounters, and its alert characteristics in normal traffic operations.

Desensitization

Active BCAS airborne equipment includes a computer that determines which nearby aircraft are potential collision threats and which are not. This threat detection function is modified according to the airspace in which the

Active BCAS aircraft is operating. In sparse, high altitude airspace, the threat detection function can be quite sensitive to proximate aircraft because normal separations are large. However, as the aircraft enters relatively dense terminal airspace, it is necessary to desensitize the threat detection function in order to ensure that the alert rate is acceptable.

While desensitizing the threat detection function effectively controls the alert rate, it reduces the collision protection available. A principal challenge in the development of Active BCAS has been the design of threat detection functions which are capable of reliably protecting against midair collisions while providing acceptable alert rates in normal traffic operations.

Simulation Studies

While the flight tests conducted during 1980 provided valuable data on the operation of Active BCAS in real-world environments, there are test scenarios that are too dangerous to evaluate by flight test. In addition, the expense of flight testing argues against the large number of replications that lends confidence to experimental results. Computer simulations permit the rapid evaluation of large numbers of encounters unconstrained by flight safety considerations. Three large-scale simulation studies have been completed recently. The first study was a comprehensive alert rate analysis based on 65 hours of actual aircraft track data extracted from the ARTS III air traffic control computer in the Houston Hub. This study indicated that, if all of the tracked aircraft had been carrying properly desensitized Active BCAS equipments, the alert rate would have been approximately one per hour. The average IFR aircraft would receive one climb/descend advisory in every 19 hours of operation in this environment. If the average IFR operation (arrival/departure) spends 20 minutes in the Houston Hub airspace, the alert rate translates to one in 60 operations.

The second simulation study analyzed the ability of Active BCAS to resolve 15 actual midair collisions assuming that the aircraft involved were desensitized according to the rules employed for the Houston alert rate study. One of these collisions (Carmel, NY) resulted from an abrupt climb of 4,000 fpm by an aircraft that had been level 12 seconds prior to collision. This maneuver could not have been anticipated, and the 12 seconds available for avoidance was insufficient for reliable resolution by any realistic collision avoidance system.

Another of the midair collisions (St Louis, MO) occurred so close to the airport that Active BCAS would have been inhibited by the desensitization rules applied in the Houston study. Otherwise, Active BCAS would have been capable of resolving this encounter.

Of the remaining 13 midairs, all would have been reliably resolved by Active BCAS.

The third simulation study investigated hypothetical collision encounters to assess the ability of Active BCAS to provide resolution. The results indicated that encounters involving aircraft climbing or descending at constant rates are reliably resolved. Encounters with intruders that maneuver abruptly in the vertical direction, like the Carmel midair, were sometimes not successfully resolved. Horizontal maneuvers are substantially less troublesome for resolutions than are vertical maneuvers.

Summary

The scope and results of recent Active BCAS testing can be summarized as listed below:

*Flight Tests (225 hours)

- Encounter Flights (240 since July 1980)
  - Correct resolution
  - Timely advisories, except
  - Evidence of late alarms in dense Los Angeles airspace
- Normal Operations Tour (126 hours)

*Simulation Tests

- Houston Alert Rate Analysis (peak traffic conditions)
  - One alert per hour in Houston Hub
  - One alert every 60 operations for IFR aircraft
- Analysis of 15 Actual Midairs
  - Carmel midair not avoidable due to abrupt vertical maneuver
  - St. Louis midair resolvable but Active BCAS might have been inhibited
  - Remaining 13 resolvable
- Analysis of 5000 Hypothetical Encounters
  - Encounters with constant climb/descend rates resolvable
  - Encounters with abrupt vertical maneuvers not always resolvable

Active BCAS Development Program January 1981

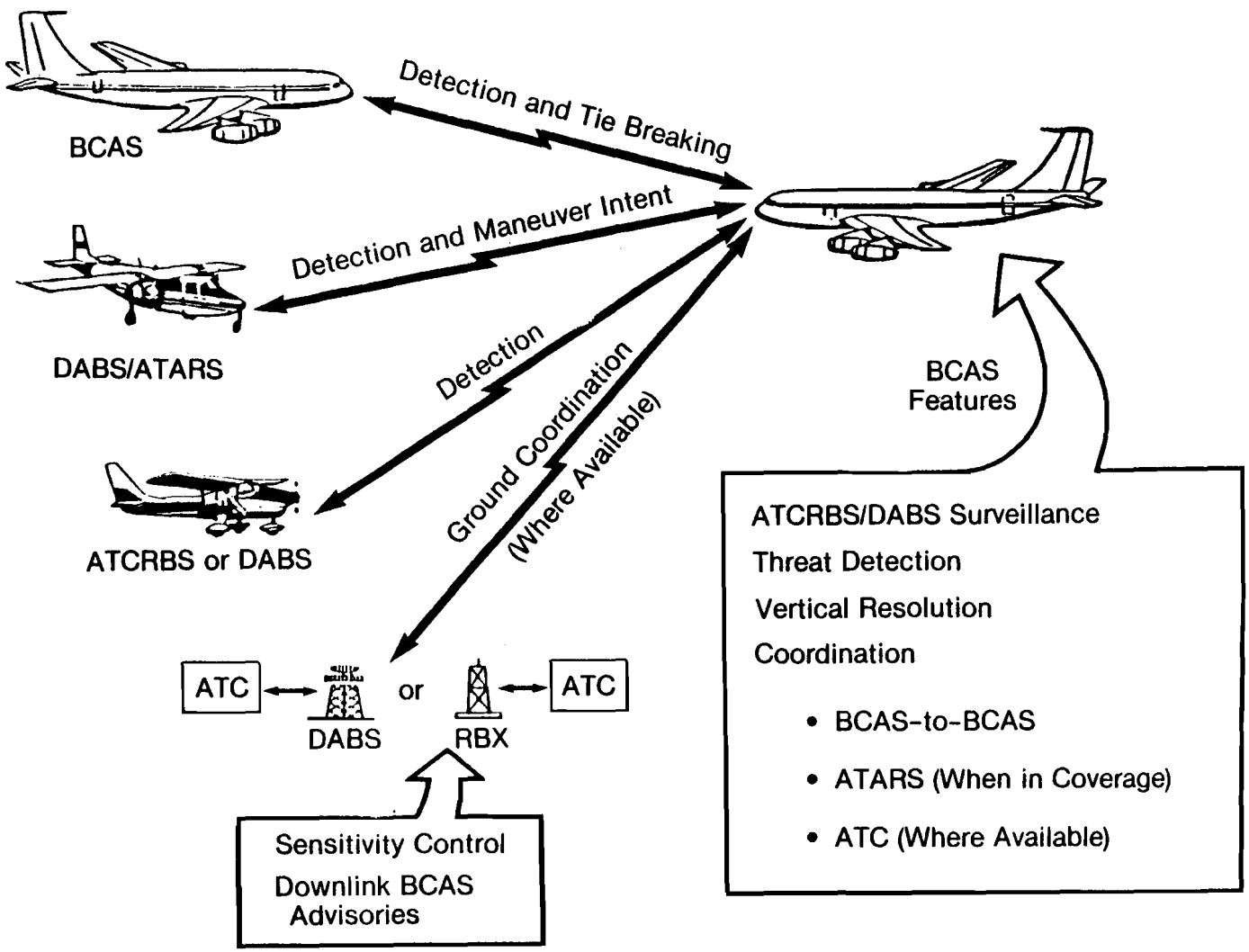
Systems Research and Development Service
Federal Aviation Administration

Active BCAS Development Program

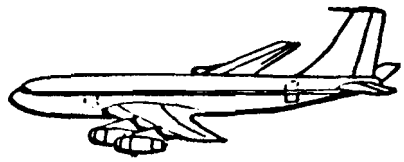
I. Program to Date
1975–1980

II. Program Planned
1981–Beyond

Active BCAS System Description



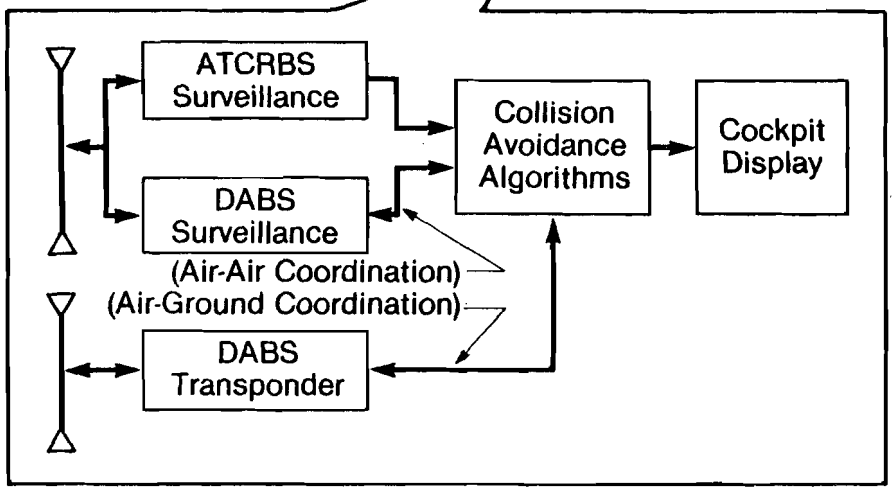
Active BCAS Elements



BCAS
on Board
Avionics

Sensitivity
Level
Controlled

- On Board
  - Manual
  - Automatic
- From Ground
  - By RBX
  - By DABS



BCAS Advisories

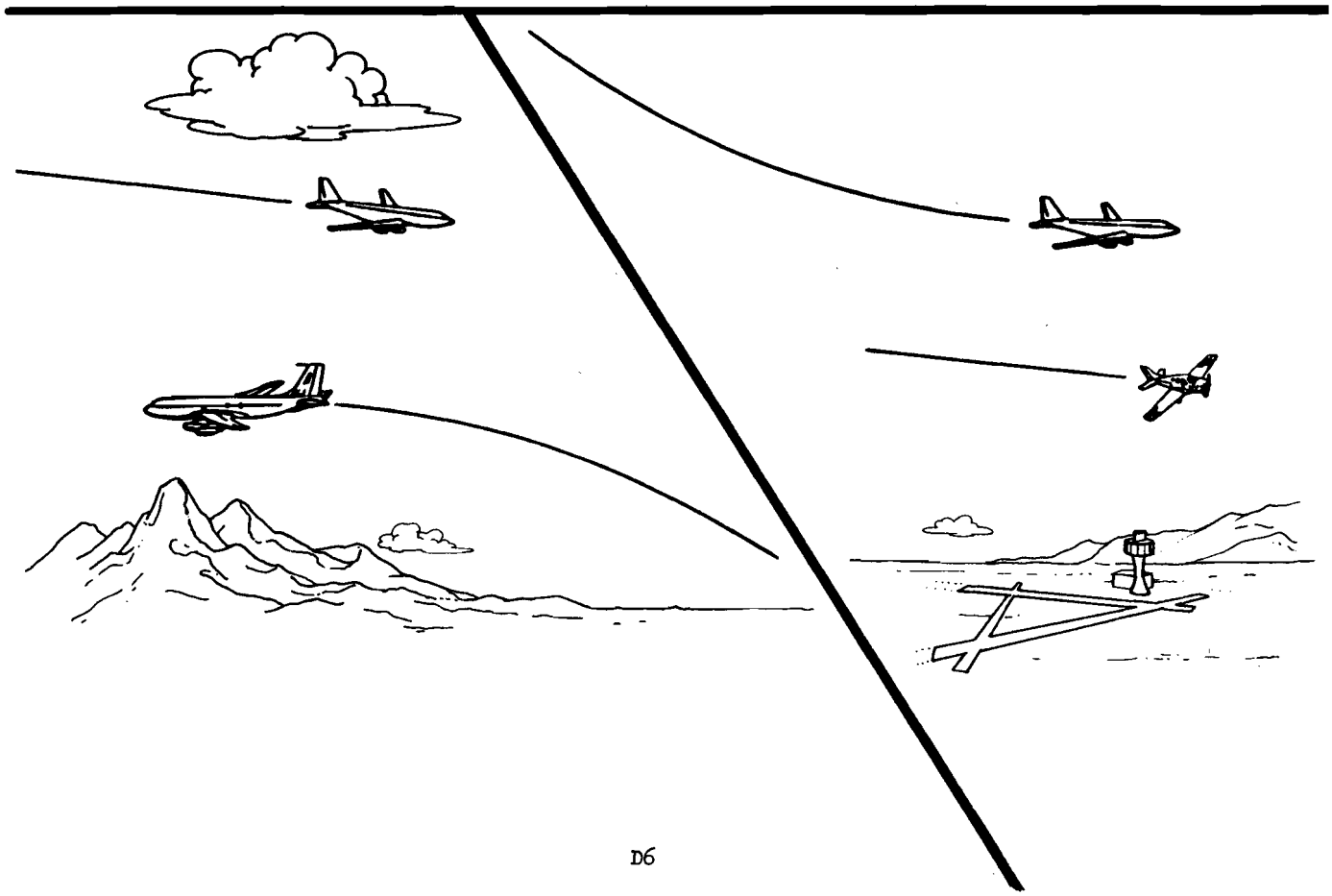
- Descend
- Climb
- Don't Descend
- Don't Climb
- Limit Altitude Rate
- Maintain Altitude Rate

I. Program to Date

Principal Activities

- **Surveillance Performance**
- Balance of Safe Resolution with Acceptable Alert Rates
- Impact on ATC System/Cockpit
- Radio Frequency Interference/Compatibility Studies

Active BCAS Flight Tests

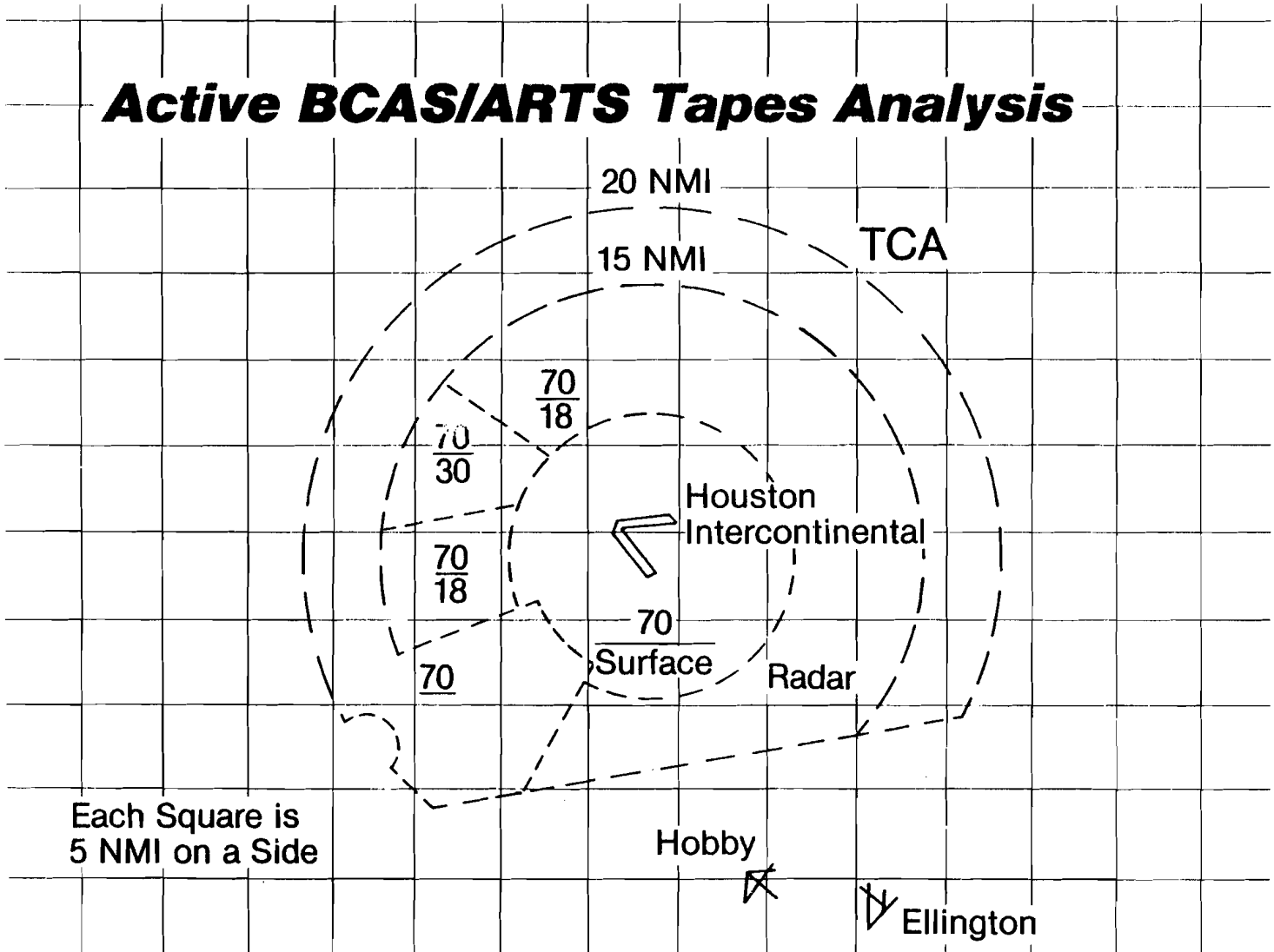


I. Program to Date

Principal Activities

- Surveillance Performance
- **Balance of Safe Resolution with Acceptable Alert Rates**
- Impact on ATC System/Cockpit
- Radio Frequency Interference/Compatibility Studies

Active BCAS/ARTS Tapes Analysis



I. Program to Date

Principal Activities

- Surveillance Performance
- Balance of Safe Resolution with Acceptable Alert Rates
- **Impact on ATC System/Cockpit**
- Radio Frequency Interference/Compatibility Studies

I. Program to Date

Principal Activities

- Surveillance Performance
- Balance of Safe Resolution with Acceptable Alert Rates
- Impact on ATC System/Cockpit
- **Radio Frequency Interference/Compatibility Studies**

II. Planned Program

1. Complete RBX Testing (FAA T.C.)
   - Technical Data Package to Operating Services

2. Complete Radio Frequency Interference/Compatibility Analysis

3. Design & Fabricate Basic Unit Enhancements (Lincoln Lab)
   - Bearing Capability for PWI
   - No-Altitude Mode C Tracking

4. T&E of Enhanced Units
   - Flight Test & Refine BCAS/BCAS Coordination Logic
   - Continue Evaluation of Logic Performance
   - Determine Utility of PWI
   - Gain More Experience in Operational Impacts

II. Planned Program

5. Evaluate Industry Fabricated Air Carrier Version
   - Dalmo Victor Contract (Deliver 3/81)
     - Industry Production Techniques
   - Basic & PWI Capability
   - T&E - FAA Technical Center
   - T&E - ARINC/Operational Airline
     - Further Operational Experience

6. Standards & Specifications
   - National Aviation Standard
   - RTCA Minimum Operational Performance Standards (MOPS), RTCA-147

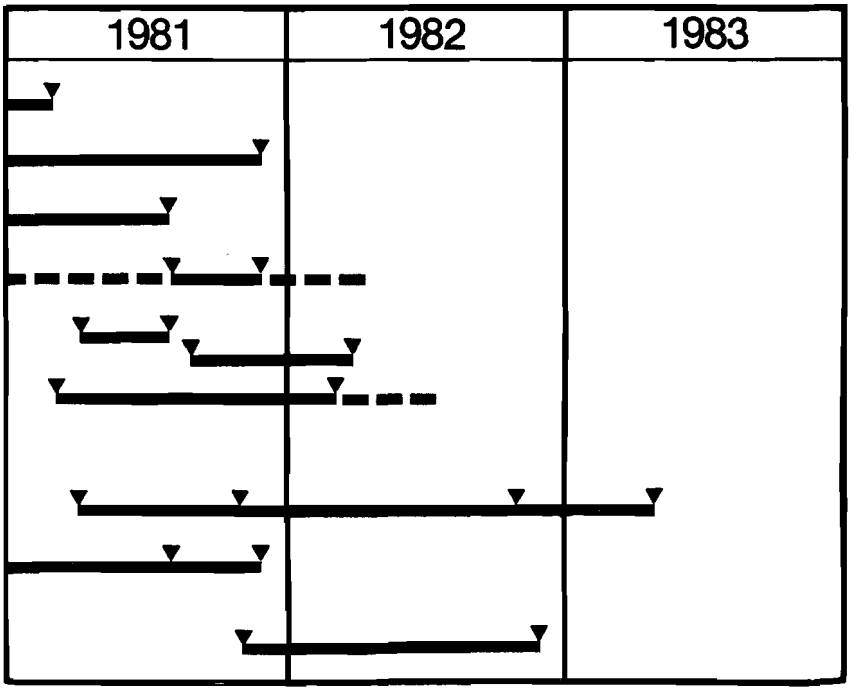
7. Develop Ground Certification Facility
   - Bench Test Simulator for Active BCAS Certification

II. Planned Program (cont.)

8. Fabricate and Test General Aviation Version
   - Design (Lincoln Lab)
     - Lower Power
     - Reduced Range
     - Minimized Cost
   - T&E (Lincoln Lab)

9. Investigate Helicopter Applications
   - Lincoln Lab Models
   - Low Altitude; Rotor/Coverage Problems, Etc.
   - Characterize Performance

Active BCAS
Planned Program Schedule



Basic

1. RBX
2. Compatibility Anal.
3. Enhancements
4. Further T&E
5. Dalmo Victor
6. Stand. & Specs.

Other

7. Ground Cert.
8. G/A Version
9. Helicopter Appl.

OPERATIONAL FLIGHT TEST
OF THE
ACTIVE BEACON COLLISION AVOIDANCE SYSTEM

Thomas P. Berry
ARINC Research Corporation

28 January 1981

Yesterday and today you have been briefed on the active BCAS development program. The requirements for the system and how it fits into the overall separation assurance program, the design of the developmental hardware, and its performance - the design of the logic, and its performance. You have been briefed on flight tests of the Lincoln Labs BCAS experimental units conducted at the FAA Technical Center. I hope you were able to visit the Tech Center flying lab and see that test installation as well as see the Lincoln equipment on display. Dick Sobocinski has just described the active BCAS equipment that Dalmo Victor is producing for the FAA. His last two slides addressed a program to fly that equipment aboard air carrier aircraft. I'll talk about that program.

ARINC Research Corporation's current involvement in the active BCAS development program is the management, data collection and data analysis for this operational flight evaluation program. We refer to it as the "Operational flight test of the active BCAS".

The objectives of the operational flight test are, first, to conduct an extended assessment of alarms that occur in normal air carrier operations, and second, identify requirements (if any) for new or modified pilot or ATC procedures. We intend to see how often alarms occur, what are the circumstances that brought about the alarms, and what would be the impact on the flight and the ATC system if the crew had maneuvered (or limited a maneuver) in response to the alarm.

This analysis will give us a good picture of the frequency of each type of alarm - positive, limit, or negative, and where in the ATC system they happen. We will also have a picture of what perturbations the ATC system exhibits as a result of aircraft following active BCAS advisories.

The principle areas of investigation are listed on this slide. We want to find out how often alarms occur and what causes them. Each time an alarm condition occurs, the test recording system will record a number of performance data, which I'll cover later. We will use the on-board data recordings to establish total alarm rates, frequency of each type of alarm, frequency of alarm by altitude strata and correlation of alarm occurrence with system perceived airspace density. We will correlate alarm occurrence with own aircraft state - that is climbs, decents and approximate speeds.

Through the examination of the tracks, we will classify which alarms are false - that is those alarms that might occur when there is in fact no other aircraft to cause the alarm. We will examine the track records and cockpit observer data sheets to identify any alarms that are clearly undesirable - those that occur when the BCAS operates correctly, but the ATC system or flight crew intentions would have obviously resolved the projected conflict situation. We will also look for those alarms that are useful - perhaps a limit vertical speed command that would have provided better separation on the other aircraft.

We are especially interested in the operation of the active BCAS in high density airspace. We will be looking at the track data to find any indication of system saturation, and the densities at which system saturation occurs. We will see how the system handles saturation, and how it recovers.

Along with the examination of system operation in high density airspace, we will look at the effect of sensitivity control on alarm rates - the question we are interested in here is "Are the sensitivity levels right, can we be somewhat more liberal in protection volumes, or is there evidence that slight reduction in protection volumes would safely and significantly reduce alarm rates?"

We will examine each alarm occurrence to see if some minor changes in flight procedures or ATC procedures should be investigated to reduce alarm rates - particularly undesirable alarms. We know, for example, that there are certain flight maneuvers that can cause the ground proximity warning system to activate. Maybe there are certain maneuvers that could cause a BCAS alarm. I don't know that there are any such maneuvers, but if they happen in normal operations, we expect to see them during this test.

The two sets of active BCAS avionics will be installed in two B-727 aircraft. The 727 was selected because it has space in the avionics compartment to accommodate the avionics, clock, and recorder system, and the cockpit has room for the display and up to two observers in relative comfort. The 727 also makes up more than 40% of the turbojet air carrier fleet, and the FAA will also use a 727 for its flight tests at the Tech Center.

Dick Sobocinski showed you the general location of the equipment in the air carrier aircraft. The antennas will be mounted on the top and bottom of the aircraft and the processor, recorder and clock will be mounted in the avionics compartment. The display will be mounted in the cockpit, however it will be located in such a manner that it will not be visible to the flight crew.

This slide shows the location of the display in relation to the cockpit seats. The display will be just aft of the second officer's console and below the level of the desk. It will be faced toward the jump seat where the test observer will be seated. This installation permits the test observer from ARINC Research to see the display and reach the controls. It also allows a limited capability for interested non-test observers to see the display. We expect FAA flight operations personnel, air carrier flight

management personnel, BCAS program management personnel and other similar observers will be interested in seeing the system in operation.

The operational flight test is primarily for data collection. It is not a controlled experiment inasmuch as flight profiles, encounter geometry, frequency or scenarios will not be established prior to the test. The aircraft will be operated in a routine manner. System stimuli will not be pre-defined, and no pass-fail criteria will be established.

We will collect data from a minimum of 900 hours of normal air carrier flight operations. The flight operations will cover the full range of operations of the selected air carrier, and will include operations into dense airspace as typified by TCA's and also into less restrictive terminal areas. While we don't expect to see every combination of ATC procedures and airspace densities, the test will expose the active BCAS to a wide range of conditions. To ensure that we don't unnecessarily bias the test, we do not plan to tie the test aircraft to specific repeatable routings. They will be scheduled as a regular part of the air carrier fleet. We expect to have an ARINC Research observer on about 40% of the flights, to correlate the flight conditions, ATC situations and cockpit activity with alarm events.

The test recording system will be event-driven. Each time a projected conflict situation is sensed by the Active BCAS, the recording system will record the data shown on this slide. The GMT time will allow us to correlate the event with the estimated location of the aircraft, based on its flight plan and out-off-on-in (OOOI) reports. We will use the track files of all tracked aircraft, the range, range-rate, altitude and altitude rate of the intruder, own altitude and perceived airspace density to develop a chronological record of each alarm event.

In addition to providing a chronological record of the event, this record will be used to develop statistical data on the operation of the system. This statistical data will include the frequency of alarms, types of commands generated, altitude dispersion, alarm rates as a function of density, duration of alarm, point of closest approach, and conflict geometry. This record can also be used to drive an event recreation where own aircraft reactions can be varied to study the effect of following the active BCAS commands on the miss distance, ATC system and flight profile of the aircraft.

In addition to the data recorded by the test recorder, we will use 000I data from the air carrier to estimate location of the aircraft in relation to its departure or landing airport at the time of the alarm. In many of the incidents we will have the record of the ARINC Research observer, and when a 727 rated observer is aboard, he will be asked to provide an evaluation of the incident to include subjective evaluation of the work-load and ATC system impact that would have resulted if the crew had followed the BCAS command.

Three phases of data analysis are planned. The first phase will consist of a "quick-look" examination of the data to determine if there are any problems with either the BCAS or recording system operation. At the same time, the time of each event on the tape will be determined for correlation with observer records.

The next step in the data analysis will be the development of the chronological record of the alarm event. The recorded data will be merged with the observer record to form this record. The chronological record will be manually examined to classify, where possible, the alarm as true, false, undesirable, or desirable.

Following the analysis of each individual alarm, statistical data accumulated over the course of the test will be analyzed to develop the alarm statistics I mentioned earlier.

The operational flight test is the first time that the active BCAS will be operated in its intended environment for a significant amount of time. This will be the first time that air transport industry personnel will be able to gather a large amount of relevent data on the operation of the system in relatively short time - data that was generated with the randomness of the "real world" that they see every day.

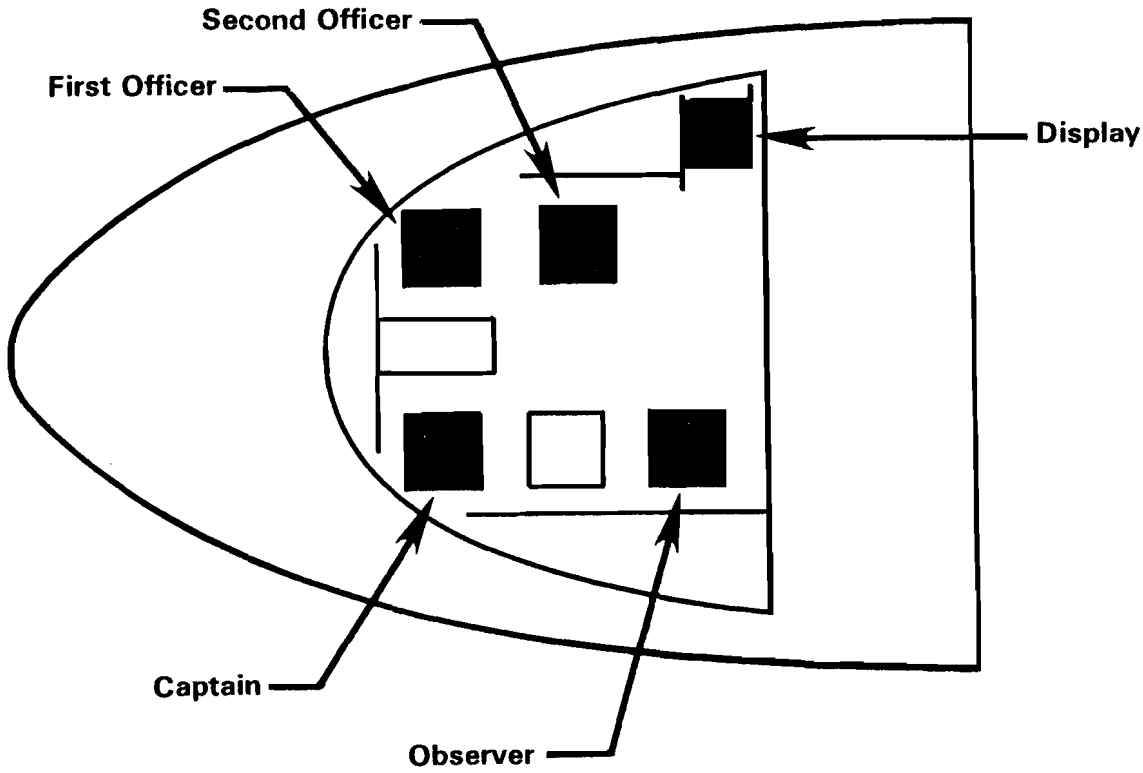
OBJECTIVES

- To conduct an extended assessment of alarms that occur in normal air carrier operations
- To identify requirements (if any) for new or modified pilot or ATC procedures

PRINCIPAL AREAS OF INVESTIGATION

- What is the alarm rate of the active BCAS in an operational environment and under what circumstances do these alarms occur?
- What is the false alarm rate?
- How many of the alarms are clearly undesirable?
- How many of the alarms are useful?
- How does the active BCAS performance degrade in high-density airspace?
- What is the effect of sensitivity control?
- Can minor operational changes reduce the alarm rate?
- What new flight and ATC procedures appear to be warranted?

DISPLAY LOCATION



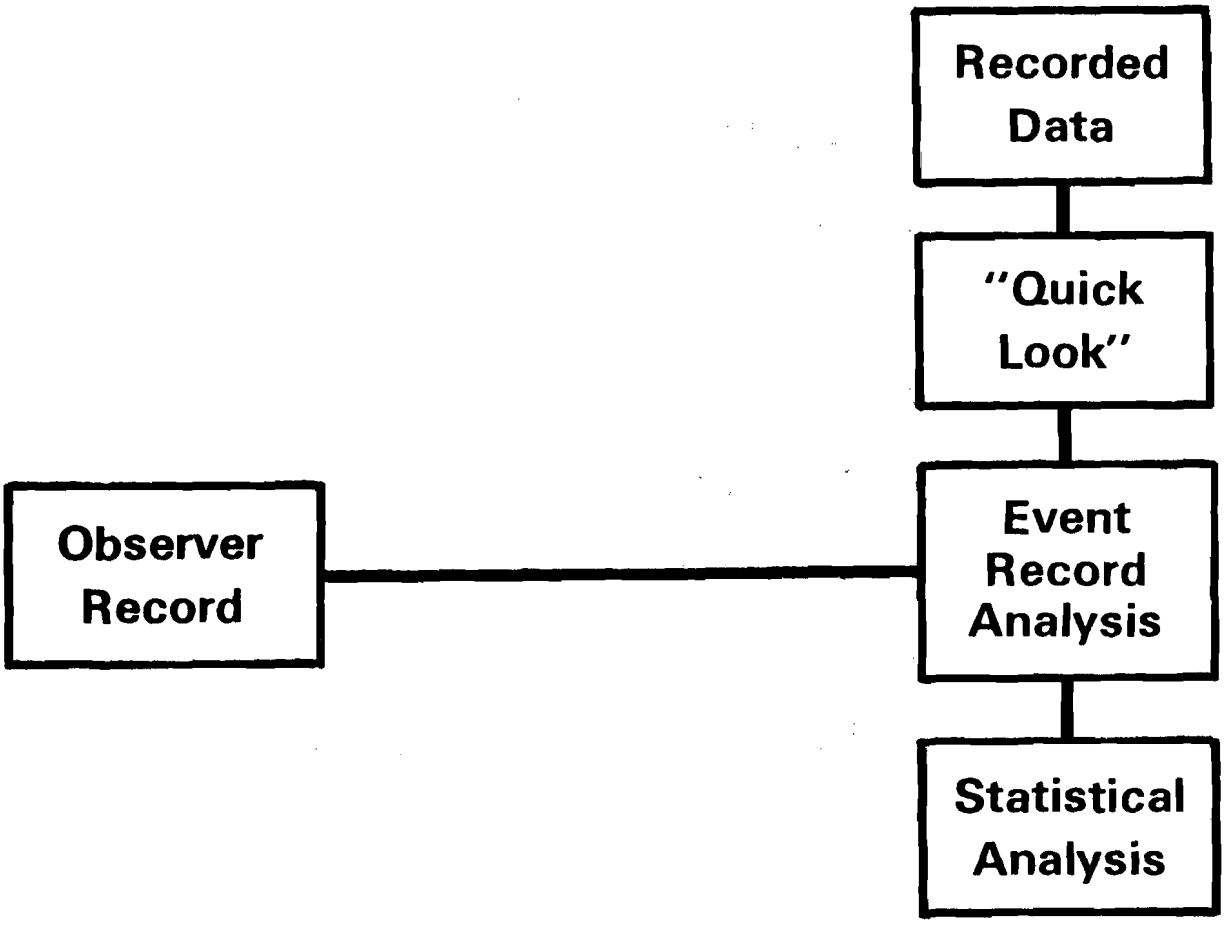
DATA COLLECTION

- 900 Hours Minimum Flight Time
- One Air Carrier
- All Classes of Airspace – Group I and Group II TCAs, TRSAs, and Standard Control Areas
- Two B-727 Aircraft
- Cockpit Observer

RECORDED DATA

- GMT Time
- Command Type
- Track Files of all Tracked Aircraft
- Range and Range-Rate of Intruder
- Altitude and Altitude-Rate of Intruder
- Own Altitude
- Own Transponder Code
- Perceived Airspace Density

DATA ANALYSIS



ACTIVE BCAS SURVEILLANCE PROCESSING

JERRY D. WELCH

M.I.T. LINCOLN LABORATORY

OVERVIEW — BCAS SURVEILLANCE

- ACTIVE BCAS SURVEILLANCE ELEMENTS
- DABS SURVEILLANCE
- ATCRBS SURVEILLANCE

ACTIVE BCAS ELEMENTS

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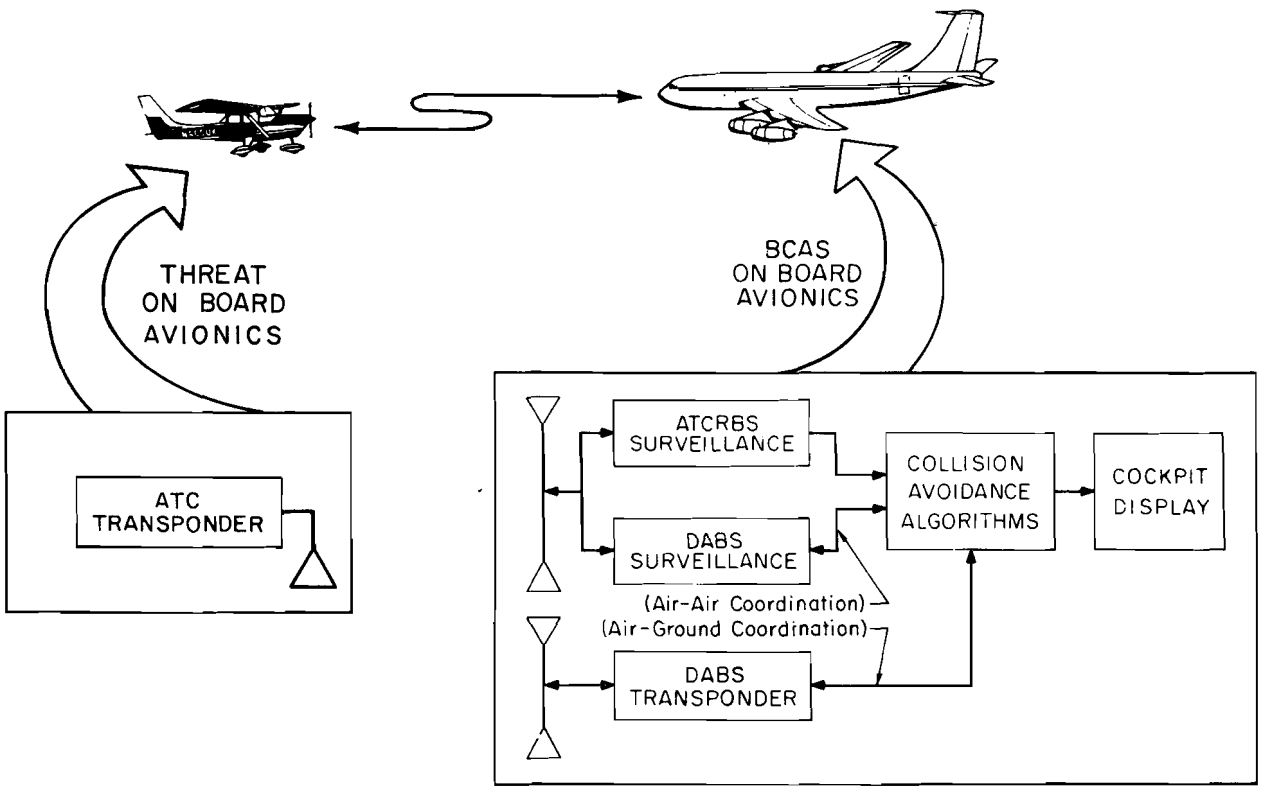
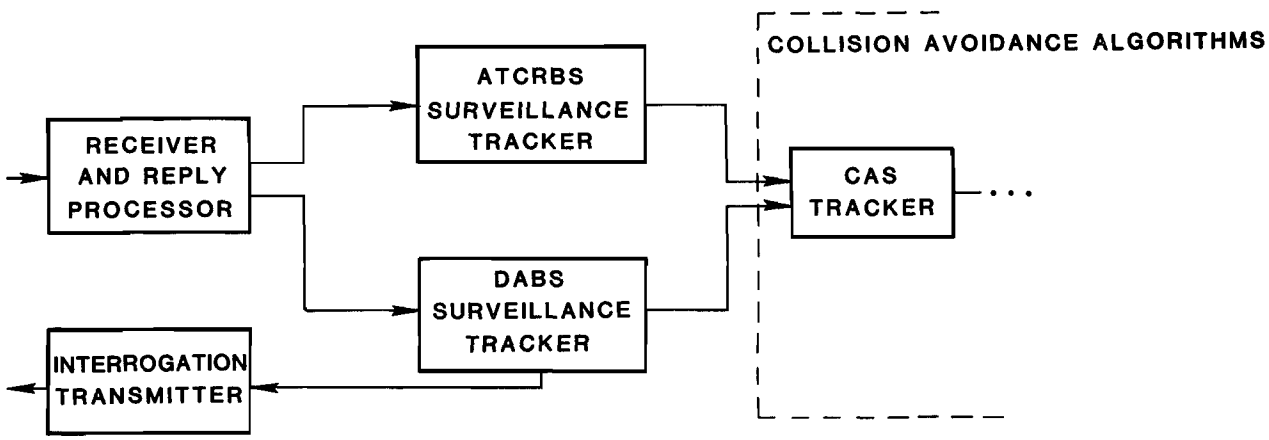


SURVEILLANCE ELEMENTS OF BCAS AVIONICS



DABS SURVEILLANCE

DABS SURVEILLANCE — FUNCTIONS

DETECT DABS TARGETS

SCHEDULE DABS AND ATCRBS INTERROGATIONS

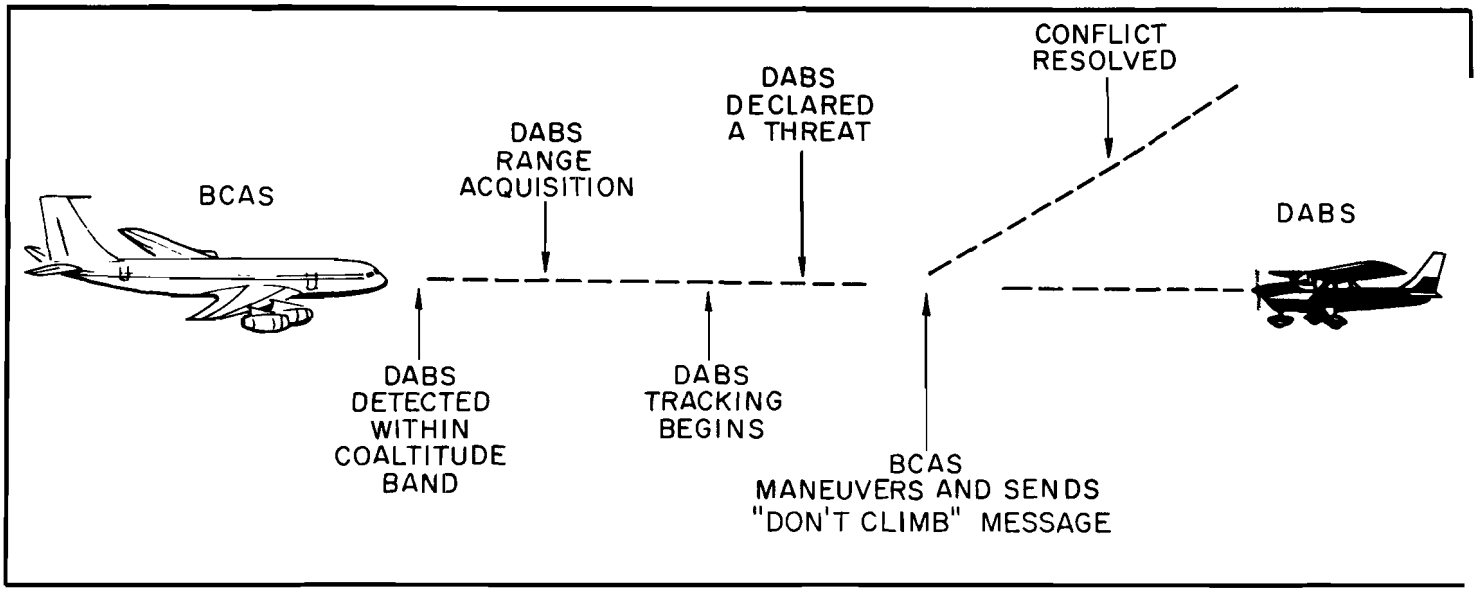
ASSOCIATE DABS REPLIES WITH TRACKS

MAXIMIZE TRACK PROBABILITY FOR TARGETS OF INTEREST
(I.E., OVERCOME EFFECTS OF MULTIPATH & ATCRBS FRUIT)

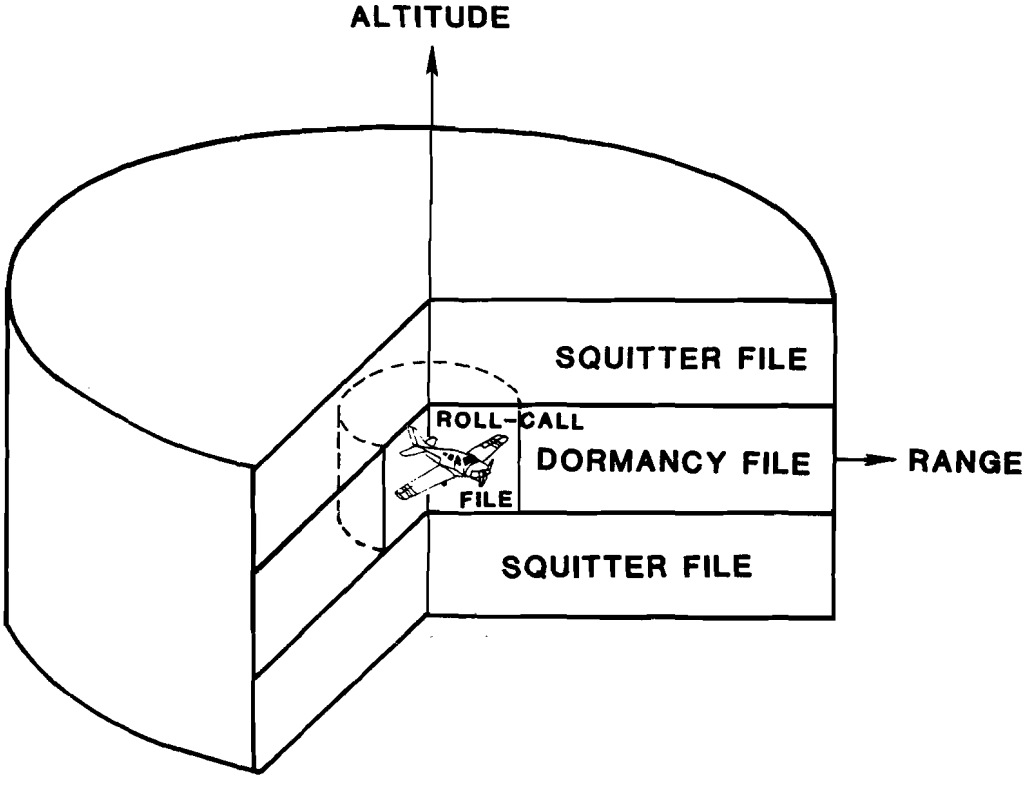
MINIMIZE DABS INTERROGATION RATE FOR ALL TARGETS

REF. FAA-RD-80-127, PAGES 18-21

DABS SURVEILLANCE
EXAMPLE OF BCAS – DABS ENCOUNTER



DABS SURVEILLANCE – RELATION BETWEEN TARGET LOCATION AND TRACK STATE



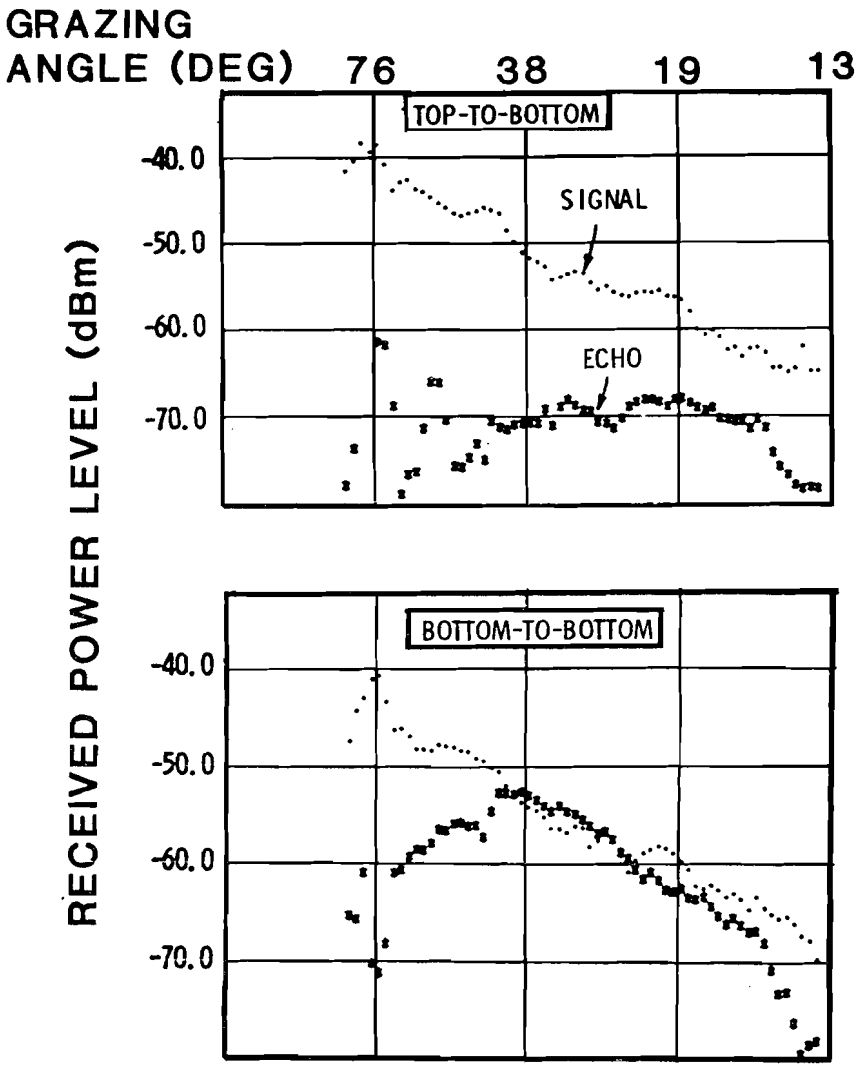
DABS SURVEILLANCE — CHARACTERISTICS

- NO FALSE TRACKS BECAUSE ADDRESSES ARE PARITY PROTECTED

- NO SYNCHRONOUS INTERFERENCE BECAUSE:
  - ACQUISITION IS PASSIVE
  - INTERROGATIONS ARE UNIQUELY ADDRESSED

- LOW-LEVEL MULTIPATH REJECTED BY:
  - DIFFERENTIAL PHASE SHIFT KEYING IN INTERROGATIONS
  - PULSE POSITION MODULATION IN REPLIES
  - DYNAMIC THRESHOLDING IN RECEIVERS

BCAS SURVEILLANCE
AIR TO AIR MULTIPATH MEASUREMENTS
(OCEAN - SEA STATE 1, ALT. - 9500 FT.)



REF. FAA-RD-77-87, PAGES 38-49

C42-1943

DABS SURVEILLANCE — CONCLUSIONS

DABS DETECTION AND TRACKING IS POSSIBLE

IN DENSE TRAFFIC (>25 AIRCRAFT IN 10 MILES)

OVER ALL TERRAIN

WITH LOW INTERROGATION RATES (< 2 PER TARGET PER SECOND)

WITH STRAIGHTFORWARD PROCESSING

ATCRBS SURVEILLANCE

ATCRBS SURVEILLANCE — FUNCTIONS

- DETECT CONVENTIONAL ATCRBS TARGETS
- ASSOCIATE ATCRBS REPLIES WITH TRACKS
- MAXIMIZE TRACK PROBABILITY FOR ALL TARGETS

  (I.E., OVERCOME EFFECTS OF MULTIPATH & GARBLE)
- MINIMIZE FALSE TRACK RATE

  (I.E., OVERCOME LIMITATIONS OF UNPROTECTED REPLY CODES)

REF. FAA-RD-80-127, PAGES 22-29

ATCRBS SURVEILLANCE GARBLE REDUCTION TECHNIQUES

- SPECIAL MODE C INTERROGATION

  REMOVES DABS TRANSPONDERS FROM ATCRBS POPULATION

- WHISPER-SHOUT INTERROGATION SEQUENCE

  DIVIDES ATCRBS TRANSPONDER POPULATION INTO SMALLER GROUPS

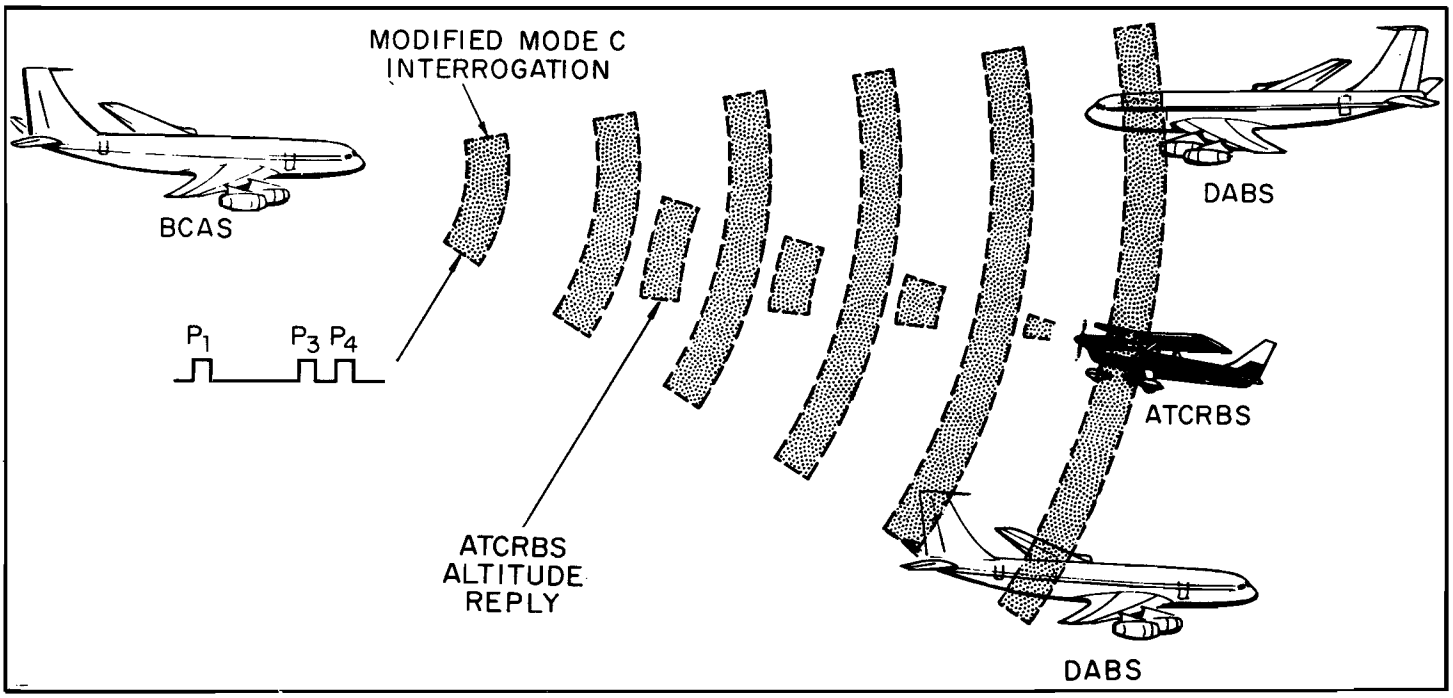
- REPLY PROCESSOR

  SEPARATES AND SORTS OVERLAPPING REPLIES, FLAGS PHANTOMS

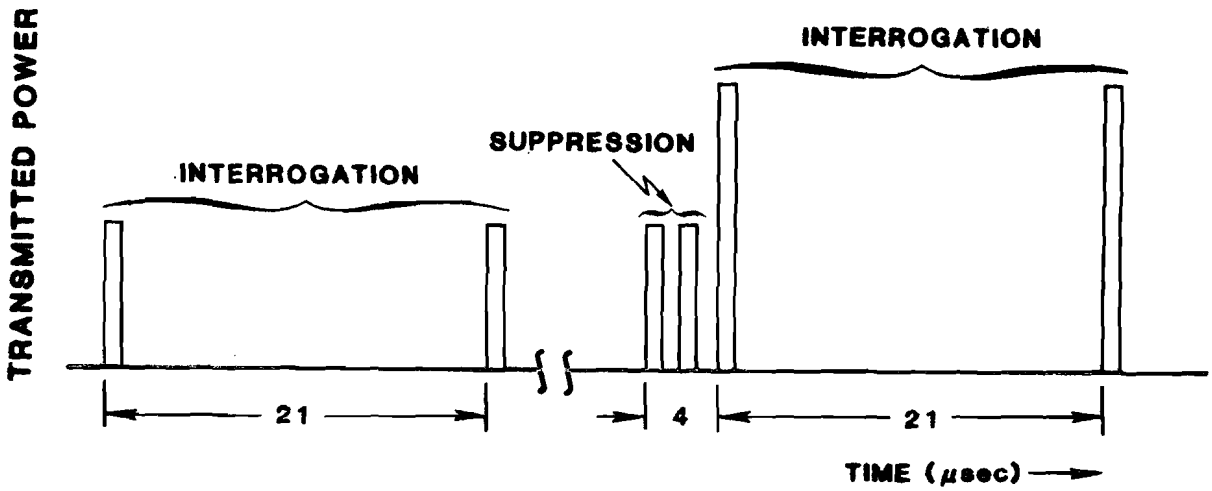
- TRACKER (REPLY CORRELATOR)

  REJECTS REPLIES WITH CORRUPTED CODES

ATCRBS SURVEILLANCE
SPECIAL MODE C INTERROGATIONS



ATCRBS SURVEILLANCE
WHISPER - SHOUT TECHNIQUE



REF. FAA-RD-80-134, PAGES 60-66

ATCRBS SURVEILLANCE REPLY PROCESSOR

- SLOPE DETECTS LEADING AND TRAILING EDGES
- UNCOVERS HIDDEN LEADING EDGES
- CLOCKS LEADING EDGE STREAM AT 8.27 MHZ (12 SAMPLES IN 1.45 μsec)
- DETECTS & BUFFERS UP TO 4 OVERLAPPING REPLIES
- FLAGS POTENTIAL GARBLED PULSES
- FLAGS POTENTIAL PHANTOM REPLIES

ATCRBS SURVEILLANCE PHANTOM REPLIES

- DEFINITION –

  REPLY WHOSE BRACKET PULSES <u>COULD</u> BE CODE PULSES OF OTHER REPLIES

- ADVANTAGES OF PHANTOM ELIMINATION –

  REDUCE PROCESSING LOAD IN SOFTWARE

  REDUCE FALSE TRACK RATE <u>SIGNIFICANTLY</u> (10 TO 1)

- DISADVANTAGE OF PHANTOM ELIMINATION –

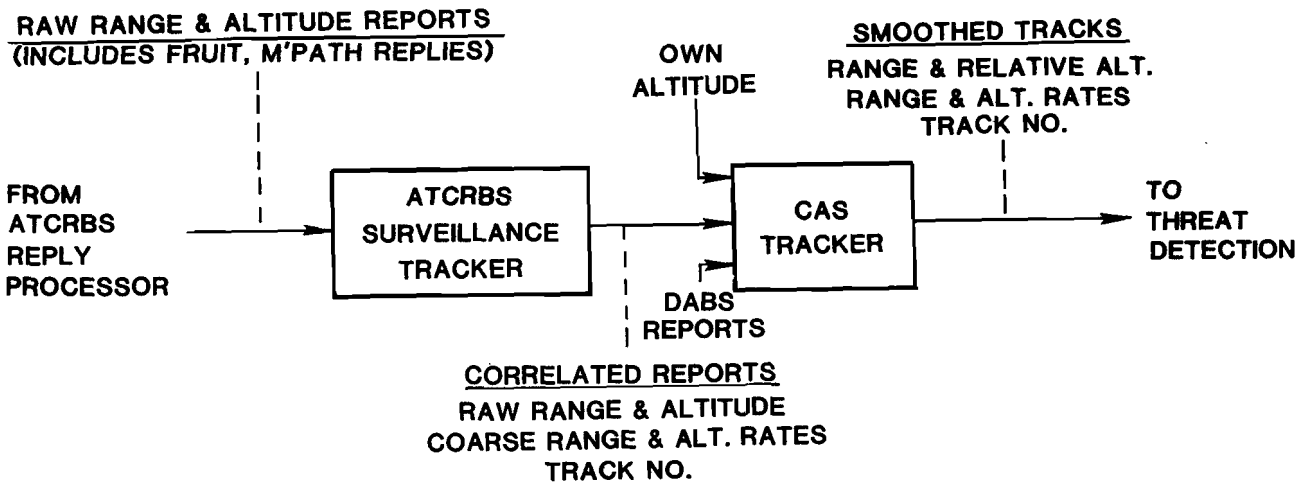
  TRACK PROBABILITY DROPS SLIGHTLY (1%)

- CONCLUSION –

  PHANTOM REPLIES SHOULD BE ELIMINATED

REF. FAA-RD-80-134, PAGES 69-73

ATCRBS SURVEILLANCE – TRACKING PARTITION



ATCRBS SURVEILLANCE — TRACKER

- NEW TRACK FORMATION

  ACCEPTS ONLY REPLIES NOT USED TO EXTEND TRACKS

  FORMS TENTATIVE TRACK IF 3 CONSECUTIVE REPLIES CORRELATE

- TRACK EXTENSION

  CORRELATES UNGARBLED REPLIES WITH EXISTING TRACKS

- TRACK MERGE

  ELIMINATES REDUNDANT TRACKS

- TRACK ESTABLISHMENT

  CONVERTS TENTATIVE TRACK TO ESTABLISHED TRACK IF ANOTHER REPLY CORRELATES WITHIN THE NEXT 2 SECONDS

TRACKING RELATIVE ALTITUDE RATE
(CAS TRACKER FUNCTION)

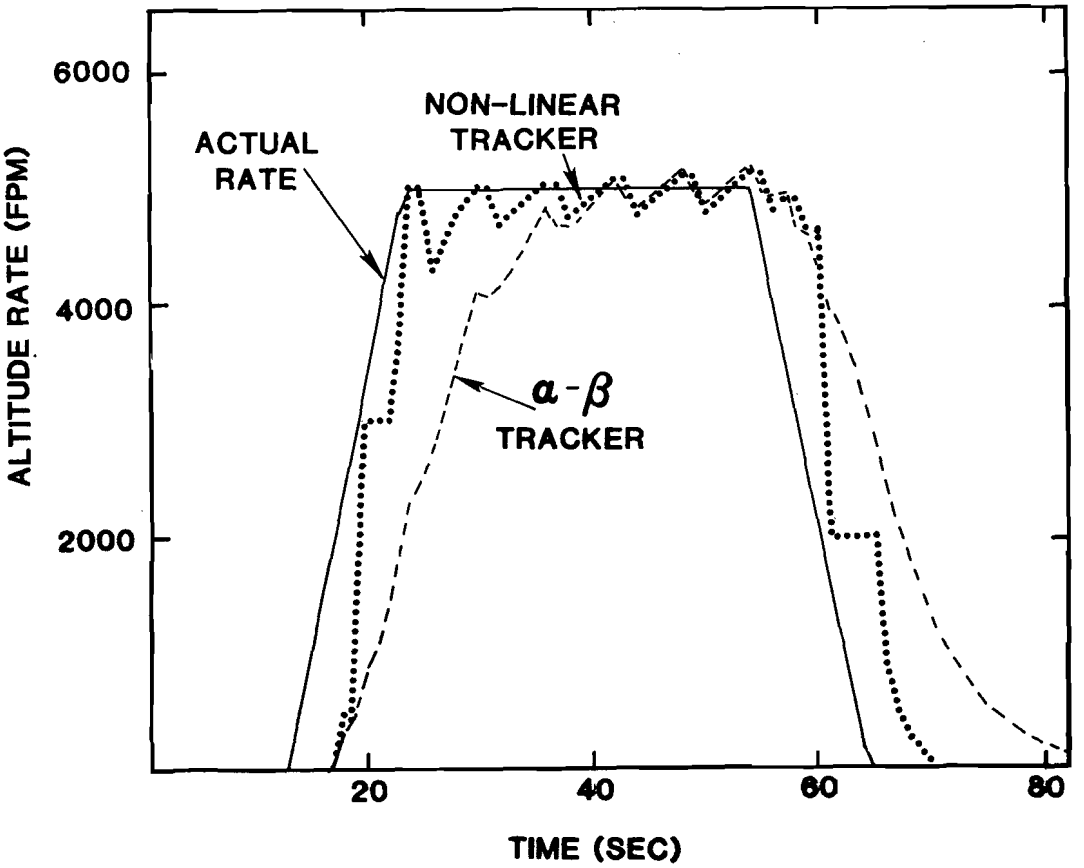
ENCODING ALTIMETERS GIVE 100 FT ALTITUDE QUANTIZATION

CONVENTIONAL (α-β) TRACKERS DO NOT RESPOND WELL TO COARSE QUANTIZATION

NON-LINEAR TRACKER TRACKS "TIME IN QUANTIZATION LEVEL", NOT ALTITUDE

HAS IMPROVED RESPONSE TO STEP INPUTS AND ACCELERATIONS

ALTITUDE RATE TRACKER COMPARISON



REF. FAA-RD-80-139, TO BE PUBLISHED

ATCRBS SURVEILLANCE OVERCOMING MULTIPATH

- DYNAMIC THRESHOLDING (DMTL)

  REJECTS LOW-LEVEL REPLY MULTIPATH

- WHISPER - SHOUT

  AVOIDS LOSS OF WEAK REPLIES DUE TO DMTL

  PREVENTS MODE CONVERSIONS IN INTERROGATIONS

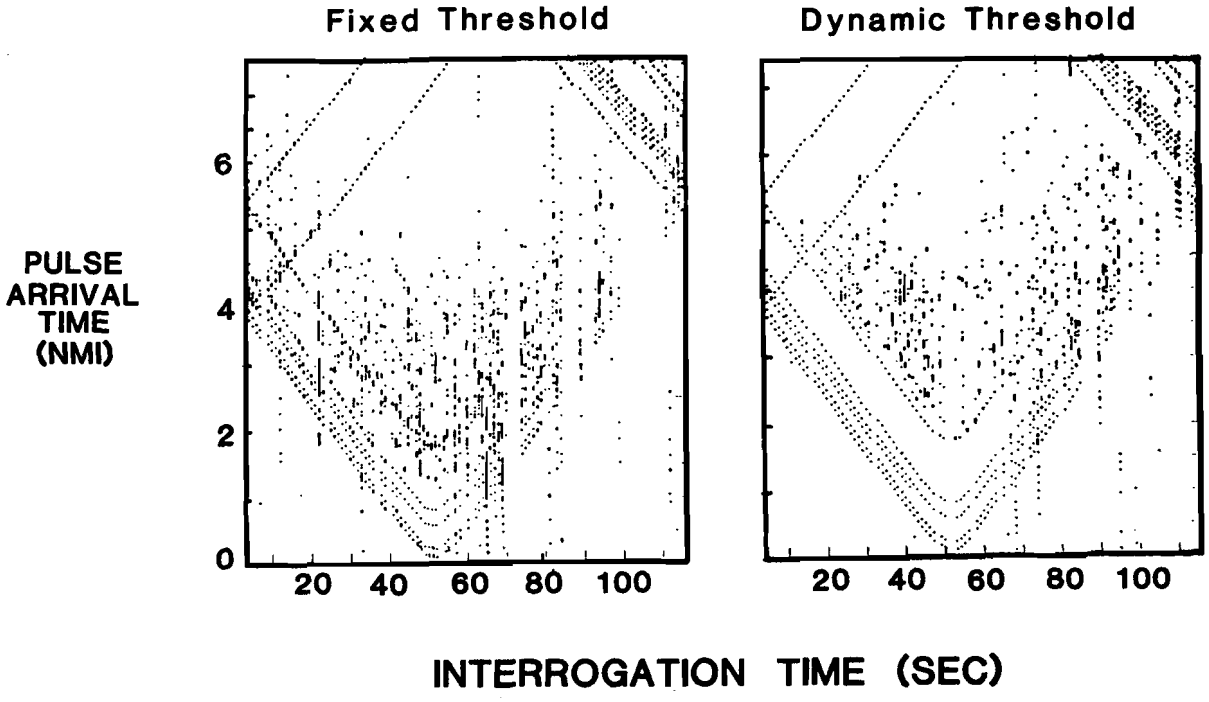
- TOP - MOUNTED ANTENNA ON BCAS AIRCRAFT

  DISCRIMINATES AGAINST GROUND REFLECTIONS

- GEOMETRICAL FILTER IN SOFTWARE

  REJECTS SPECULAR REFLECTIONS FROM THE SEA

EXPERIMENTAL RESULTS - ATCRBS DYNAMIC THRESHOLDING



REF. FAA-RD-80-134, PAGES 56-60

C42-1789A

ATCRBS SURVEILLANCE — CONCLUSIONS

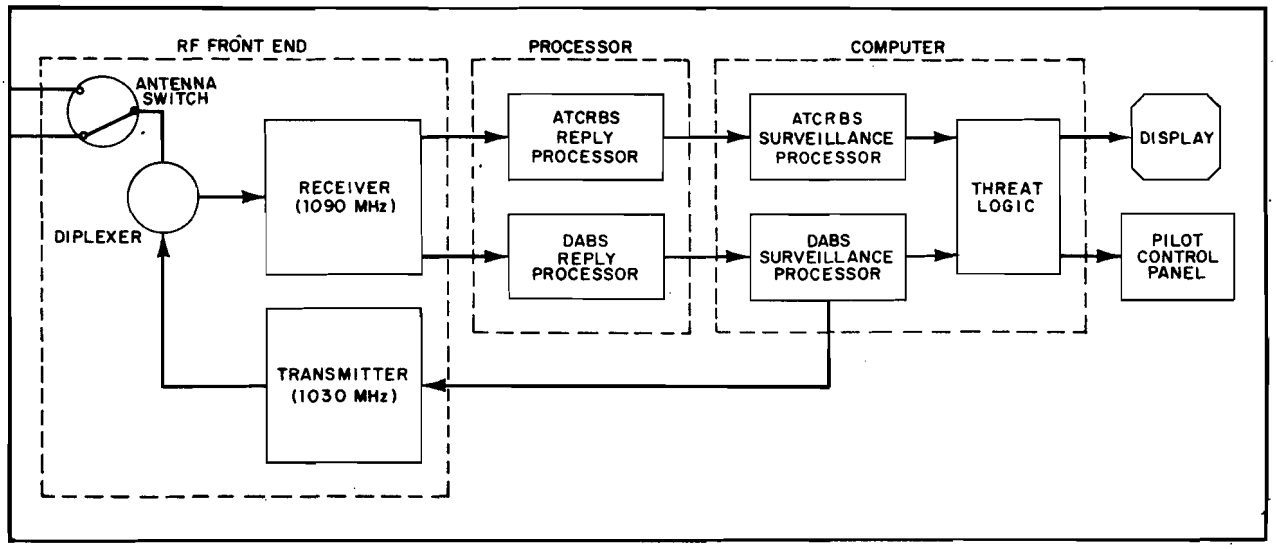
ATCRBS DETECTION AND CORRELATION IS POSSIBLE

IN MODERATE TRAFFIC (> 12 AIRCRAFT IN 10 MILES)

OVER ALL TERRAIN

WITH LOW FALSE TRACK RATES (< 2 PER HOUR)

BCAS EXPERIMENTAL UNIT



REF. FAA-RD-80-127, PAGES 30-33

ACTIVE BCAS SURVEILLANCE PERFORMANCE

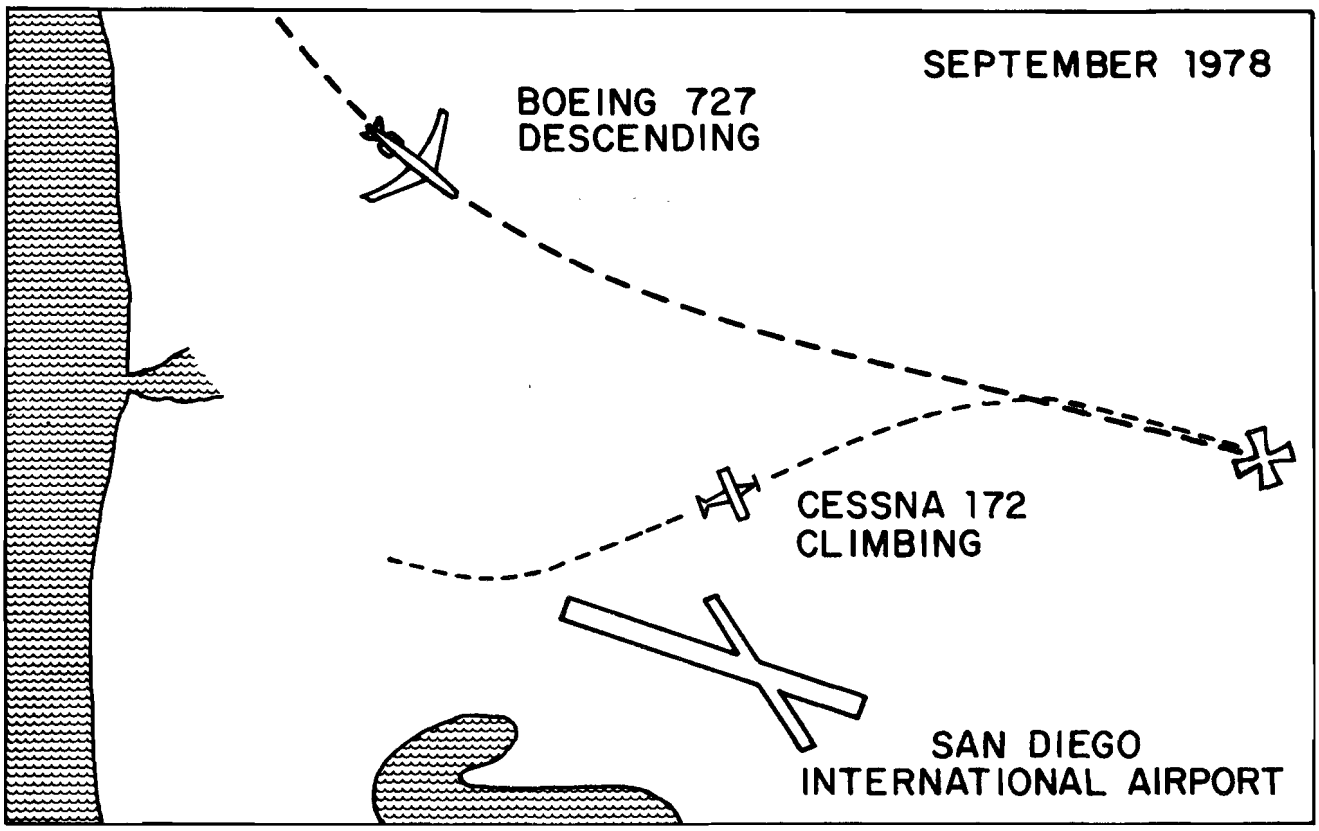
WILLIAM H. HARMAN

M.I.T. LINCOLN LABORATORY

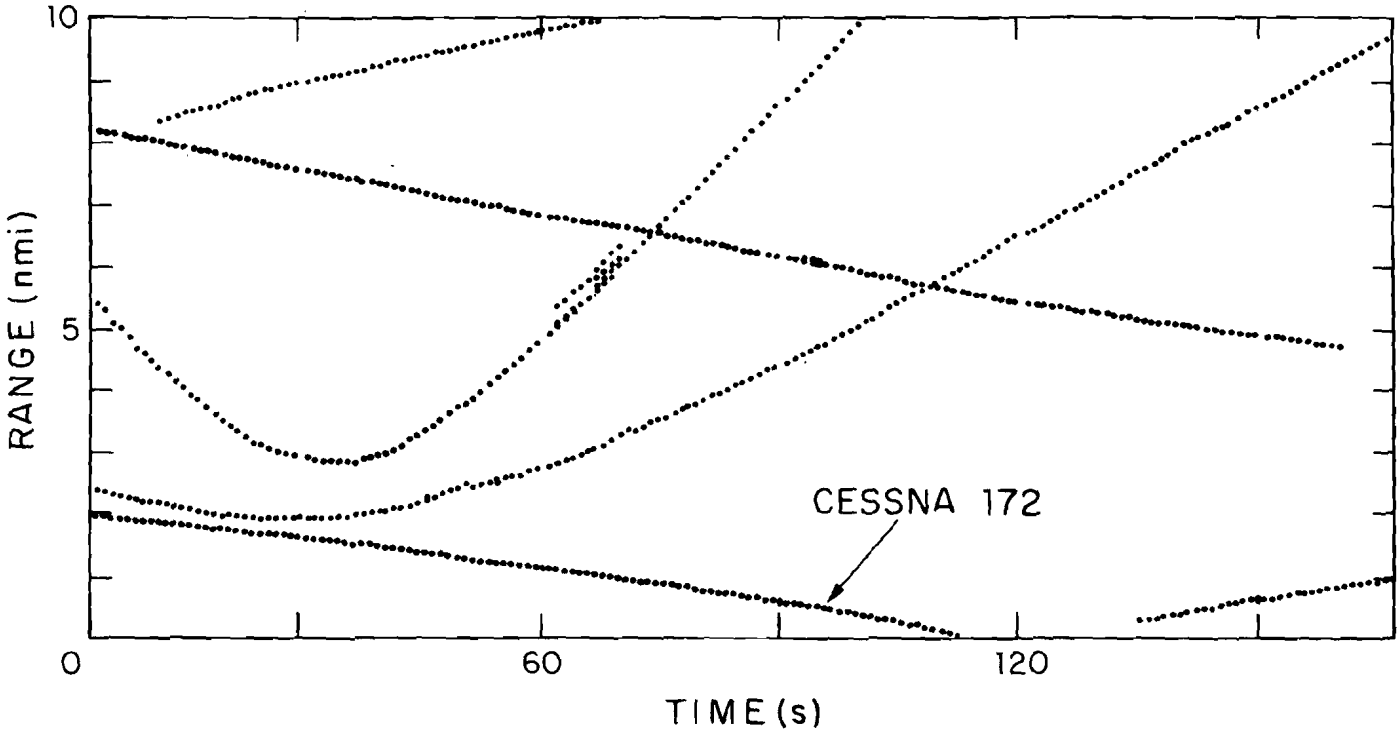
Air-to-Air Surveillance : Performance Measures

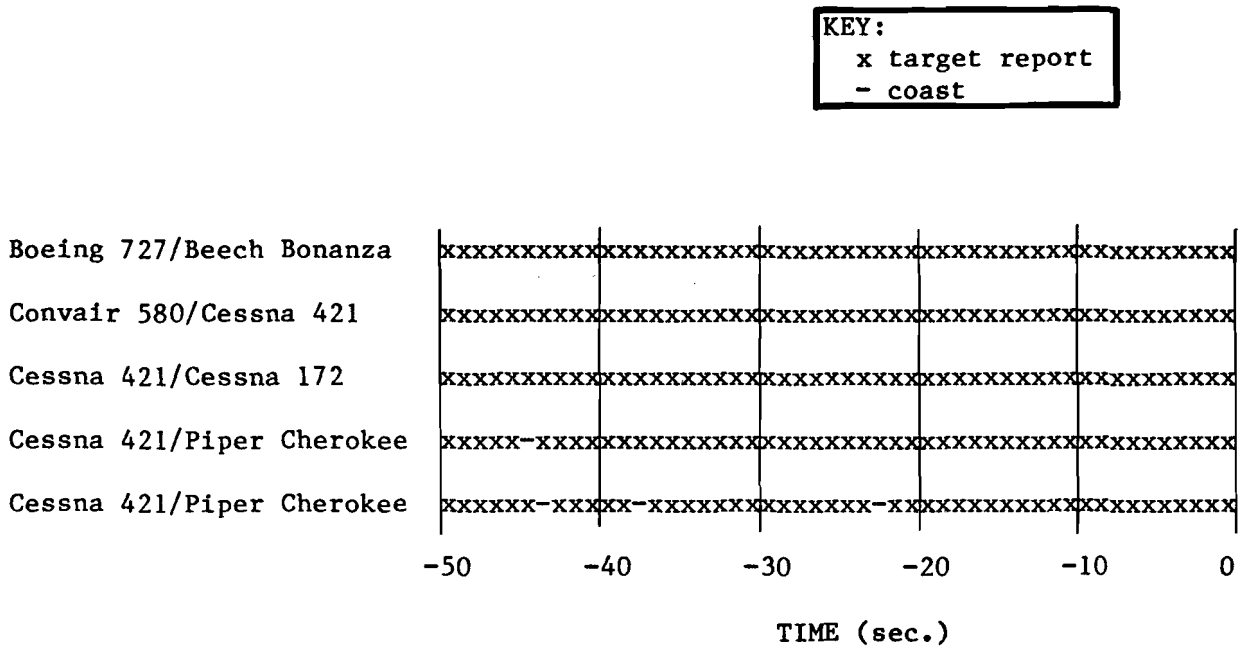
- Probability of track
- Probability of report
- Rate of false alarms

105899-N


SEPTEMBER 1978
BOEING 727
DESCENDING
CESSNA 172
CLIMBING
SAN DIEGO
INTERNATIONAL AIRPORT

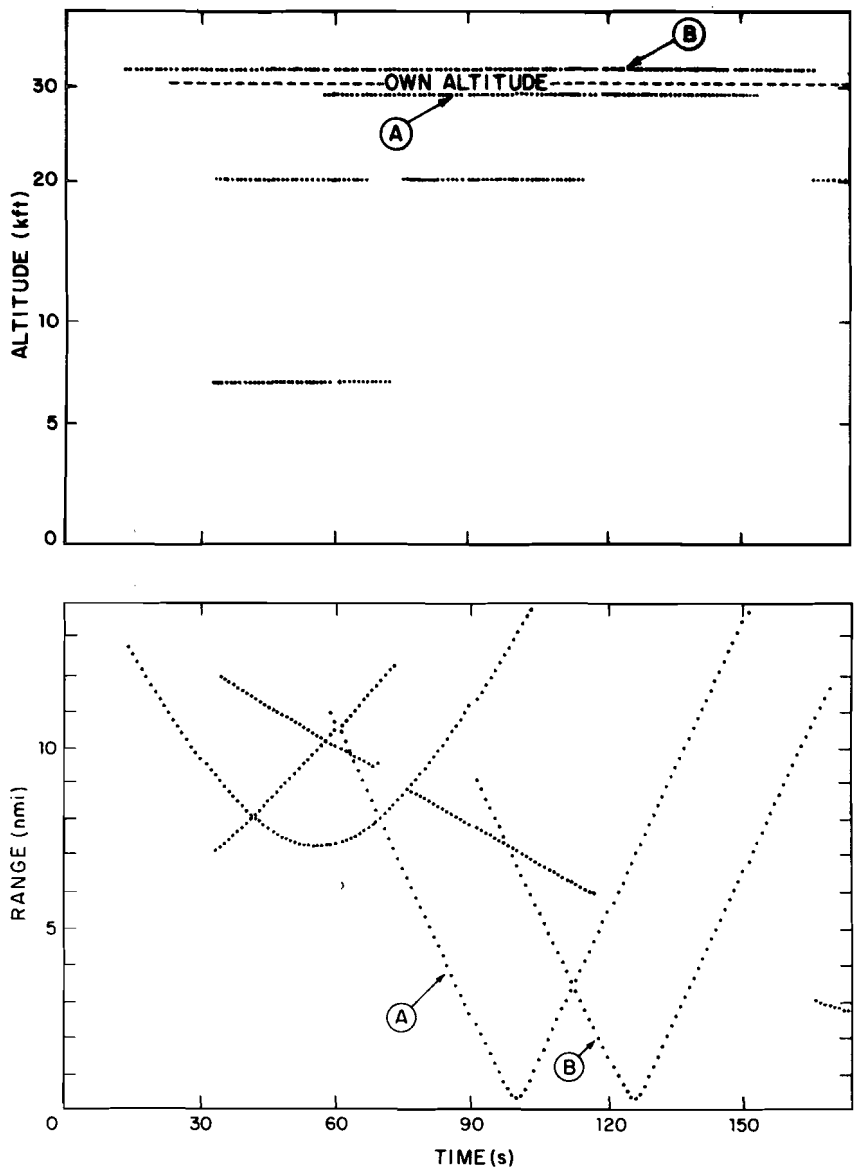
Re-enacting the San Diego Collision as a test of BCAS



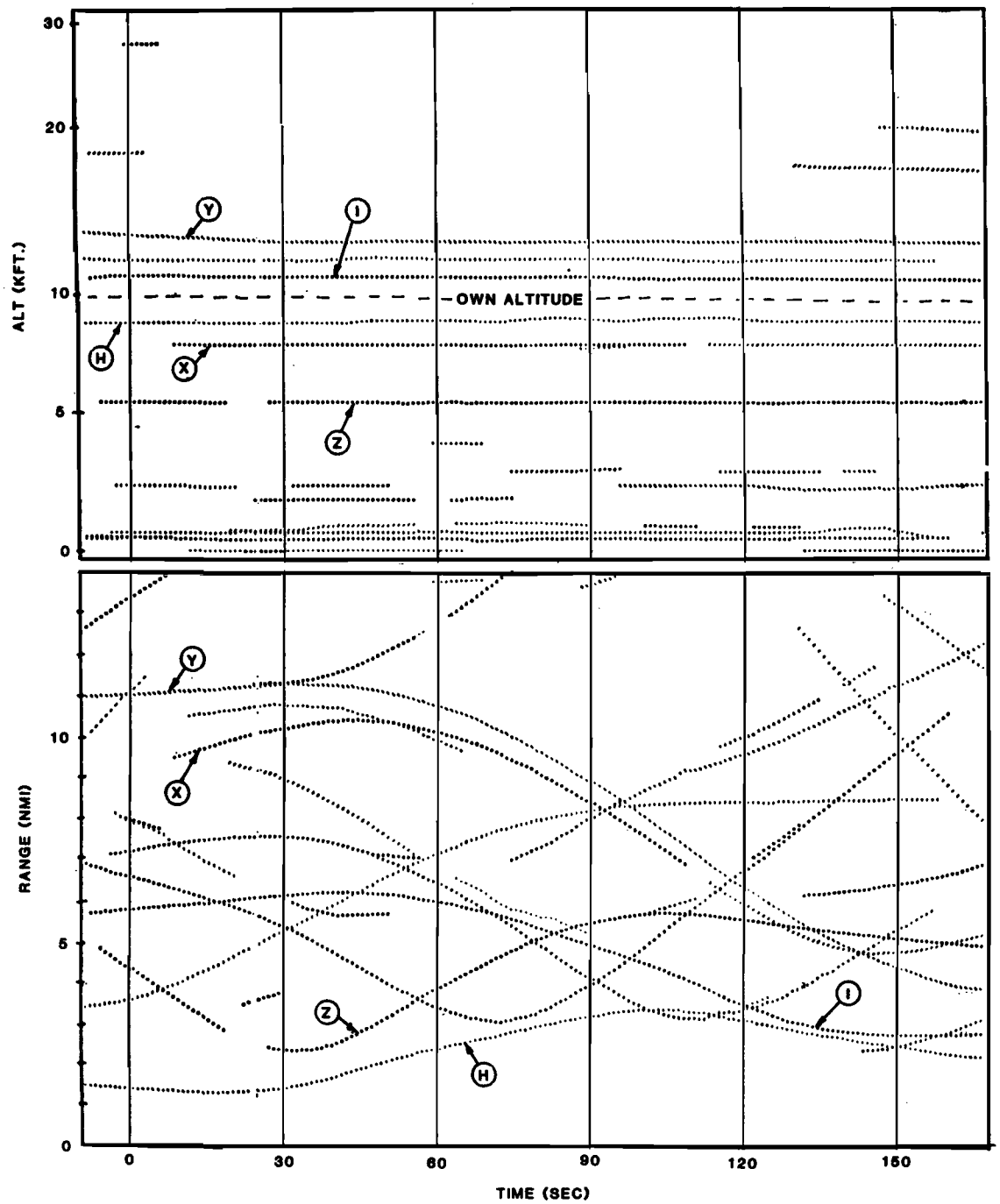


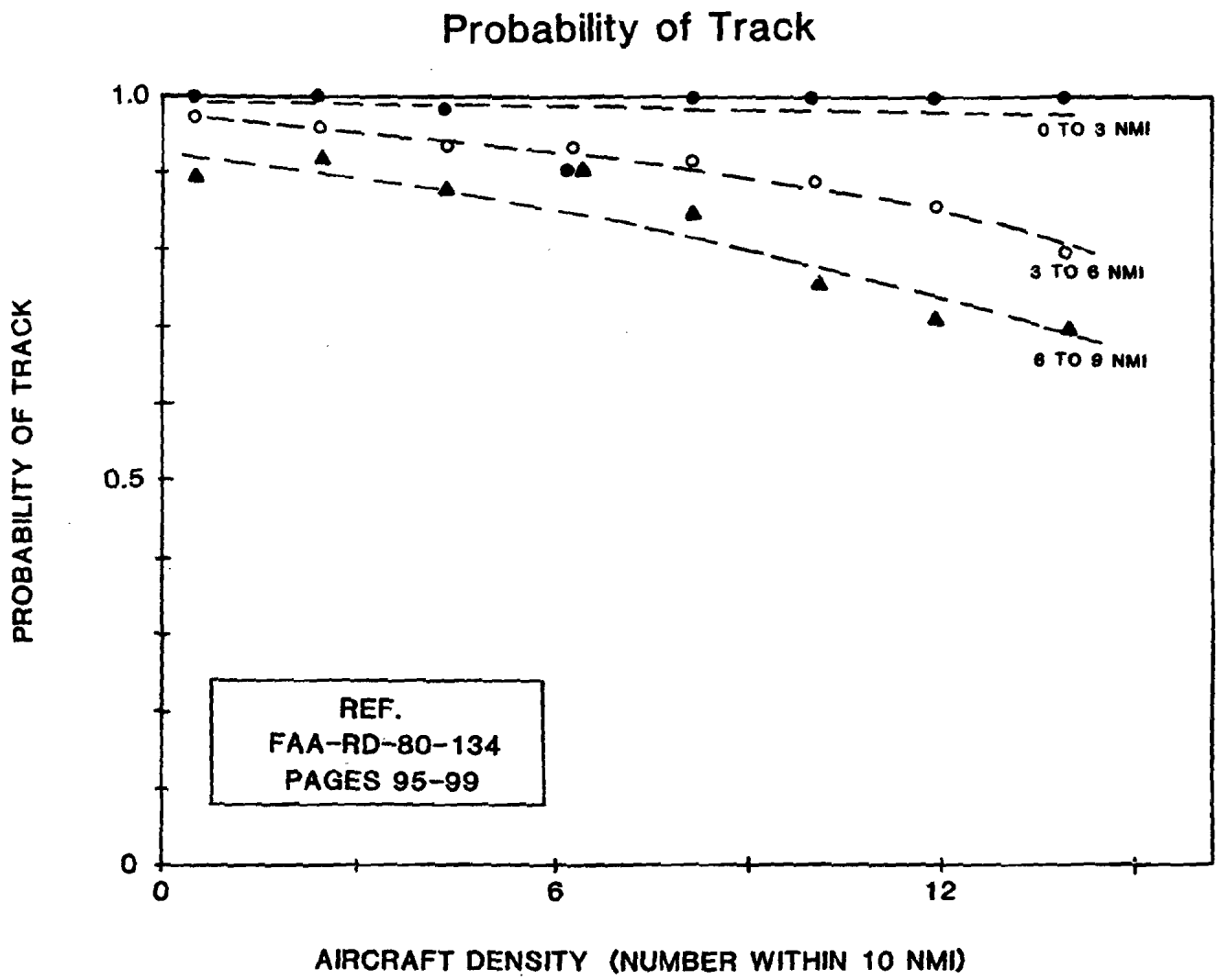
Re-enacting the San Diego Collision with Other Aircraft Types

High-Speed Encounters That Occurred By Chance

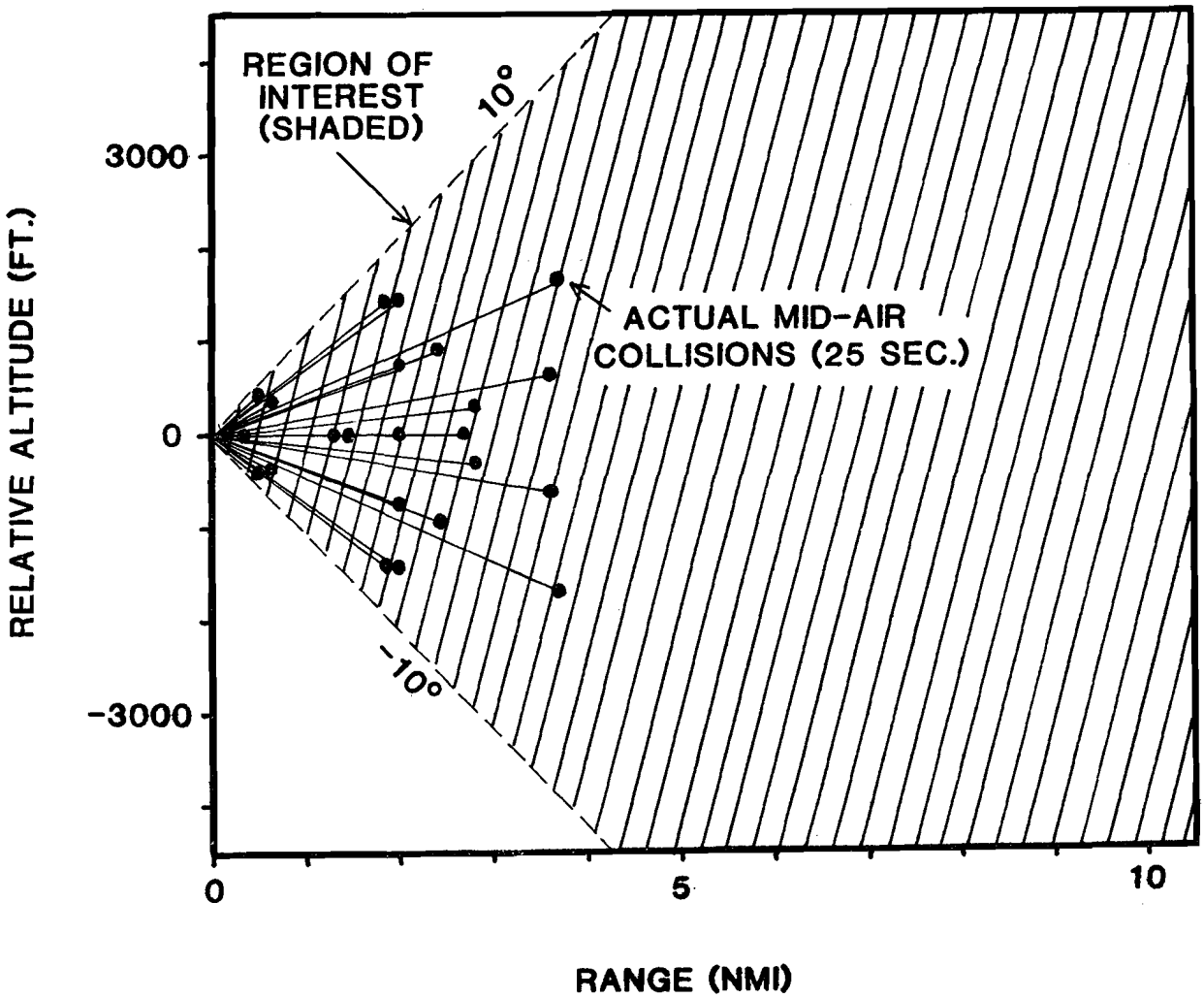


Surveillance In Higher Aircraft Density

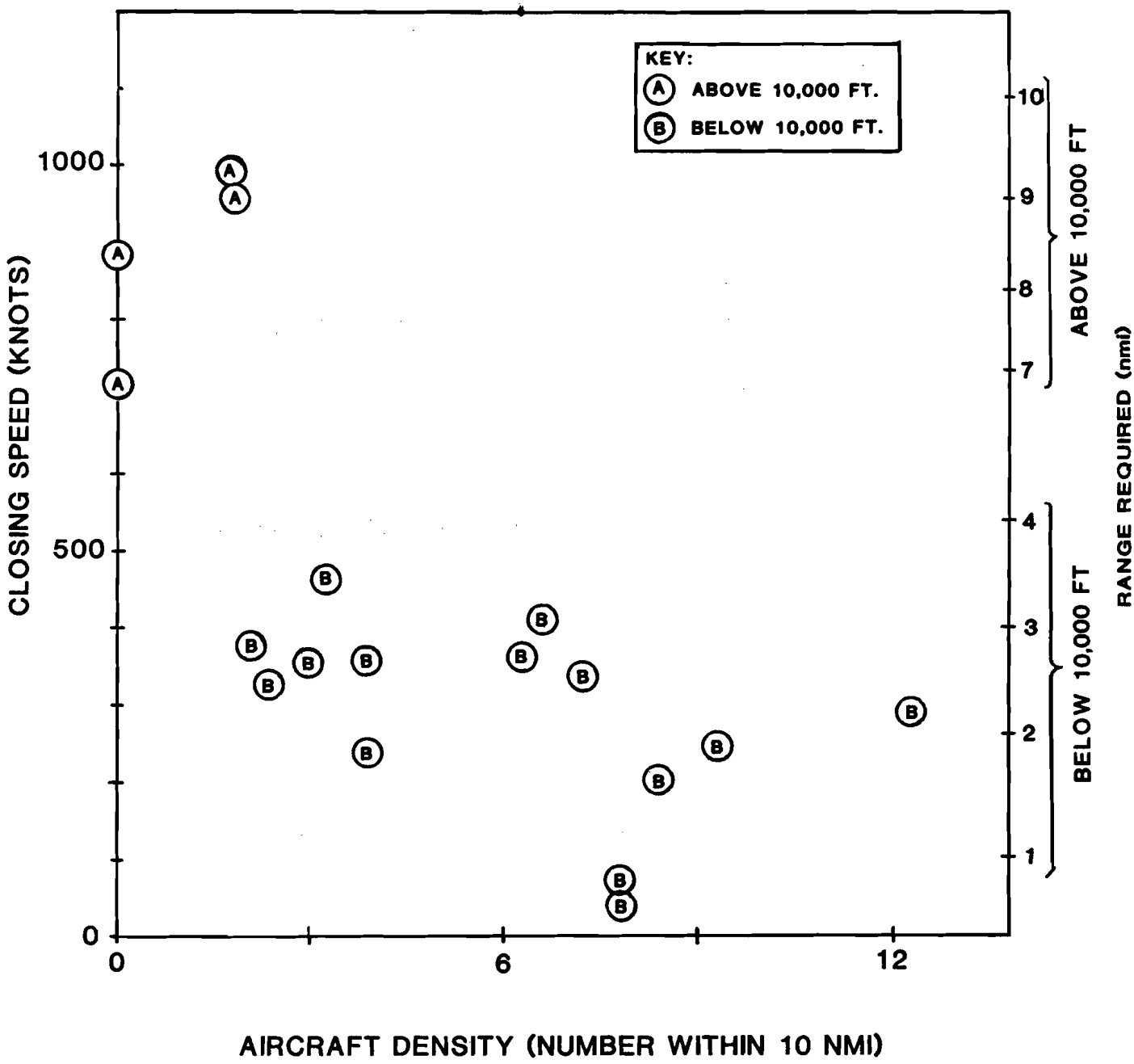



Probability of Track
1.0
0.5
0
PROBABILITY OF TRACK
0 TO 3 NMI
3 TO 6 NMI
6 TO 9 NMI
REF.
FAA-RD-80-134
PAGES 95-99
0
6
12
AIRCRAFT DENSITY (NUMBER WITHIN 10 NMI)

Geometries of Actual Mid-Air Collisions



Speed/Density Combinations



ESTIMATE OF OVERALL SUCCESS PROBABILITY

ATCRBS mode

Surveillance at time alarm is needed

$$P\,(\text{track}) = \iint P\,(\text{track} \mid \text{range, density})\; P\,(\text{range, density})$$

$$= 96\%$$

REF. FAA-RD-80-134 , PAGES 100-102.

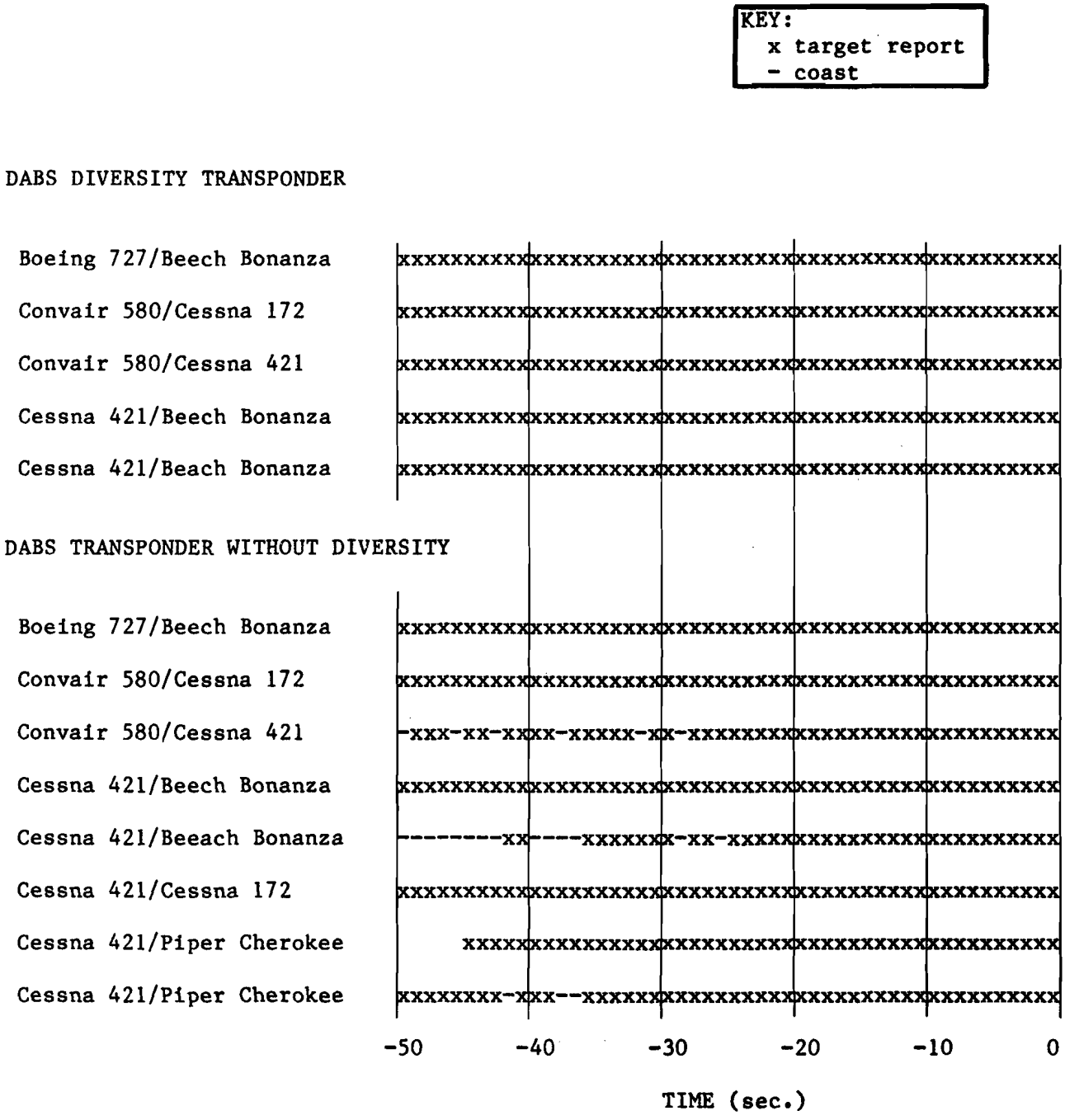
PROBABILITY OF TARGET REPORT

NUMBER OF OVERLAPS \ RANGE	0 to 3 nmi	3 to 6 n mi	6 to 9 nmi
0	.93	.90	.87
1	.89	.84	.78
2	.80	.78	.71
3	.79	.75	.66
4	not available	.69	.62

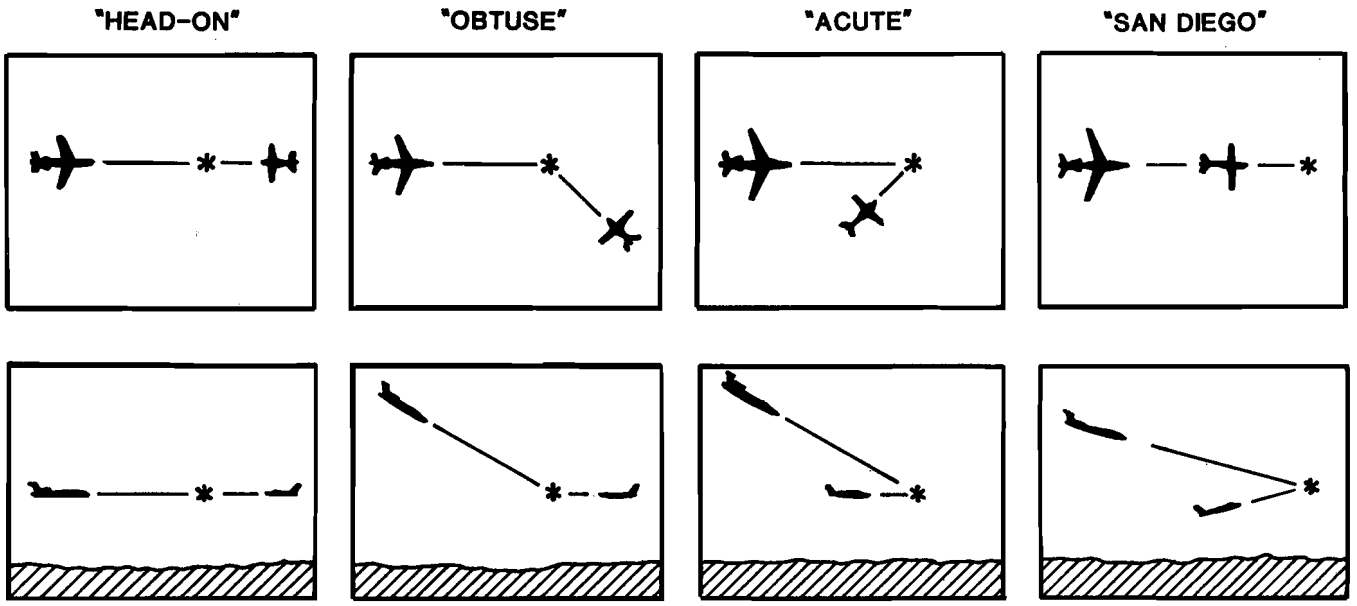
ATCRBS Surveillance Summary

Performance in Chance Encounters ("cases of interest")

Probability of Track	96%
Probability of Report	60 to 95%
Rate of False Alarms	0 in 242 hours

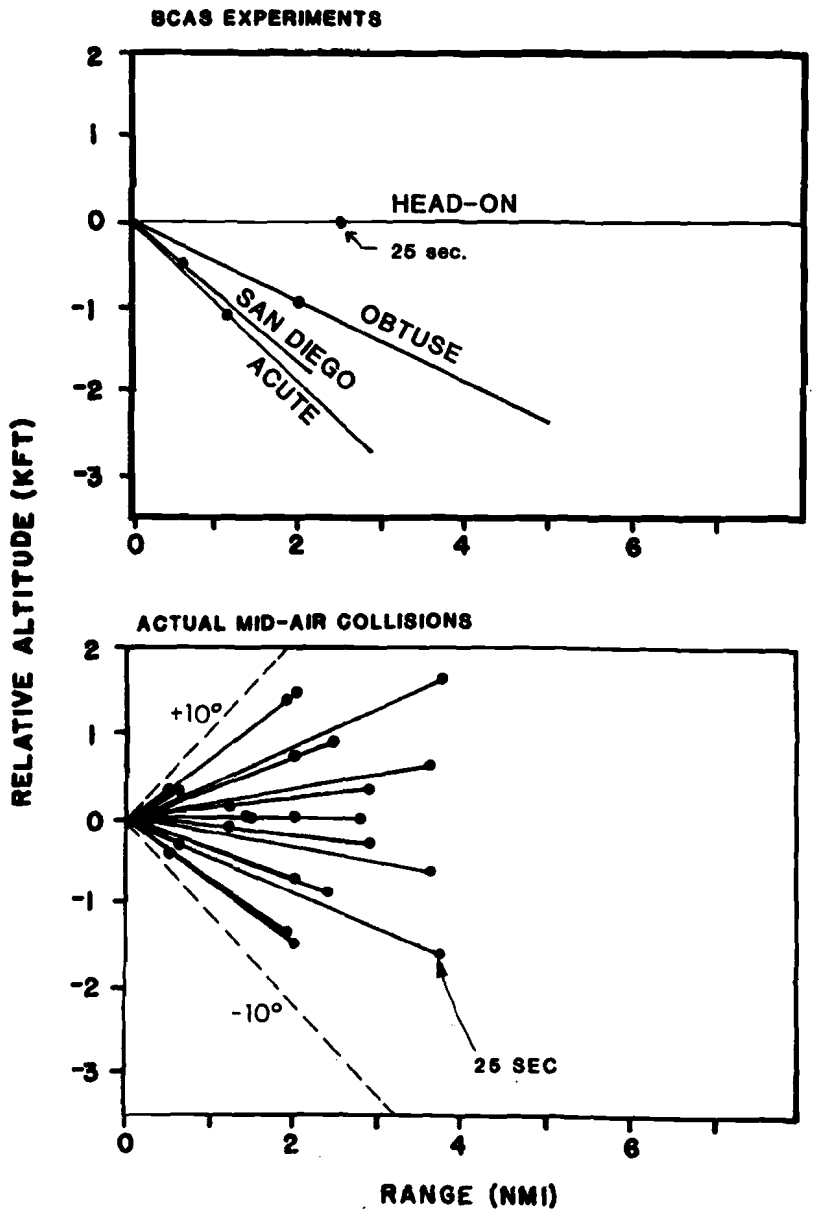


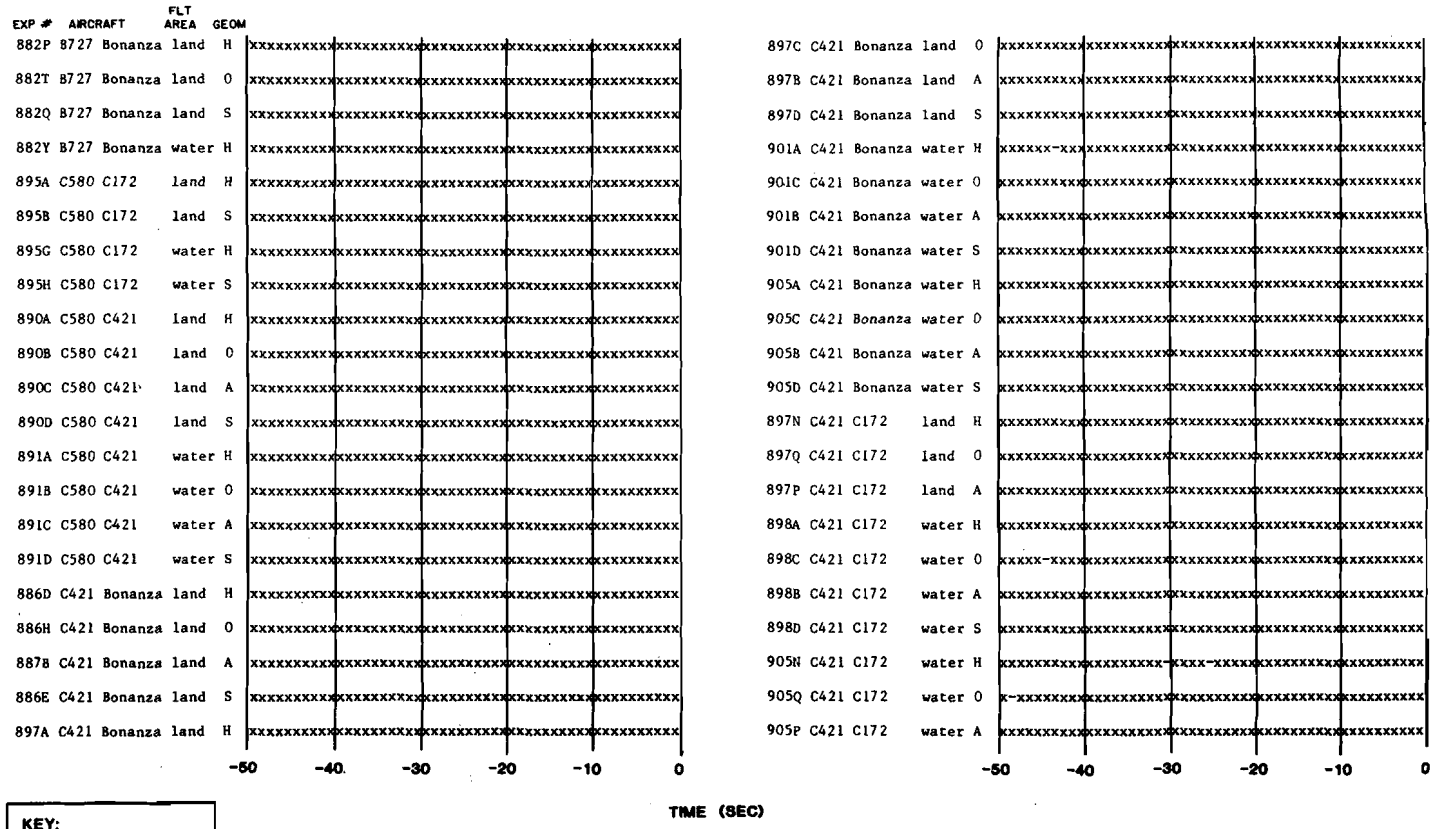
Re-enacting the San Diego Collision - DABS Mode



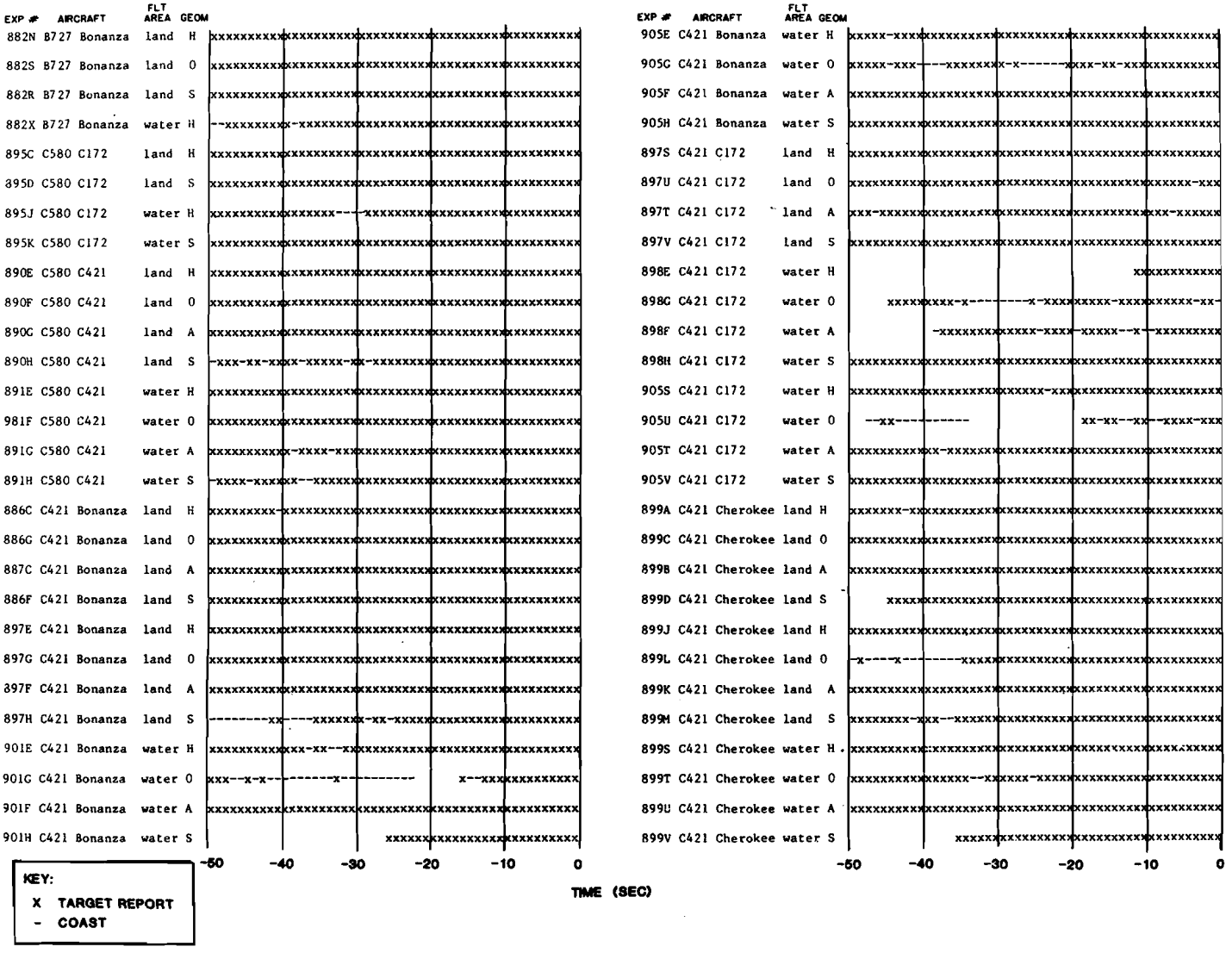
Flight Paths for Lincoln Laboratory Testing of BCAS Surveillance

Conditions Under Which BCAS Is Being Tested at Lincoln Laboratory





Results of 42 Encounters; DABS Diversity Transponder



Results of 56 Encounters; DABS Transponder Without Diversity

DABS Surveillance Summary : Experiments in Severe Geometries

	DABS Diversity Transponder (42 encounters)	DABS Transponder Without Diversity (56 encounters)
Probability of track (%)	100	96
Probability of report (%)	> 99	95
False alarms	(0)	(0)

REF. — FAA-RD-80-134, PAGES 45-51.

SUMMARY:

GOOD QUALITY AIR/AIR SURVEILLANCE OBSERVED IN FLIGHT TESTS

	TRACKING REAL AIRCRAFT	RATE OF FALSE TRACKS
DABS diversity transponder	NEAR PERFECT	ZERO
DABS transponder without diversity	WITH HIGH PROBABILITY	ZERO
ATCRBS transponder without diversity	WITH HIGH PROBABILITY	LOW

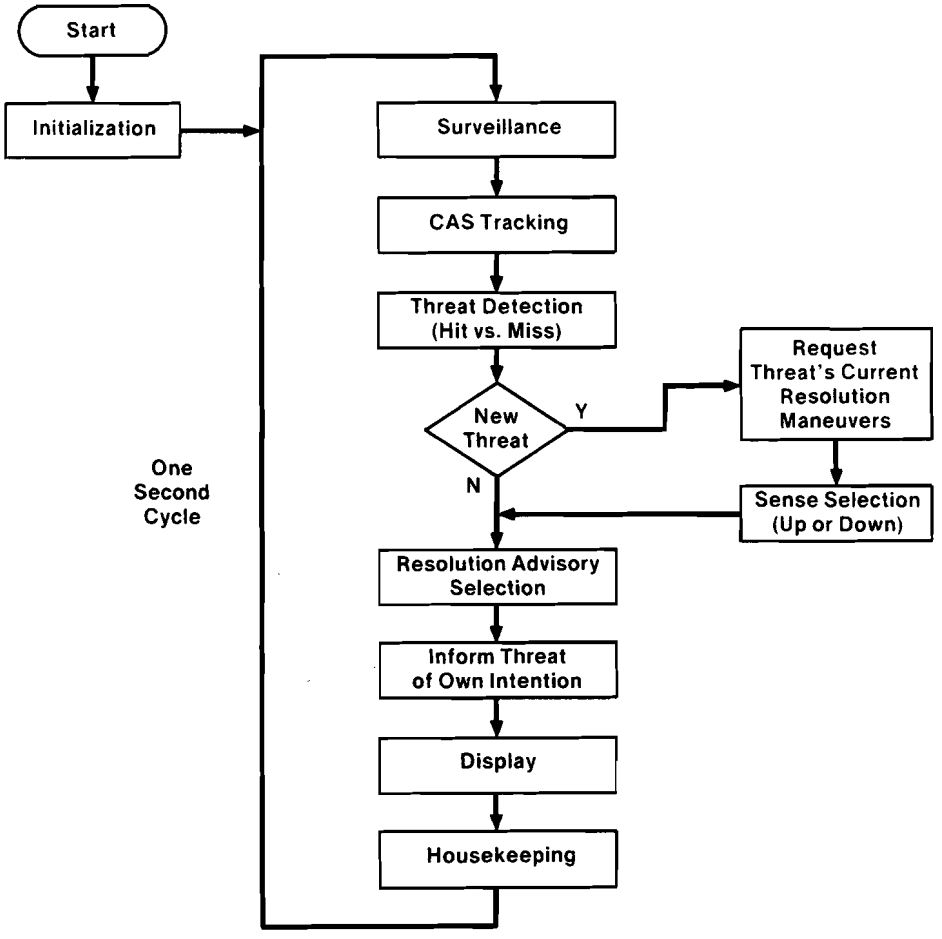
Description of Active BCAS Collision Avoidance Logic

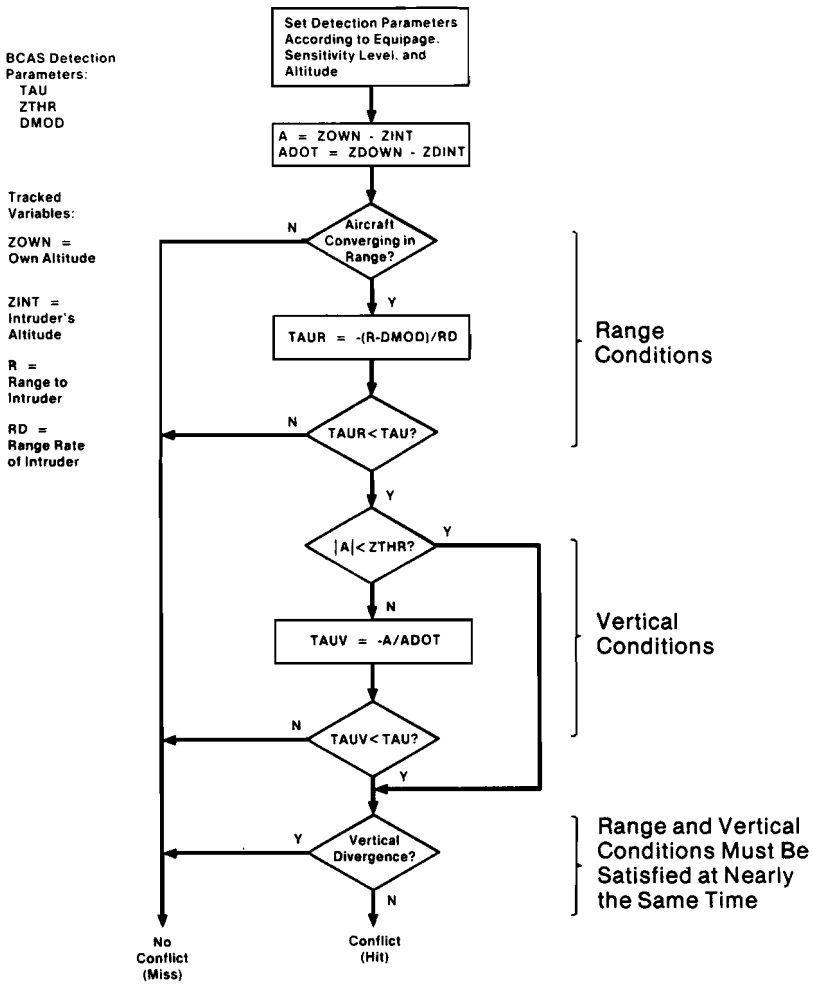
Dr. A.L. McFarland

28 January 1981

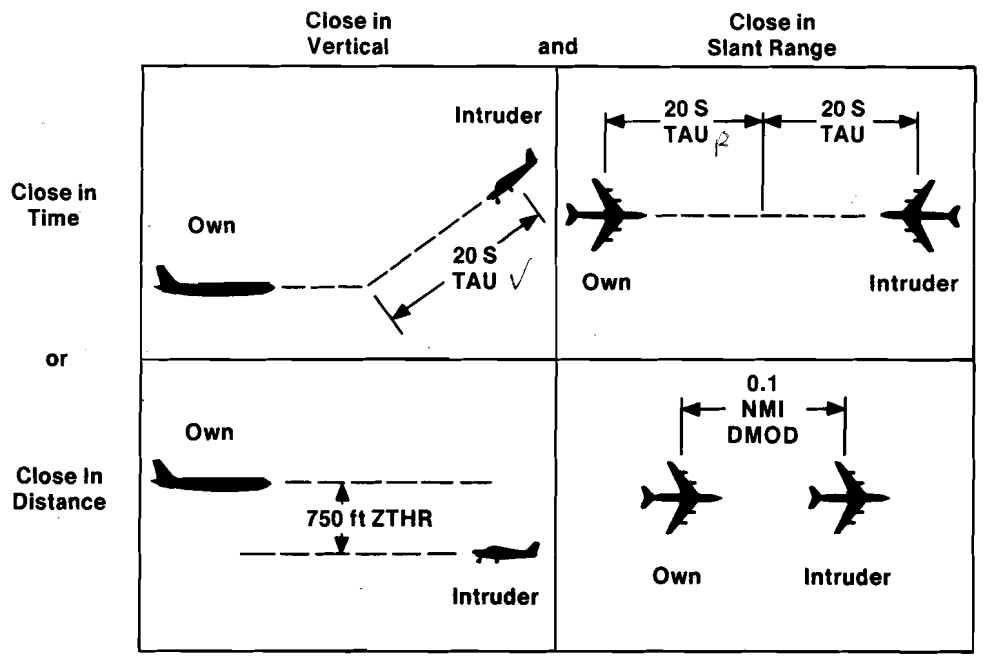
The MITRE Corporation

The BCAS Logic Cycle

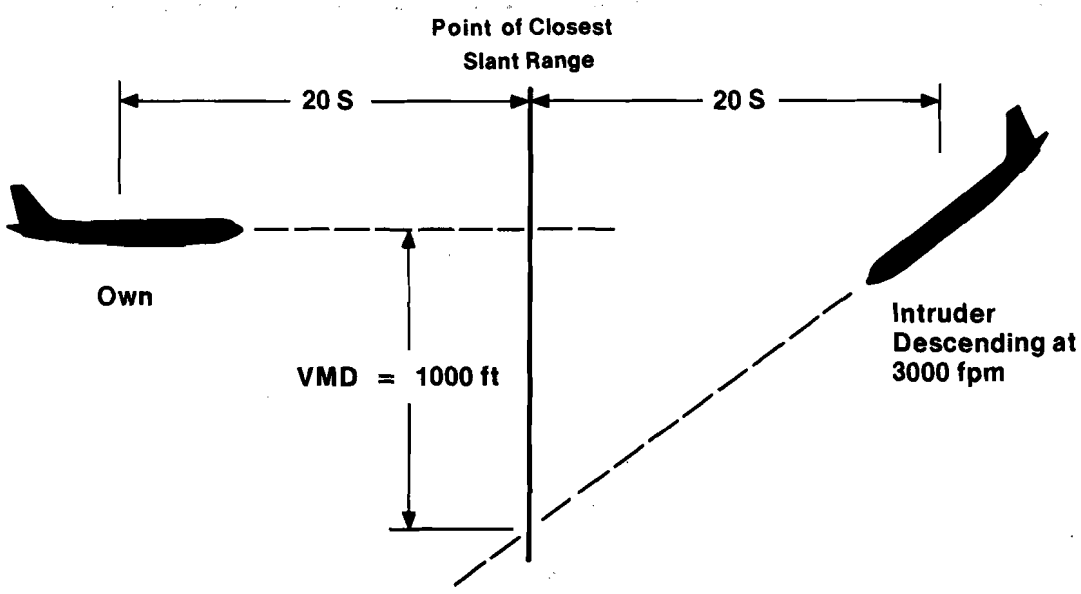



BCAS Detection Parameters:
TAU
ZTHR
DMOD
Tracked Variables:
ZOWN = Own Altitude
ZINT = Intruder's Altitude
R = Range to Intruder
RD = Range Rate of Intruder
Set Detection Parameters According to Equipage, Sensitivity Level, and Altitude
A = ZOWN - ZINT
ADOT = ZDOWN - ZDINT
Aircraft Converging in Range?
N
Y
TAUR = -(R-DMOD)/RD
TAUR < TAU?
N
Y
|A| < ZTHR?
Y
N
TAUV = -A/ADOT
TAUV < TAU?
N
Y
Vertical Divergence?
Y
N
No Conflict (Miss)
Conflict (Hit)
Range Conditions
Vertical Conditions
Range and Vertical Conditions Must Be Satisfied at Nearly the Same Time

Threat Detection Criteria



Vertical Miss Distance (VMD)



VMD is the Predicted Vertical Separation at the Time of Closest Slant Range
No Conflict If | VMD | >ZTHR (750 ft)

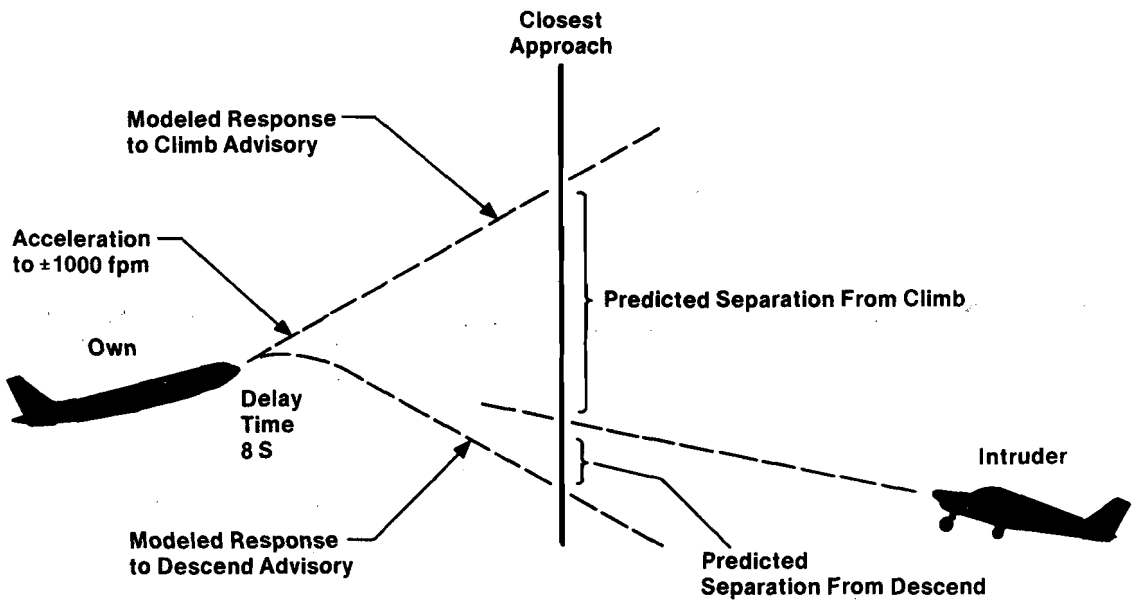
Variation of CAS Thresholds

- Smaller Parameters Used Closer to Busy Airports
  - Parameter Values Determined by Sensitivity Level Setting
- Sources For Sensitivity Level Setting
  - Ground Radar Beacon Transponder (RBX)
  - Ground ATARS
  - BCAS Logic Using Radar Altimeter, Barometric Altimeter
  - Pilot's Switch
- Altitude Variation of Vertical Thresholds
  - Altimetry Error Increases With Altitude
  - Vertical Separation Standards
  - Controlled By Own Barometric Altimeter

Conflict Resolution

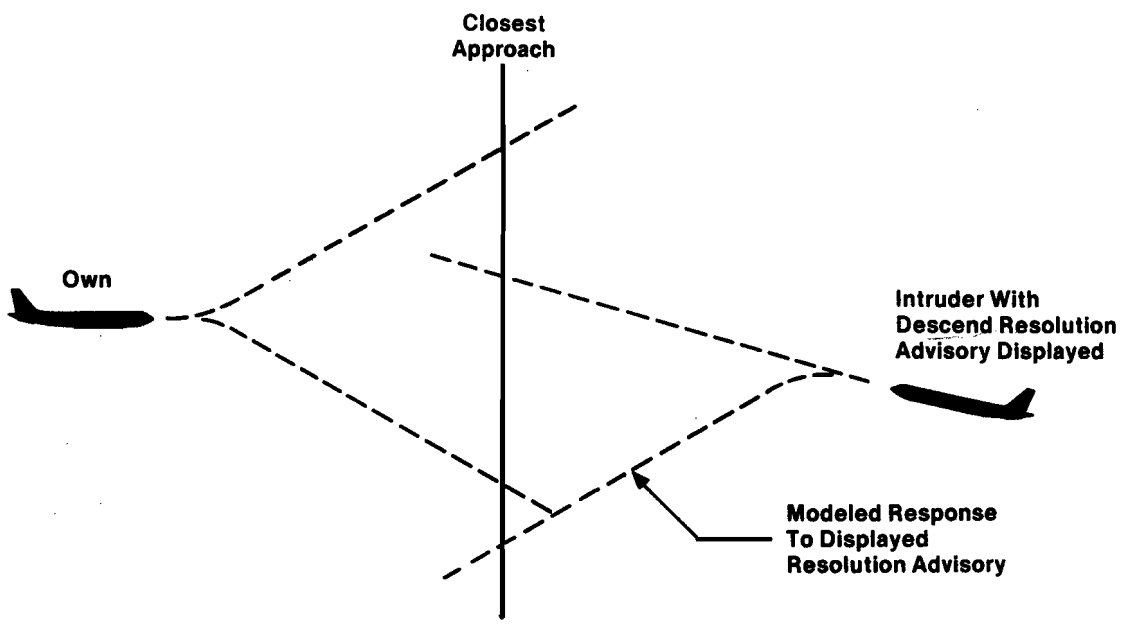
- Resolution Consists of:
  - Determining Threat's Maneuver
  - Selecting Sense of Resolution Advisory to Achieve Largest Predicted Separation
  - Selecting Type of Resolution Advisory to Produce Least Disruption

Modeling for Sense Selection (Unequipped Intruder)



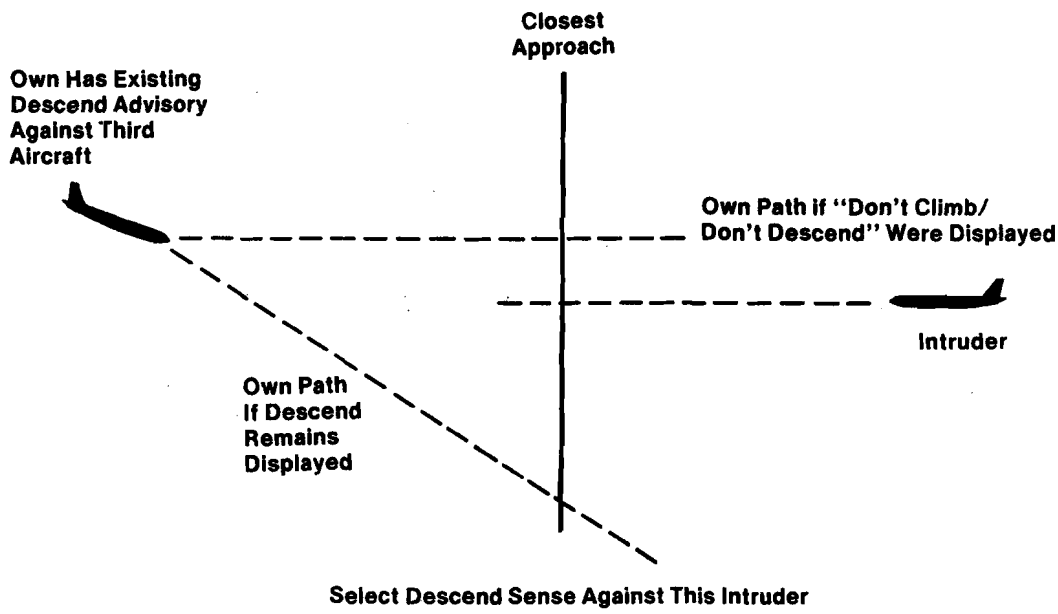
Select Maneuver with Greater Separation at Closest Approach (Climb)

Modeling for Equipped Intruder With Resolution Advisory



Select Maneuver With Greater Separation at Closest Approach (Climb)

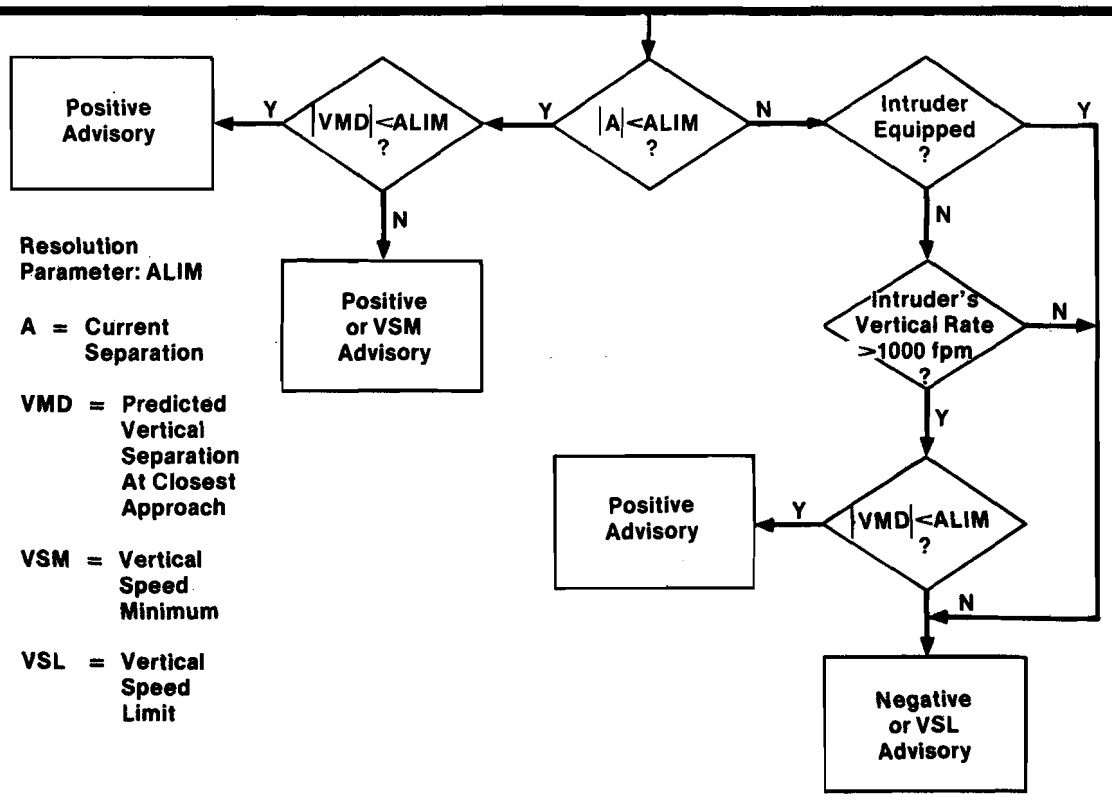
Modeling When Own Has Resolution Advisory



Types of Resolution Advisory

Climb Sense	Class	Descend Sense
Climb	Positive	Descend
Don't Descend	Negative	Don't Climb
Limit Descent to 500 fpm Limit Descent to 1000 fpm Limit Descent to 2000 fpm	Vertical Speed Limits	Limit Climb to 500 fpm Limit Climb to 1000 fpm Limit Climb to 2000 fpm
Climb Faster Than 500 fpm Climb Faster Than 1000 fpm Climb Faster Than 2000 fpm	Vertical Speed Minima	Descend Faster Than 500 fpm Descend Faster Than 1000 fpm Descend Faster Than 2000 fpm

Selecting Type of Advisory



Resolution Parameter: ALIM

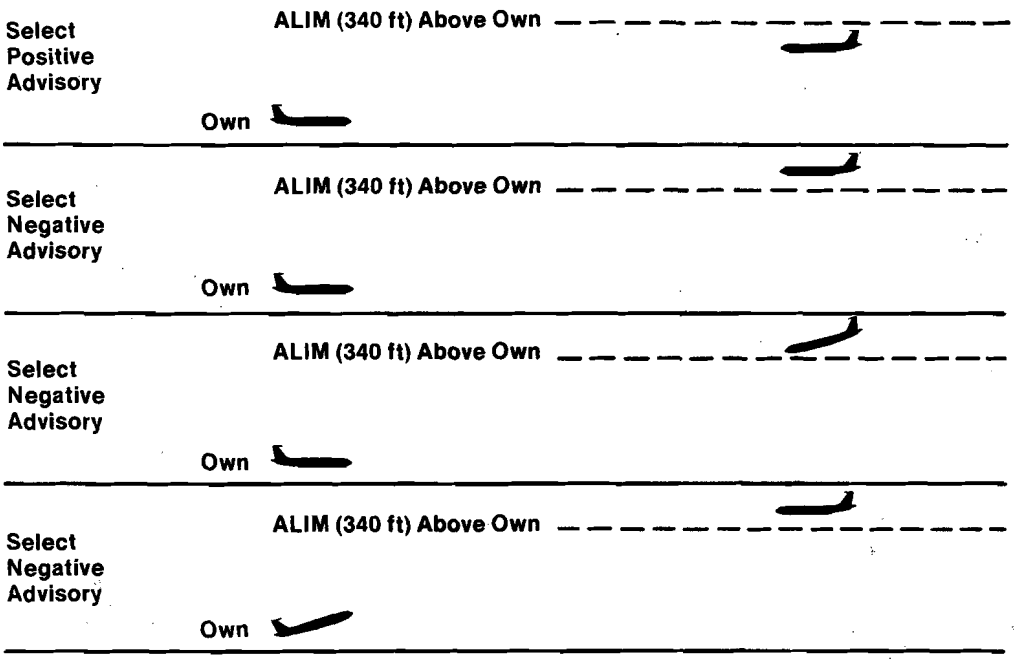
A = Current Separation

VMD = Predicted Vertical Separation At Closest Approach

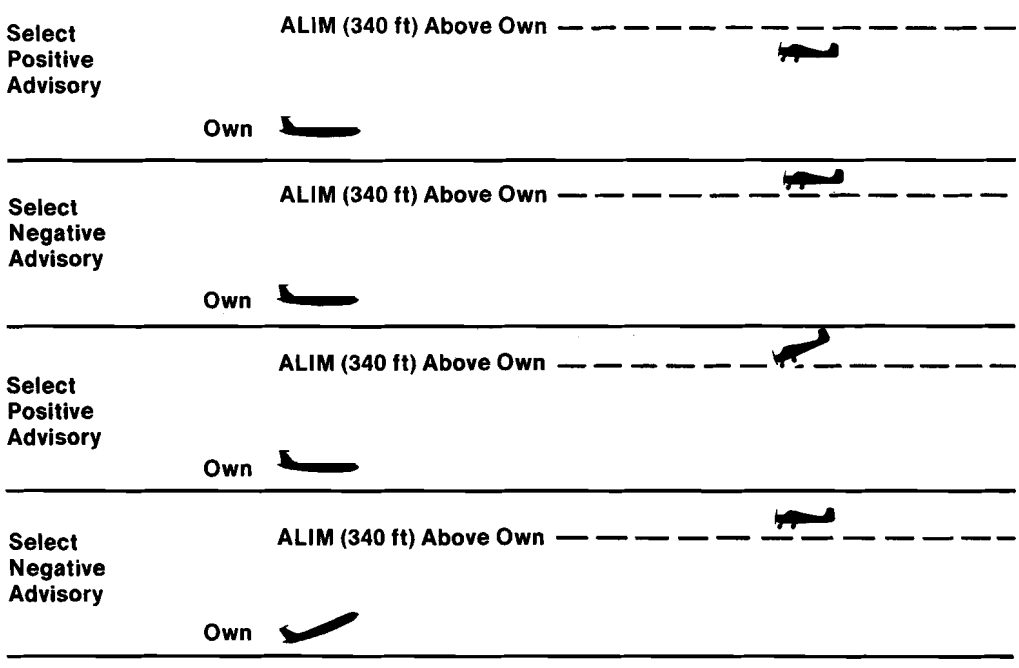
VSM = Vertical Speed Minimum

VSL = Vertical Speed Limit

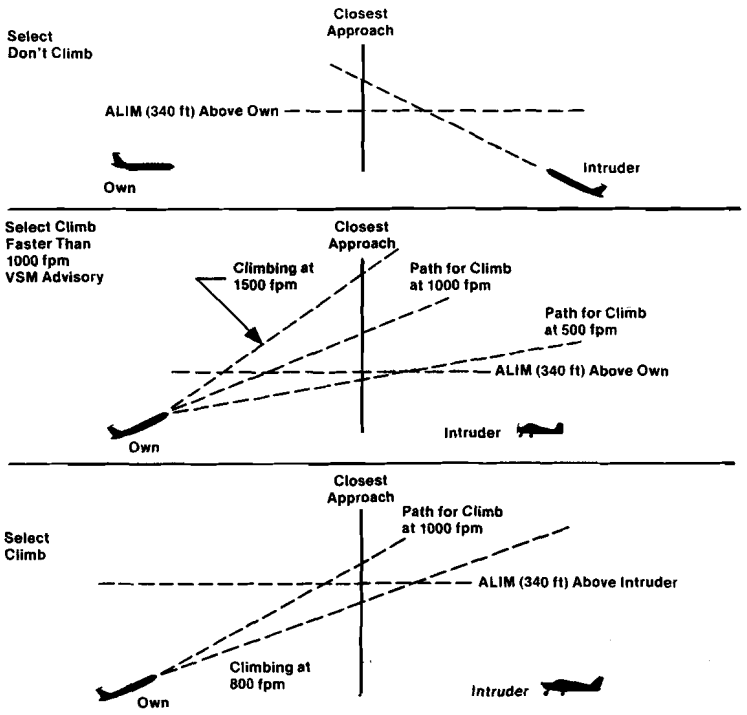
Selection of Advisory Type Against BCAS-Equipped Intruder



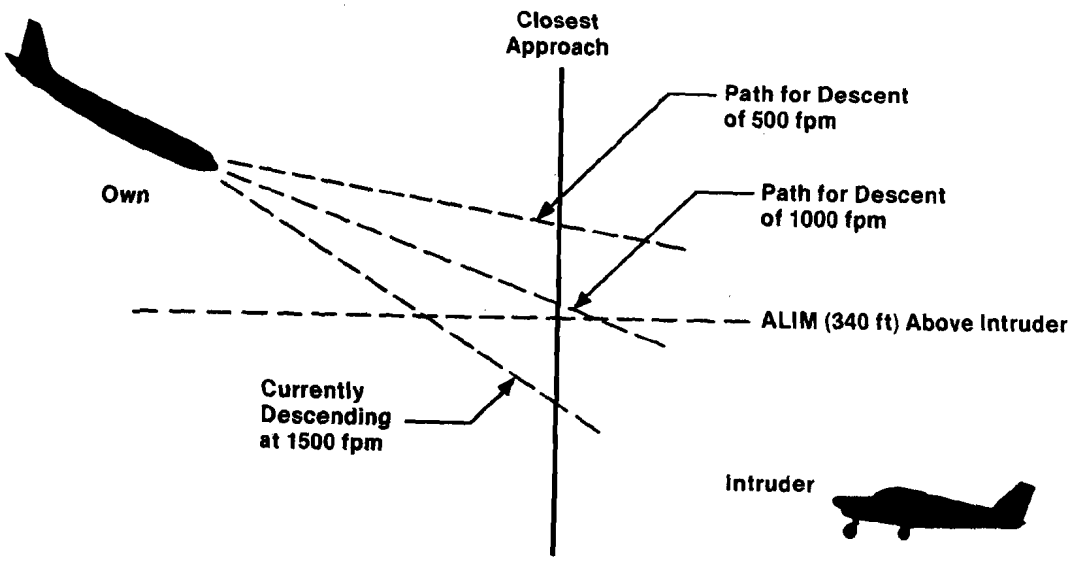
Selection of Advisory Type Against Unequipped Intruder



Vertical Divergence Situations



Vertical Speed Limits (VSLs)



Select Limit Descent to 1000 fpm

Multiaircraft Logic Results in Selected Cases

Select "Descend"	Own		2 Threats Any Equipage Both Above Own At Closest Approach
Select "Don't Climb And Don't Descend"	Own		2 Equipped Intruders One Above, One Below, At Closest Approach
Select "Descend"	Own		Unequipped 100 ft Above Unequipped 100 ft Below

Coordination Logic

BCAS Coordination Using the RAR

RAR = Resolution Advisory Register

- RAR Supports All Collision Avoidance System Coordination
  - BCAS—BCAS
  - ATARS—BCAS
  - ATARS—Multi-Site
- RAR is Carried By
  - BCAS Avionics
  - ATARS Avionics

Coordination Data Structures

	ATARS Site A	ATARS Site B	ATARS Site C	ATARS Site D	Own BCAS	All Other BCAS
Climb						
Don't Descend						
DDES/500						
DDES/1000						
DDES/2000						
Descend						
Don't Climb						
DCL/500						
DCL/1000						
DCL/2000						
Turn Left						
Turn Right						
Don't Turn Left						
Don't Turn Right						

RAR

Threat 1		24-Bit DABS Address	
Threat 2		24-Bit DABS Address	
Threat 3		24-Bit DABS Address	

BCAS Threat File

BCAS-BCAS Coordination

Own

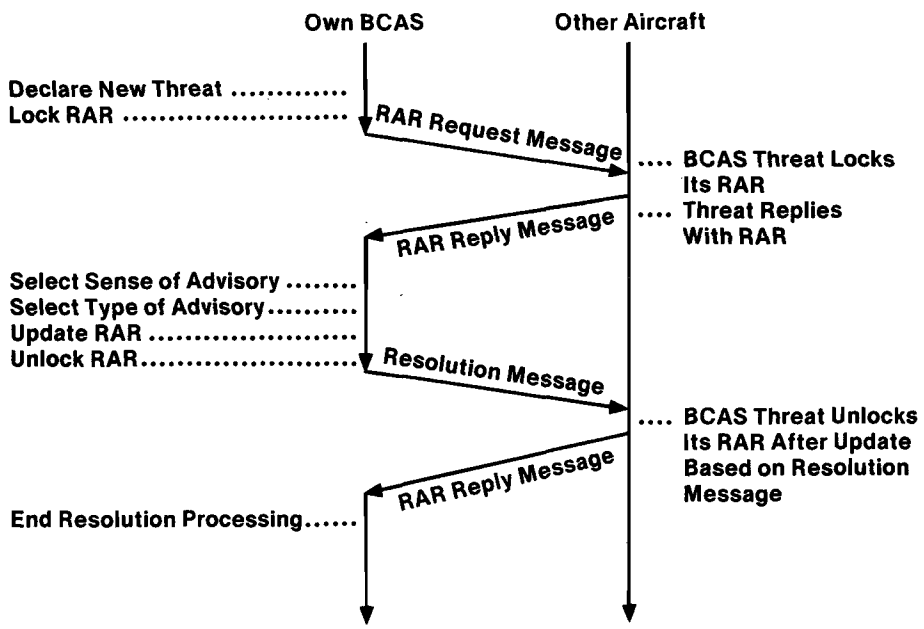
Own RAR: Empty

Other BCAS

Other RAR: Empty

- Suppose Own BCAS Is First to Initiate Coordination
- Initiating a Coordination With no Previous Constraints Involves the Following Two-Transaction Process

Two-Transaction Coordination With New Threat



A Complete BCAS-BCAS Coordination Sequence

#1 Detects Conflict

BCAS #1	BCAS #2
RAR: Empty	RAR: Empty

#1 Coordinates and Resolves Conflict

BCAS #1	BCAS #2
RAR: Climb	RAR: Record of #1's Maneuver in Other BCAS Column Threat File: Record of #1's Maneuver and 24-Bit ID

#2 Coordinates and Resolves Conflict

BCAS #1	BCAS#2
RAR: Climb & Record of #2's Maneuver	RAR: Descend & Record of #1's Maneuver
Threat File: Climb & Record of #2's Maneuver	Threat File: Descend & Record of #1's Maneuver

ATARS-BCAS Coordination

- BCAS National Standard Provides for all BCAS-BCAS and ATARS-BCAS Coordination
- Responsibility for Generating Resolution Advisories Determined on a Pairwise Basis
  - ATARS Is Responsible Whenever Both Aircraft in a Pair Are in Coverage of the Same ATARS Site
  - BCAS Responsible Otherwise
- Transitions in Responsibility Are Handled Smoothly Using RAR Information

Traffic Advisory Logic

- Detection Logic Similar to That for Resolution Advisories
- Parameters Larger
- Traffic Advisories Coordinated With ATARS

Display Logic

- Display Strongest Climb Sense and Strongest Descend Sense Resolution Advisory (BCAS or ATARS)

Composite of RAR Advisories	Displayed AS
Don't Descend	Don't Descend and
Limit Descent to 1000 fpm	Limit Climb to
Limit Climb to 500 fpm	500 fpm

- Display Strongest Advisory of Each Horizontal Sense: (ATARS Only)

Turn Left Sense	Class	Turn Right Sense
Turn Left	Positive	Turn Right
Don't Turn Right	Negative	Don't Turn Left

- Smoothing of Advisories
  - Sense of Advisory Against a Given Threat Never Changes
  - 2 Out of 3 Logic to Start Advisories
  - 2 in a Row Logic to Stop Advisories
  - 5 Second Clamp Before Advisory Type Can Change

Active BCAS
Collision Avoidance Logic Assessment

Dr. A. L. McFarland

28 January 1981 **The MITRE Corporation**

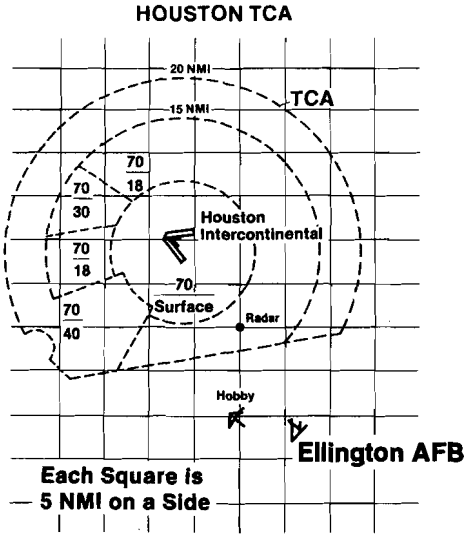
Measures of Logic Performance

- **Number of Unwanted Alerts—Studied Through:**
  - — Recorded Data From Houston
  - — Operational Flight Tests
- **Interaction With Normal Air Traffic Control—Studied Through:**
  - — Recorded Data From Houston
  - — Operational Flight Tests
- **Collision Avoidance Capability—Studied Through:**
  - — Monte Carlo Simulation of 15 Actual Mid-Air Collisions

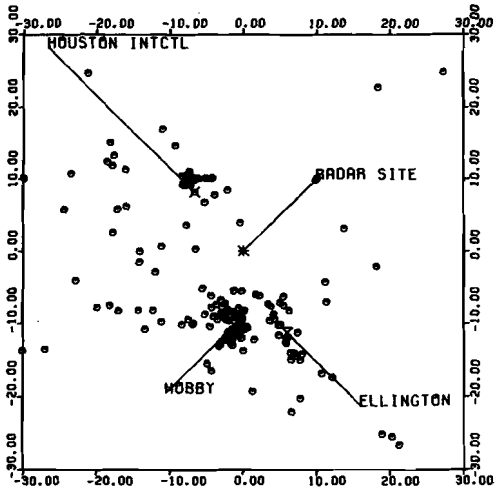
Houston Data Set

- Radar Data Collected at Houston Intercontinental Airport Totaling 65.02 Hours
- All ATC Code and 1200 Code (VFR) Mode C Aircraft Tracked
- Average Instantaneous Counts
  - — ATC Code Aircraft 21.3
  - — 1200 Code Aircraft 3.2

The Houston Terminal Environment



Location of Alerts with Logic Not Desensitized

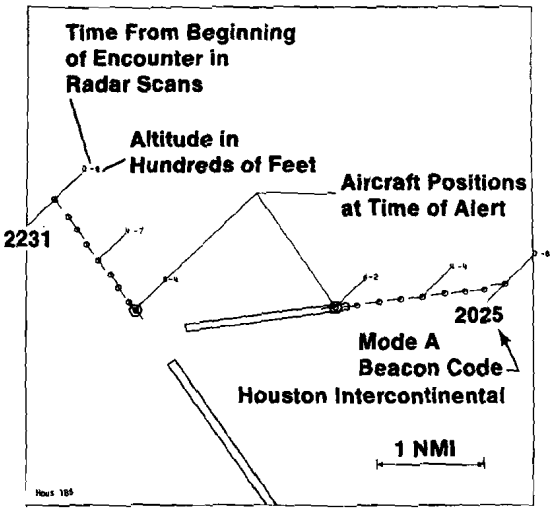


200 POSITIVE ALERTS

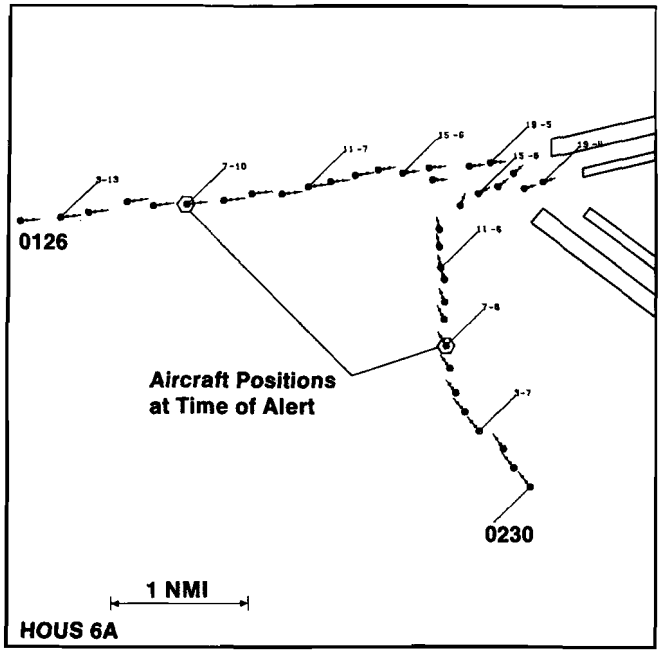
TAU = 25 S
DMOD = 0.3 NMI
ALIM = 470 Ft

} Parameters Applied in All Regions

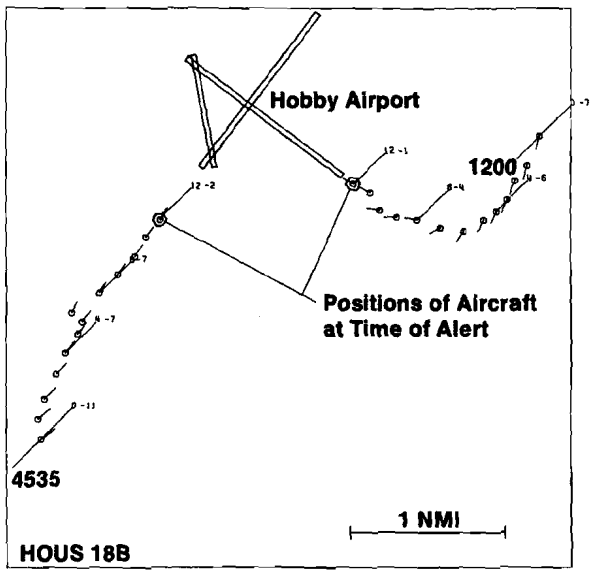
Alert Involving Aircraft Landing on Runways 26 and 14



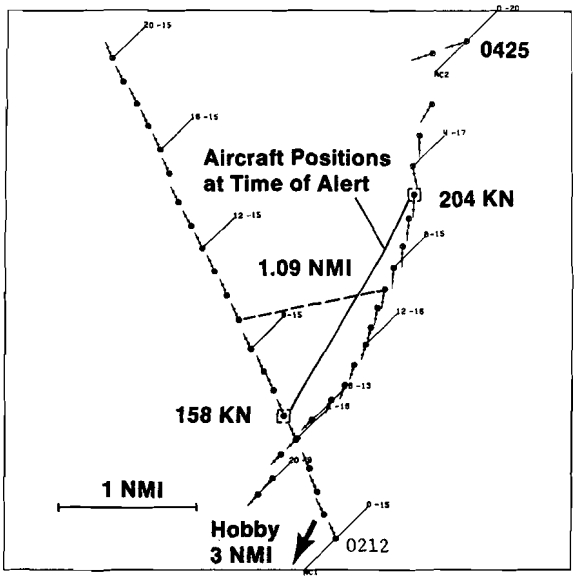
Alert Involving Aircraft Landing on Runways 8 and 9S



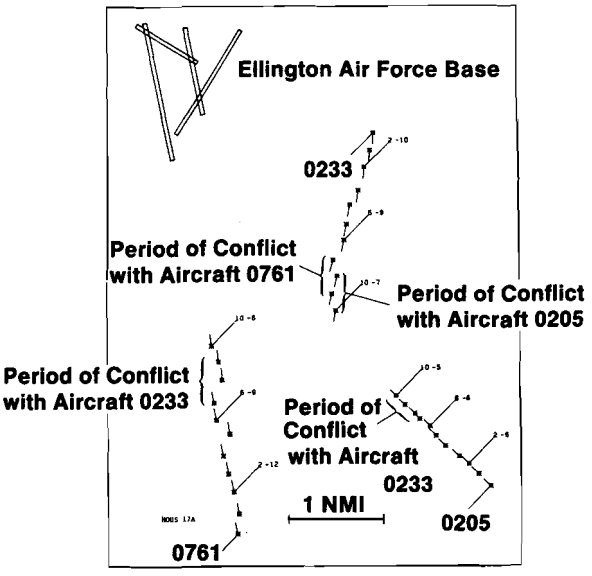
Alert Involving Simultaneous Landings on Intersecting Runways



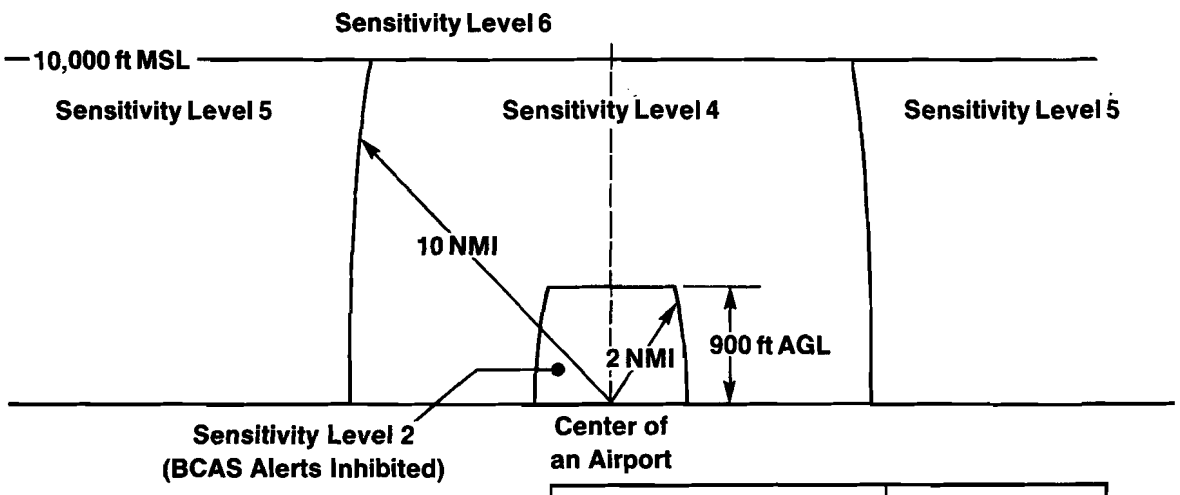
An Unnecessary Positive Alert with Logic Not Desensitized
Alert Eliminated with Desensitized Logic



Multiple Aircraft Encounter Occurring At More Than 2 NMI From Closest Airport



Sensitivity Level Boundaries



Parameter	Sensitivity Level		
	4	5	6
TAU (S) Equipped Threat	18	25	30
TAU (S) Unequipped Threat	20	25	30
DMOD (NMI)	0.1	0.3	1.0

Desensitization Results

- The Alert Rate for Unequipped Intruders in the Houston Environment is 64 Positive Alerts in 65 Hours of Data
  - — Logic Treats One Aircraft in Every Conflict Pair as Unequipped
  - — Desensitized Parameters and Sensitivity Level Regions Used
- Breakdown of 64 Positive Alerts
  - — 20 Alerts Involving Two ATC Code Aircraft
  - — 32 Alerts Involved One 1200 Code and One ATC Code Aircraft
  - — 12 Alerts Involved Two 1200 Code Aircraft
- 5 of the 64 Alerts Occurred Above 10,000 ft MSL
- No Alerts Occurred Above 18,000 ft MSL

Average Per-Aircraft Positive Alert Rates with Desensitized Logic

Composite for All Aircraft	Rate for ATC Code Aircraft	Rate for 1200 Code Aircraft
1 Alert in 12 Hours	1 Alert in 19 Hours	1 Alert in 4 Hours

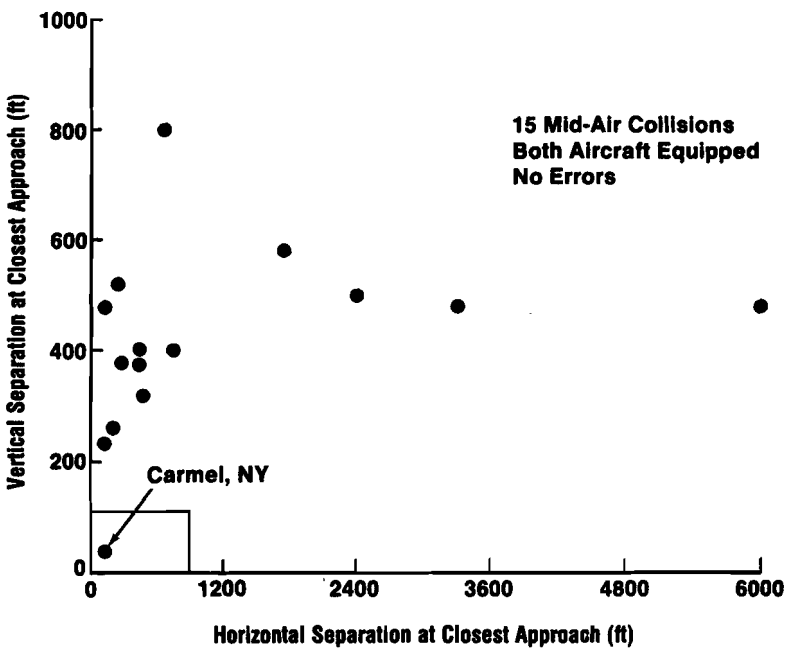
The Monte Carlo Simulation Program

- **Simulation Environment Provides:**
  - — Altimetry Error Models
  - — Pilot and Aircraft Response Models
- **Significant Parameters Used in the Simulation**
  - — Repetitions—20
  - — Update Rate—Once Per Second
  - — Mean Response Delay—5 Seconds
  - — Escape Climb Rate—1000 fpm
  - — Escape Descent Rate—1000 fpm
  - — Acceleration Rate—1/3 g
  - — Altimetry Bias Error for Equipped Aircraft = 64 ft One-Sigma
  - — Altimetry Bias Error for Unequipped Aircraft = 100 ft One-Sigma
- **The Simulation Program "Flies" BCAS Equipped Aircraft According to Advisories Displayed and the Pilot/Aircraft Models Specified**

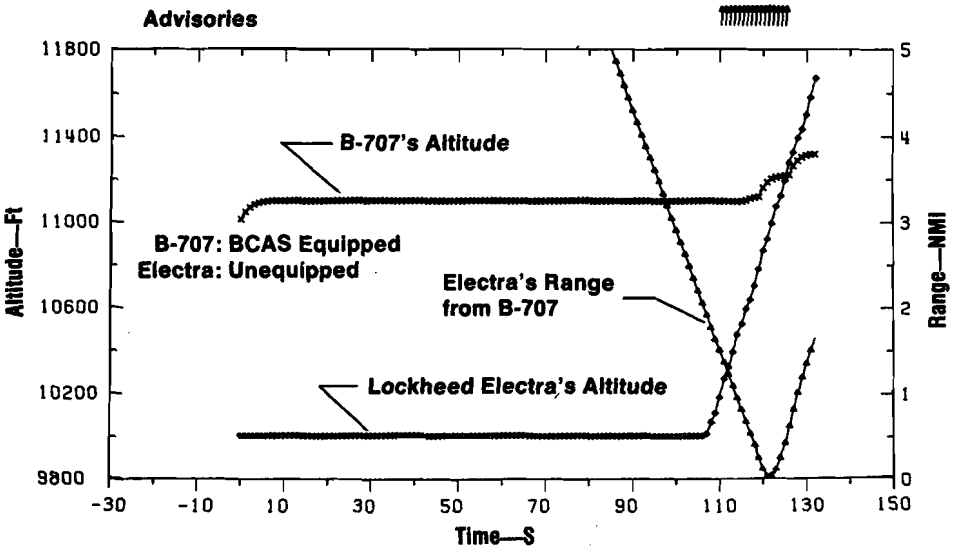
The 15 Actual Mid-Air Collisions That Were Simulated

Location	Date	Sensitivity Level	Type of Aircraft
St. Louis, Mo.	3/68	2	DC-9/C-150
Newport News, Va.	1/75	4	T-29/C-150
Fairland, In.	9/69	4	DC-9/PA-28
Whittier, Ca.	1/75	4	Twin Otter/C-150
Appleton, Wi.	6/72	4	C-580/DHC-6
Hendersonville, N.C.	7/67	4	B-707/C-310
San Diego, Ca.	9/78	4	B-727/C-172
Milwaukee, Wi.	8/68	5	C-580/C-150
Urbana, Oh.	3/67	5	DC-9/Baron
Huntsville, Mo.	7/76	5	PA-28/PA-28
Denver, Co.	6/68	5	B-727/C-337
Saxis, Va.	10/74	5	PA-24/F-106
Kingston, Vt.	11/79	6	Rockwell 690/F-111
Duarte, Ca.	6/71	6	DC-9/F-4
Carmel, N.Y.	12/65	6	Electra/B-707

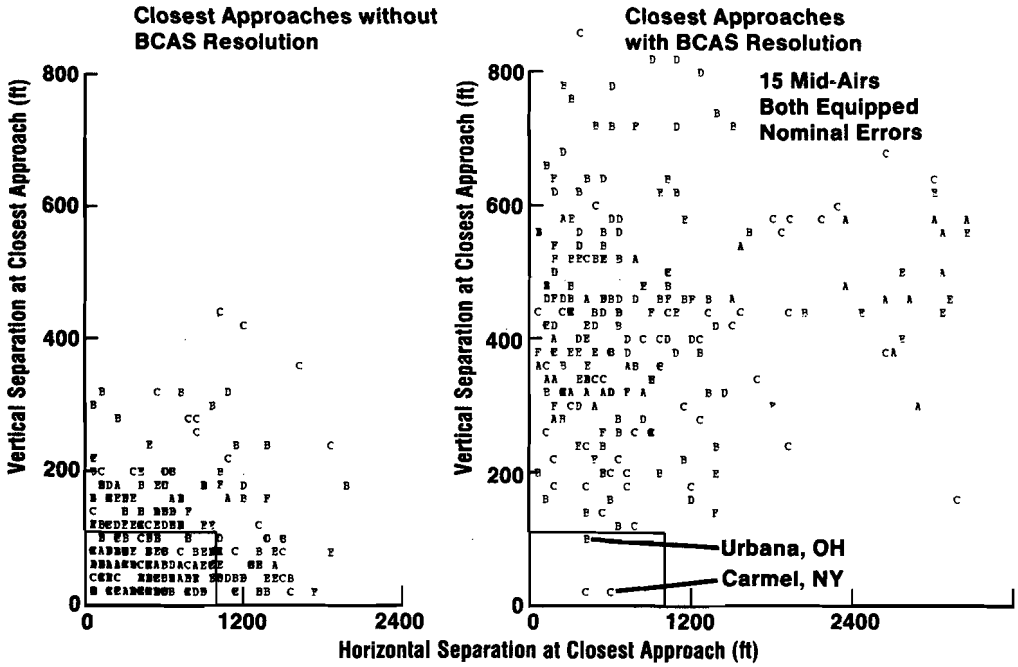
Separation Generated by BCAS



The Carmel New York Encounter

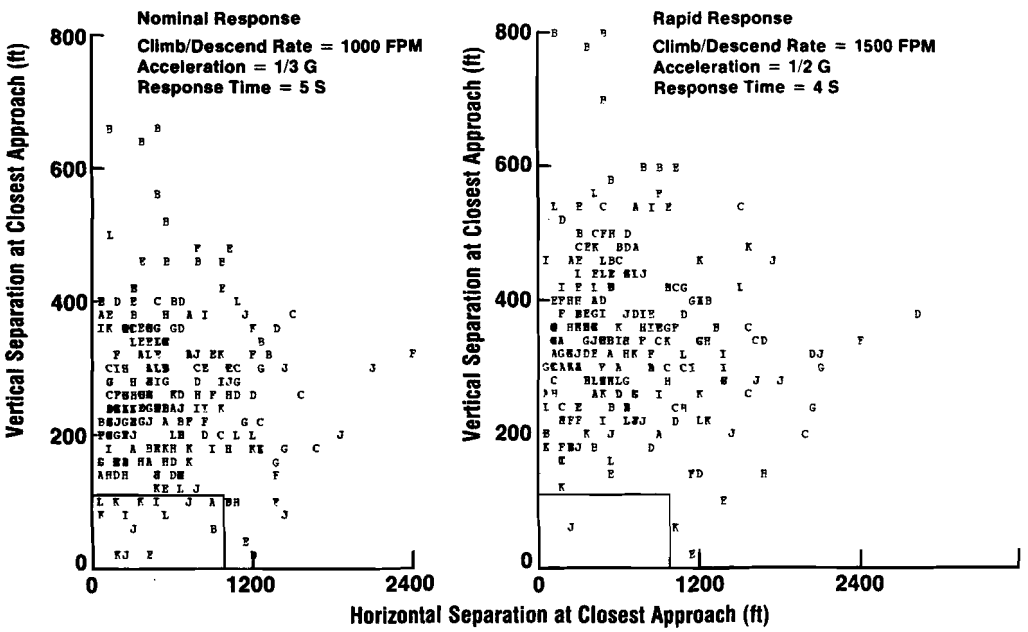


Separation Generated by BCAS

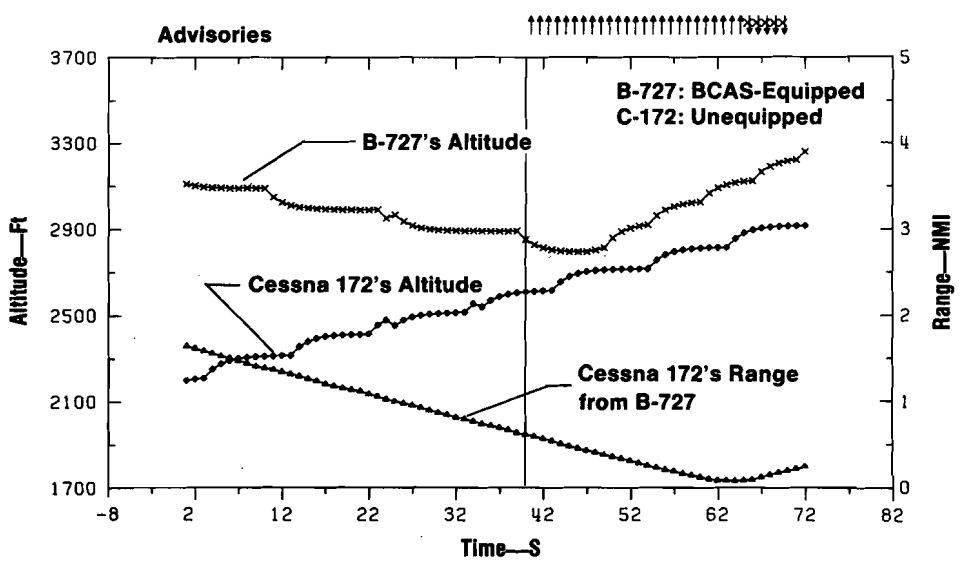


Results for One Aircraft Unequipped

6 Mid-Air Scenarios Occurring in Sensitivity Level 4

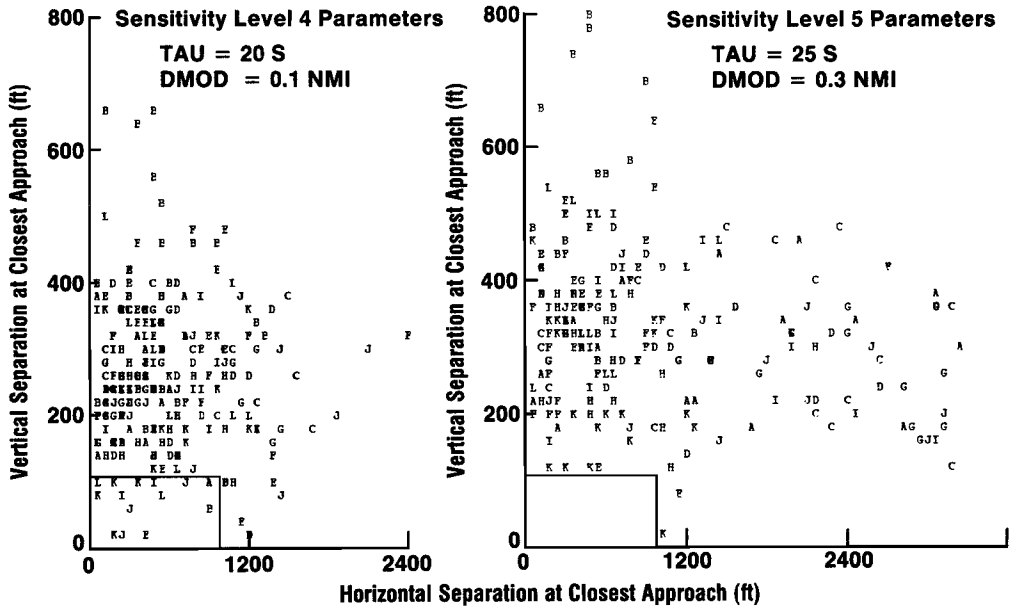


Successful BCAS Resolution of San Diego Encounter



Results for One Aircraft Unequipped

6 Mid-Air Scenarios Occurring in Sensitivity Level 4



Summary of Mid-Air Simulation Results

- Protection Is Good When Both Are Equipped Except for Scenarios Involving Abrupt Vertical Maneuvers
- Traffic Advisories Can Help Prevent Dangerous Abrupt Vertical Maneuvers
- Abrupt Vertical Maneuver by Unequipped Intruder Is Difficult for a Collision Avoidance System to Handle
- Protection for Unequipped Intruders Is Good in Most Cases With no Abrupt Vertical Maneuver
- Substantially Improved Separation Realized in Marginal Cases Through Rapid, Positive Pilot Response

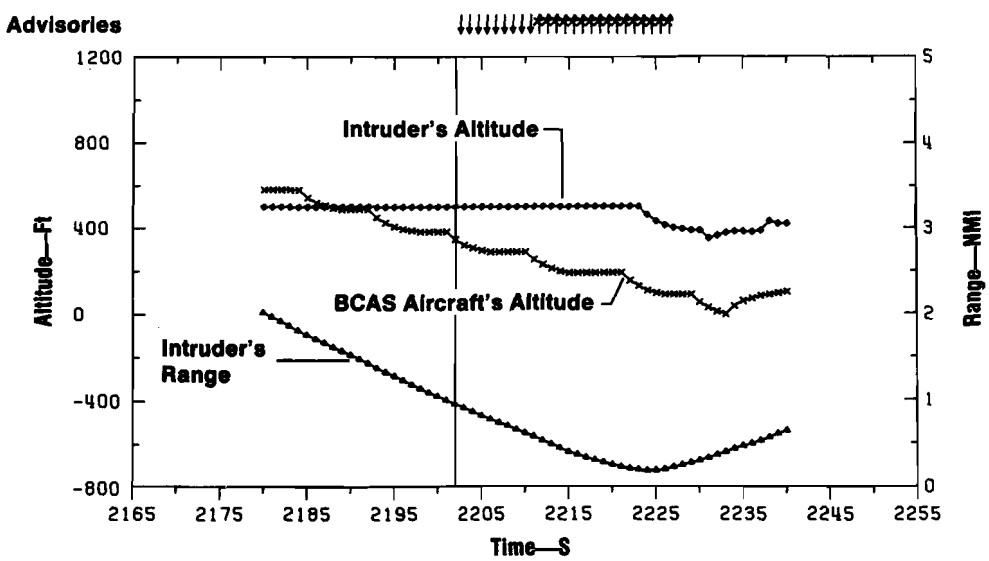
Logic Assessment From Operational Flight Test Results

Unplanned Encounter Summary

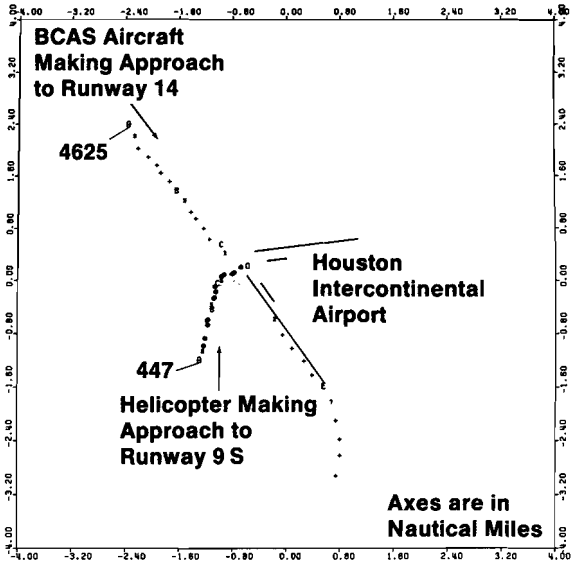
Encounter Number	Location	Altitude AGL (ft)	Sensi-tivity Level	BEU Advisory Sequence
1	Dallas	2500	5,4	D, NC, D
2	Houston	300	4	D, NC
3	Houston	4900	5	C, ND
4	Denver	500	4	D
5	Denver	5600	5	C, ND, C
6	Denver	400	4	C
7	Denver	700	4	NC
8	Salt Lake City	1300	4	ND, C, ND
9	Salt Lake City	2000	4	ND
10	Los Angeles	7600	5	LD
11	Los Angeles	7700	5	C, ND
12	Los Angeles	8100	5	D
13	Los Angeles	8100	5	LD
14	Seattle	3600	5	ND, LD
15	San Francisco	400	5	NC
16	San Francisco	1700	5	ND, C
17	San Francisco	1500	5	NC
18	New York	900	4	ND, C

D—Descend, C—Climb
ND—Don't Descend, NC—Don't Climb
LD—Limit Descend, LC—Limit Climb

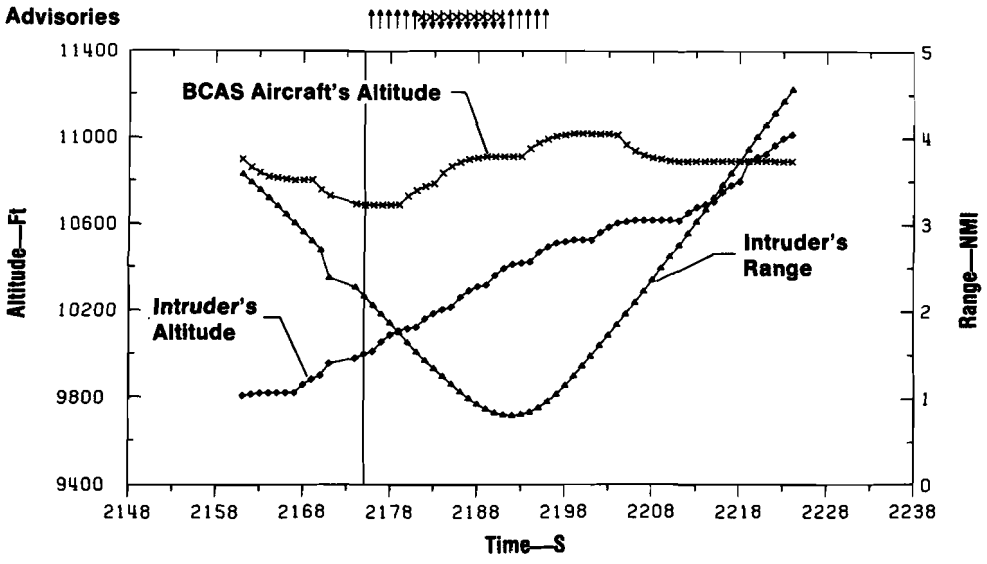
Encounter with Helicopter on Approach to Houston



ARTS Plot of Encounter with Helicopter



BCAS Encounter at Denver



Summary of Results from Operational Flight Tests

- Average of One Positive Alert Every 10 Hours
- No Alerts Due to Phantom Aircraft
- Many Alerts on Final Approach Due to Aircraft on the Ground
- Four Alerts Due to Airborne Aircraft at or Below 500 ft AGL
- No Alerts Occurred Under En Route Control

9198-A

ACTIVE BEACON COLLISION AVOIDANCE SYSTEM (ABCAS) PROGRAM

28 JANUARY 1981

DALMO VICTOR OPERATIONS
Bell Aerospace TEXTRON
Division of Textron Inc.

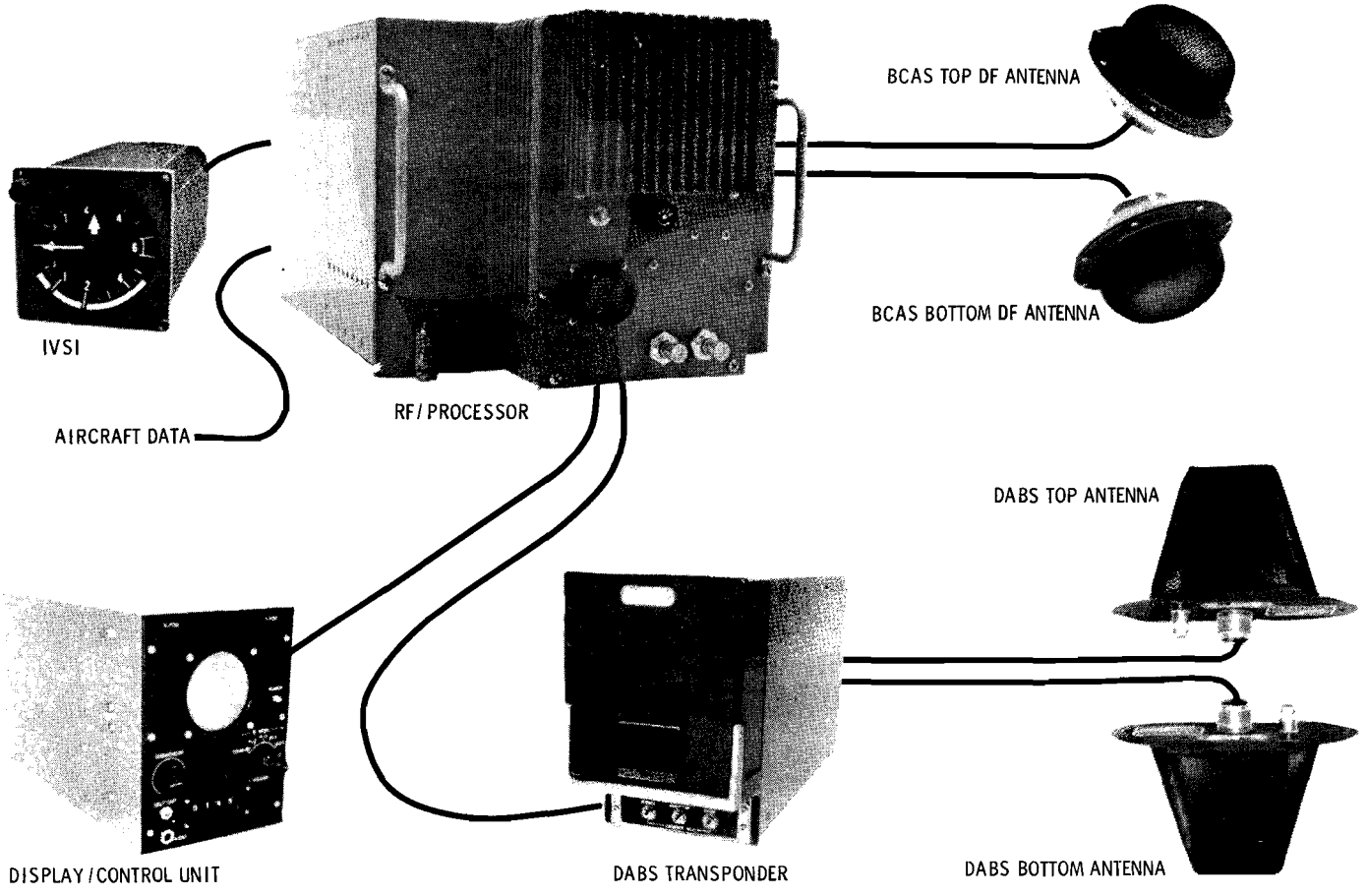
R-3711-9842A

OBJECTIVES

- DEVELOP A PREPRODUCTION MODEL OF AN ACTIVE BCAS UNIT WITH DIRECTION FINDING CAPABILITY
- MEET THE REQUIREMENTS OF SPECIFICATION FAA-ER-250-2
- DELIVER THREE SYSTEMS TO THE FAA BY MARCH 1981
- OPERATIONAL EVALUATION OF THE DALMO VICTOR BCAS UNITS AT THE FAA TECHNICAL CENTER
- SUPPORT EVALUATION ON IN - SERVICE AIRLINE AIRCRAFT

DALMO VICTOR ABCAS FOR FAA OPERATIONAL EVALUATION

3711-57



DALMO VICTOR AIRBORNE UNIT STATUS

- AWARDED CONTRACT FOR THREE FAA ABCAS UNITS MARCH 1980
- EXTENSIVE INTERFACE WITH LINCOLN LABS / MITRE HAS BEEN CONDUCTED TO OBTAIN MAXIMUM BENEFIT OF THEIR WORK
- THE CRITICAL DESIGN REVIEW WAS SUCCESSFULLY COMPLETED IN JUNE 1980
- DALMO VICTOR IS PROCEEDING WITH AN AGREED DESIGN
- THE DALMO VICTOR PROTOTYPE ATCRBS DEGARBLER MODULE WAS TESTED AT LINCOLN LABS.
- INTEGRATION TESTING OF MODULES IN THE DV SYSTEM WAS STARTED IN NOVEMBER 1980
- ABCAS WILL BE DELIVERED TO THE FAA IN MARCH 1981

SPECIFICATION FAA-ER-250-2

- PROVIDE PROTECTION AGAINST AIRCRAFT CARRYING ATCRBS OR DABS TRANSPONDERS WITH ENCODING ALTIMETERS
- OPERATE IN ENVIRONMENTS UP TO 0.02 AIRCRAFT PER SQUARE NAUTICAL MILE AVERAGE
- OPERATE TO AVOID SUDDEN SYSTEM COLLAPSE UNDER OVERLOAD CONDITIONS
- OPERATE IN THE ENVIRONMENT OF:
  - ATCRBS FRUIT - 15,000 REPLIES/SECOND
  - DABS FRUIT - 2,000 REPLIES/SECOND
  - ATCRBS/DABS REPLY PROBABILITY - 0.9
- PROVIDE DESENSITIZATION MANUALLY BY THE FLIGHT CREW OR AUTOMATICALLY UNDER CONTROL OF THE GROUND SYSTEM
- COORDINATE WITH OTHER BCAS AIRCRAFT AND GROUND RBX/ATARS

DV/LINCOLN LAB/MITRE COMMONALITY

TRANSMITTER/RECEIVER

A FUNCTIONALLY EQUIVALENT MINIATURIZED DESIGN IMPLEMENTS THE FAA DESIGN REQUIREMENTS

DEGARBLER

THE DEGARBLER IS EQUIVALENT TO THAT DEFINED BY LINCOLN LABS

DABS DECODER

THE LINCOLN LABS DESIGN IS BEING IMPLEMENTED

DV/LINCOLN LAB/MITRE COMMONALITY (CONT.)

COMPUTER

- A DALMO VICTOR MINIATURIZED DESIGN OF THE NOVA-BASED LANGUAGE--MAXIMIZES SOFTWARE UTILIZED BY LINCOLN LABS

SOFTWARE

- LINCOLN LAB EXECUTIVE SOFTWARE
- LINCOLN LAB ATCRBS / DABS SURVEILLANCE PROGRAM MODIFIED FOR HARDWARE COMPATIBILITY
- MITRE COLLISION AVOIDANCE ALGORITHMS
- MITRE RESOLUTION ADVISORY REGISTER

9201-A

DIRECTIONAL ANTENNA

- THE ANTENNAS HAVE BEEN DESIGNED, FABRICATED, AND TESTED IN AN ANECHOIC CHAMBER
- ANTENNA PATTERNS HAVE VERIFIED ACCURACY TO 4 DEGREES RMS FOR ELEVATION ANGLES +15 TO -30 DEGREES
- OMNI DIRECTIONAL TRANSMISSION OF UP TO +30 dBw HAS BEEN VERIFIED
- OMNI DIRECTIONAL PATTERNS ARE EQUAL WITHIN 2 dB

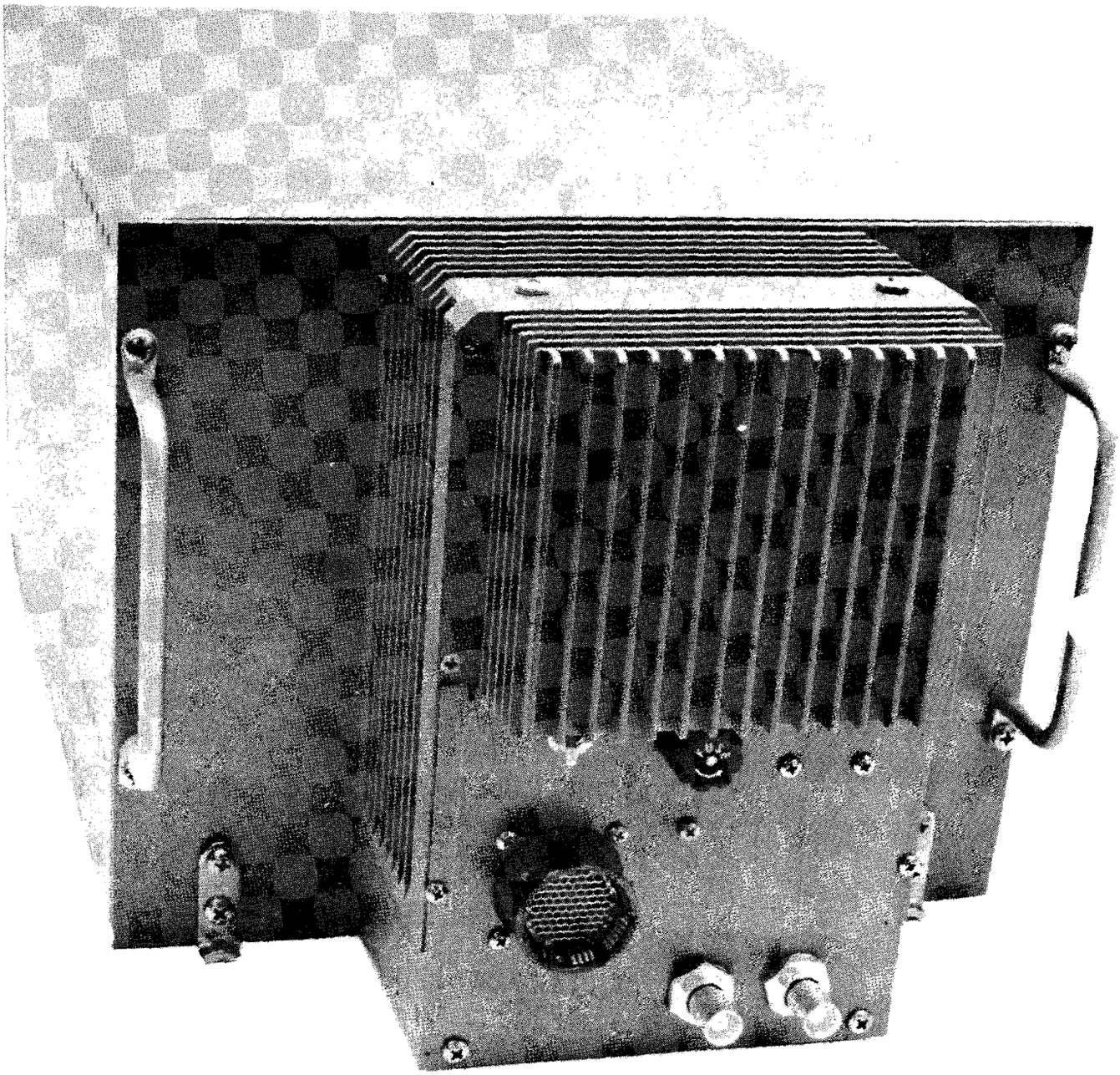
DALMO VICTOR ABCAS DIRECTIONAL ANTENNA

9202-A

RF/PROCESSOR

- PACKAGED IN AN AIRLINE 8 MCU ENCLOSURE
- PROVIDES 30 dBw 1030 MHz AT THE OUTPUT OF THE PROCESSOR - PROGRAMMABLE TO 27 dBw
- RECEIVER SENSITIVITY IS -77 dBm
- PROVIDES HARDWARE DEGARBLING OF RECEIVED SIGNALS
- NOVA BASED COMPUTER PERFORMS FUNCTIONS OF:
    1. SURVEILLANCE
    2. THREAT DETECTION
    3. THREAT RESOLUTION
    4. AIR-TO-AIR COORDINATION
    5. ATC (RBX) COORDINATION
    6. SELF TEST/IN FLIGHT MONITORING

DALMO VICTOR ABCAS R/F PROCESSOR

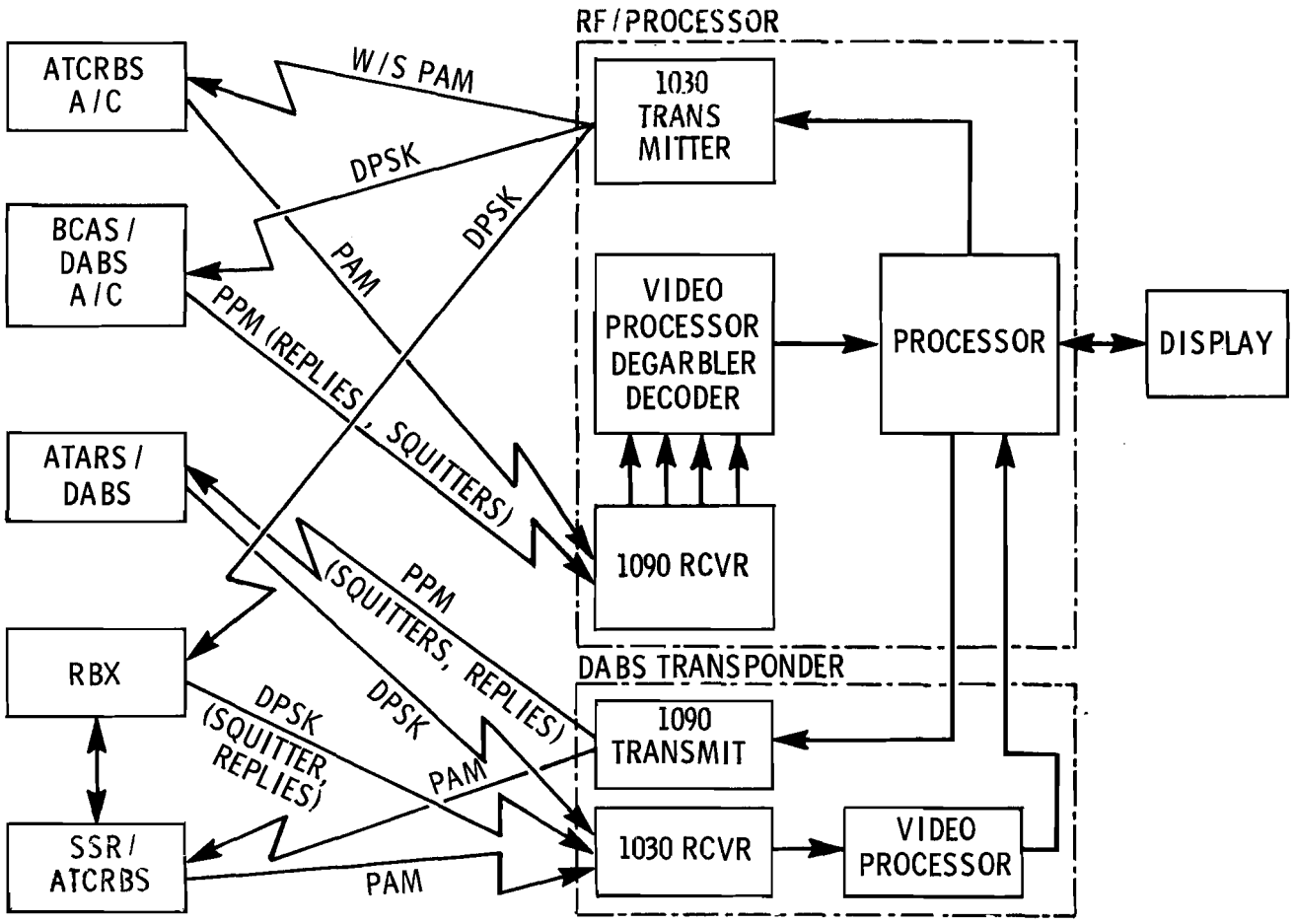


RF/PROCESSOR (CONT.)

- ACCEPTS INPUTS FROM AIRCRAFT
  1. AIR/GROUND SWITCH
  2. MAX AIRSPEED
  3. PRESSURE ENCODER
  4. RADAR ALTIMETER
  5. ATCRBS MODE A CODE
  6. DABS ADDRESS CODE
  7. MUTUAL SUPPRESSION BUS
  8. DABS SMI DATA BUS

9203-A

ABCAS COMMUNICATION LINKS

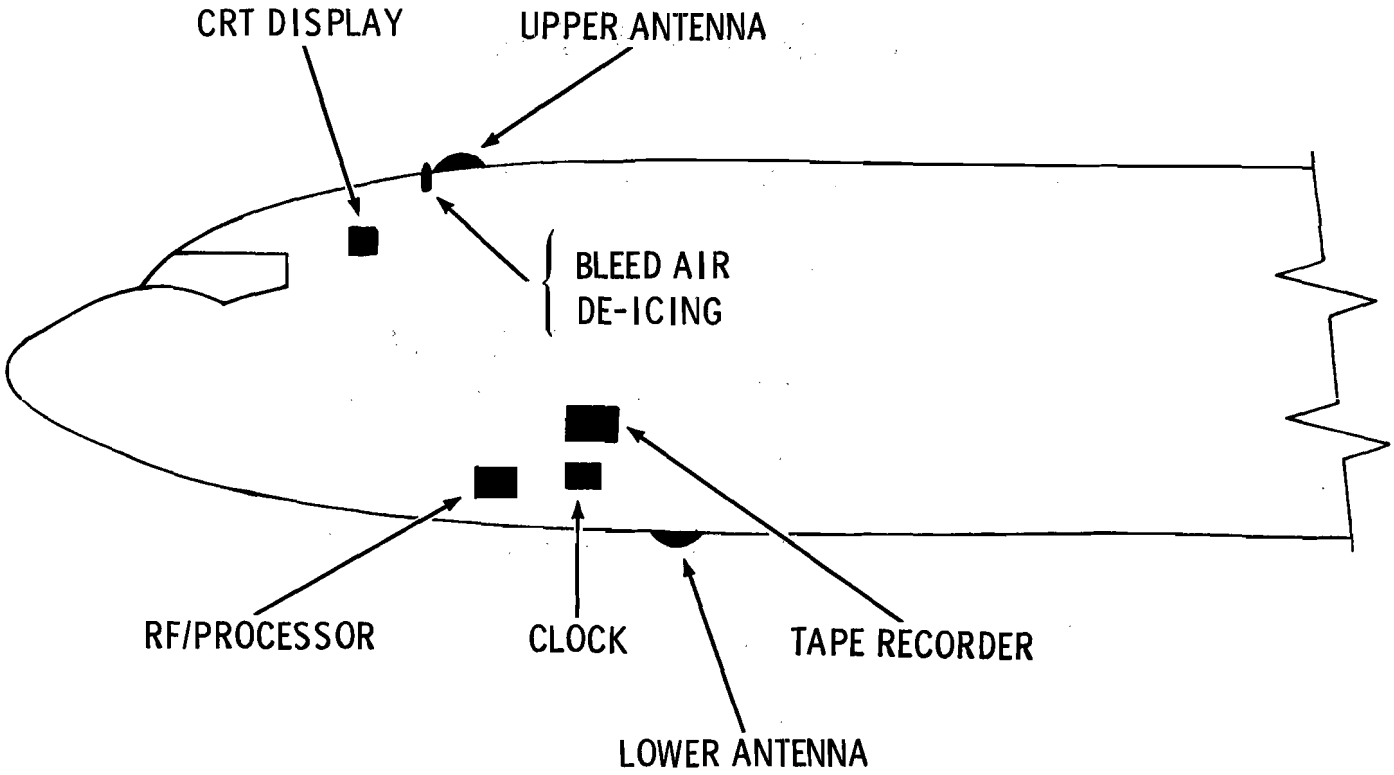


RF/PROCESSOR (CONT.)

- PROVIDES ARINC 429 DISPLAY OUTPUTS
  1. BCAS DISPLAY CONTROL UNIT
  2. INSTANTANEOUS VERTICAL SPEED INDICATOR (IVSI) (CONVERTED TO DISCRETE DISPLAY DRIVERS)
  3. COCKPIT TRAFFIC ADVISORY CRT
  4. LINCOLN LABORATORY COLOR CRT DISPLAY
- PROVIDES RS 232 OUTPUTS
  1. TAPE RECORDER
  2. PERFORMANCE MONITOR

AIRLINE - ABCAS INSTALLATION

BOEING 727

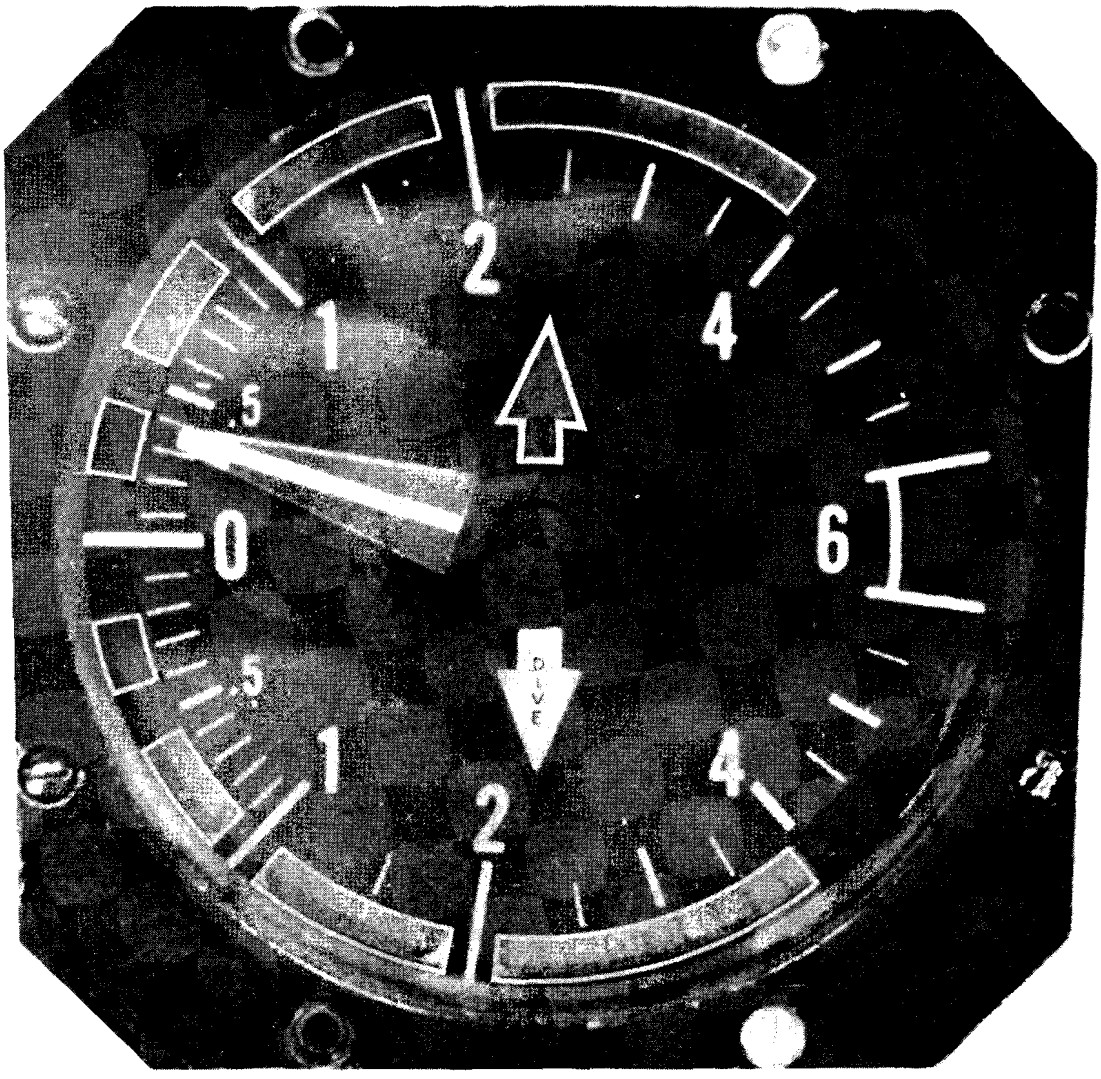


ABCAS DISPLAYS

IVSI

- "CLIMB" ARROW COMMAND
- CLIMB SEGMENTS
  - 200 TO 500 FT/MIN
  - 500 TO 1000 FT/MIN
  - 1000 TO 2000 FT/MIN
  - 2000 TO 4000 FT/MIN
- "DESCEND" ARROW COMMAND
- DESCENT SEGMENTS
  - 200 TO 500 FT/MIN
  - 500 TO 1000 FT/MIN
  - 1000 TO 2000 FT/MIN
  - 2000 TO 4000 FT/MIN

IVSI DISPLAY



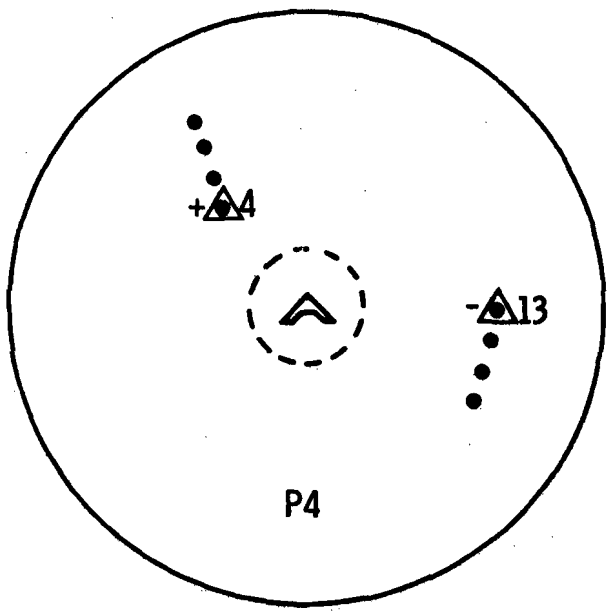
ABCAS DISPLAYS (CONT.)

TRAFFIC ADVISORY INDICATOR

- PERFORMANCE LEVEL IN USE IS DISPLAYED
- A 2 NMI RANGE RING IS DISPLAYED
- THE TOTAL DISPLAY RADIUS IS NORMALLY 10 NMI
- TARGET AIRCRAFT FORMAT
    1. RELATIVE ALTITUDE IN HUNDREDS OF FEET
    2. RELATIVE POSITION OF PREVIOUS 12 SECONDS - AT 4 SECOND INTERVALS
- IF A TARGET IS WITHIN 2 NMI THE COMPUTER AUTOMATICALLY EXPANDS THE DISPLAY TO A 5 NMI RADIUS

9143-A

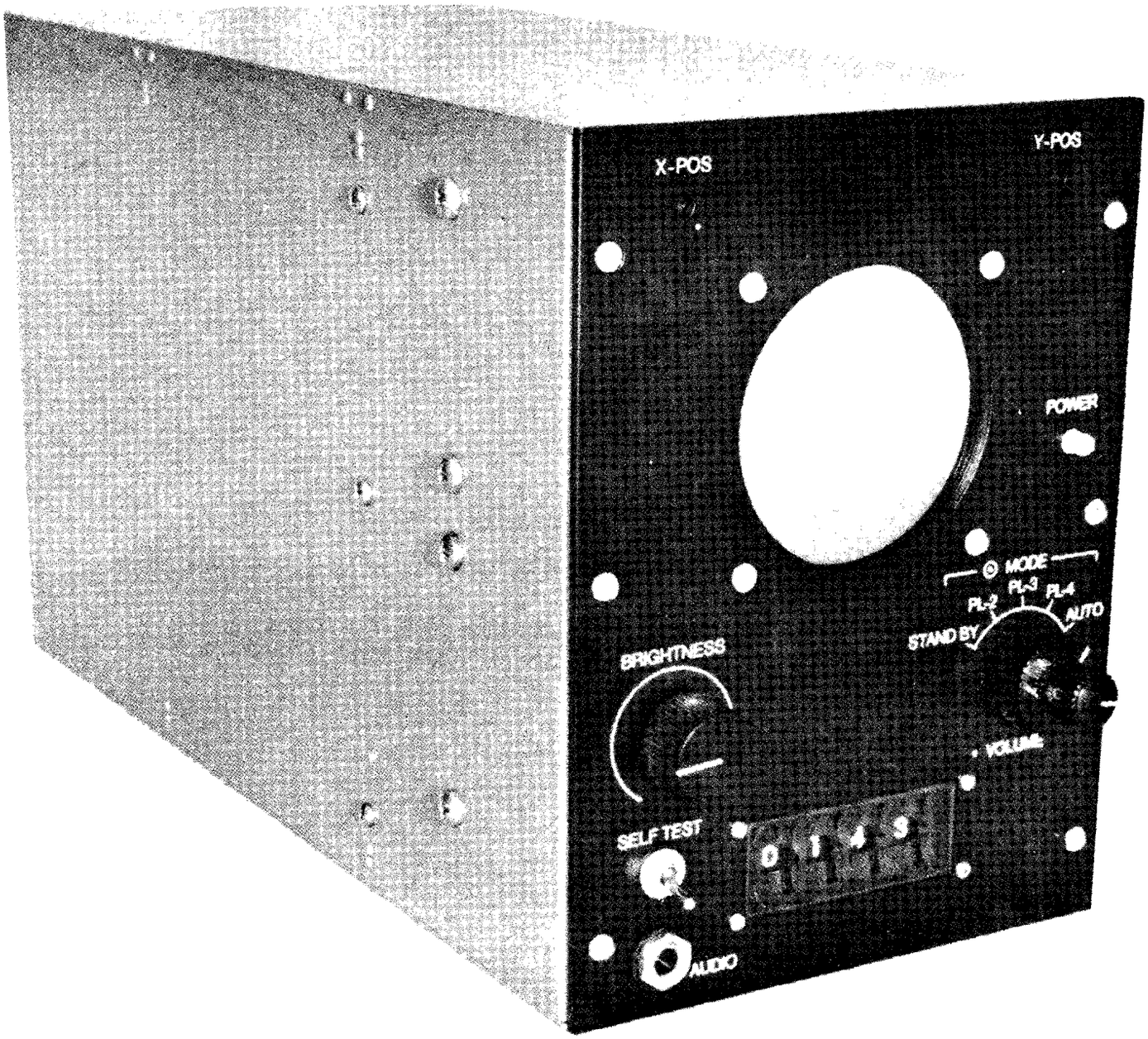
ABCAS TRAFFIC ADVISORY DISPLAY



FLIGHT MONITORING EQUIPMENT

- REAL TIME VIDEO WILL BE PROVIDED TO A RECORDER TO ESTABLISH THE BACKGROUND ENVIRONMENT
- A NINE TRACK TAPE RECORDER WILL STORE COMPUTER DATA
  - SURVEILLANCE FILES
  - CAS FILES
  - RAR CONTENTS
  - DISPLAY BUFFER
- THE FLIGHT DATA WILL BE REDUCED TO EVALUATE ABCAS PERFORMANCE
- A CRT PERFORMANCE MONITOR WILL ALLOW IN-FLIGHT DISPLAY OF ABCAS COMPUTER PROCESSED DATA

DISPLAY/CONTROL UNIT



AIRCRAFT SEPARATION ASSURANCE BIBLIOGRAPHY

January 1981

The following bibliography reflects recent activity in the Federal Aviation Administration's development program for aircraft separation assurance and related areas. The list of documents is divided into the categories of Active BCAS, ATARS, Full BCAS, ASA Overviews, and DABS.

Documents are available from the organizations listed below in accordance with the notations in the bibliography.

C: Available at document distribution table at BCAS Conference

F: Federal Aviation Administration
Attn: ARD-240
800 Independence Ave. SW
Washington, D.C. 20591

M: MITRE Corporation
Attn: N. A. Spencer
1820 Dolley Madison Boulevard
McLean, VA 22102

N: National Technical Information Service
Springfield, VA 22151

Active BCAS

1. Adkins, A. et al. "Air Traffic Control/Active Beacon Collision Avoidance System Knoxville Simulation." Report FAA-RD-80-5, May 1980. (N; 89 pgs).

2. Billmann, B. et al. "Active Beacon Collision Avoidance Logic Evaluation (ATCRBS Threat Phase)." Report FAA-RD-80-125, to be published. (N; 112 pgs).

3. Billmann, B. et al. "Modeling Pilot Response Delay to Beacon Collision Avoidance System Commands." Report FAA-RD-79-74, October 1979. (N; 32 pgs).

4. Broste, N. et al. "Preliminary Evaluation of Active Beacon Collision Avoidance System Performance (Simulated): Protection and Alarms." Report MTR-79W00135, April 1979. (M; 77 pgs).

RD 80-134 ARC 105 Andrews Dandor

5. Greenlaw, D. C. and A. L. McFarland. "Interim Results of Analysis of Active BCAS Alert Rates Using Real Houston Traffic." Report MTR-79W293, June 1980. (M; 40 pgs).

6. Grupe, J. A. et al. "Active BCAS Detailed Collision Avoidance Algorithms." Report MTR-80W286, October 1980. (M; 288 pgs).

7. Harman, W. H. et al. "Active BCAS: Design and Validation of the Surveillance Subsystem." Report FAA-RD-80-134, December 1980. (C, N; 108 pgs).

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9. Sandholm, R. "RBX Functional Description." Report FAA-RD-80-135, to be published. (N; 25 pgs).

10. Tornese, R. and A. L. McFarland. "BCAS Collision Avoidance Logic Performance During Operational Flight Tests." Report MTR-80W352, December 1980. (C, N; 108 pgs).

11. Welch, J. D. and V. A. Orlando. "Active Beacon Collision Avoidance System (BCAS) Functional Overview." Report FAA-RD-80-127, December 1980. (C, N; 41 pgs).

12. Zarrelli, L. B. "Analysis of Active BCAS Alert Rates and Protection Based on Actual Aircraft Tracks." Report MTR-80W00267, January 1981. (M; 187 pgs).

13. "U. S. National Aviation Standard for the Active Beacon Collision Avoidance System." October 1980. (C, F; 73 pgs).

ATARS

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2. Lentz, R. H. et al. "Automatic Traffic Advisory and Resolution Service (ATARS) Multi-Site Algorithms." Report FAA-RD-80-3, Rev. 1, October 1980. (N; 477 pgs).

3. "U. S. National Aviation Standard for the Automatic Traffic Advisory and Resolution Service (Draft)." To be published. (F; 50 pgs).

Full BCAS

1. Koenke, E. J. et al. "FAA BCAS Concept, Executive Summary." Report FAA-EM-78-5, April 1978. (N; 73 pgs).

ASA Overviews

1. "The FAA Aircraft Separation Assurance Program: History, Rationale and Status." Office of Systems Engineering Management, Federal Aviation Administration, Washington, D.C., September 1979. (C, F; 51 pgs).

2. "Aircraft Collision Avoidance: Concepts and Systems." Collection of papers presented at IEEE WESCON/80, September 1980. (C, F; 54 pgs).

3. Lombardo, T. G. "'Collision-Proof' Airspace," IEEE Spectrum, September 1980. (C; 3 pgs).

DABS

1. Orlando, V. A. and P. R. Drouilhet. "DABS: Functional Description." FAA Report FAA-RD-80-41, April 1980. (N; 104 pgs).

2. "U. S. National Aviation Standard for the Discrete Address Beacon System." December 1980. (C, F; 64 pgs).

*U.S. GOVERNMENT PRINTING OFFICE: 1981-0-727-425/1621