AD-A104 563 FEDERAL AVIATION ADMINISTRATION WASHINGTON DC SYSTEM--ETC F/G 1/4
THREAT ALERT AND COLLISION AVOIDANCE SYSTEM (TCAS) SYMPOSIUM.(U)
JUL 81
UNCLASSIFIED FAA/RD-81/76 NL

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U.S. Department of Transportation

Federal Aviation Administration

Systems Research & Development Service
Washington, D.C. 20590

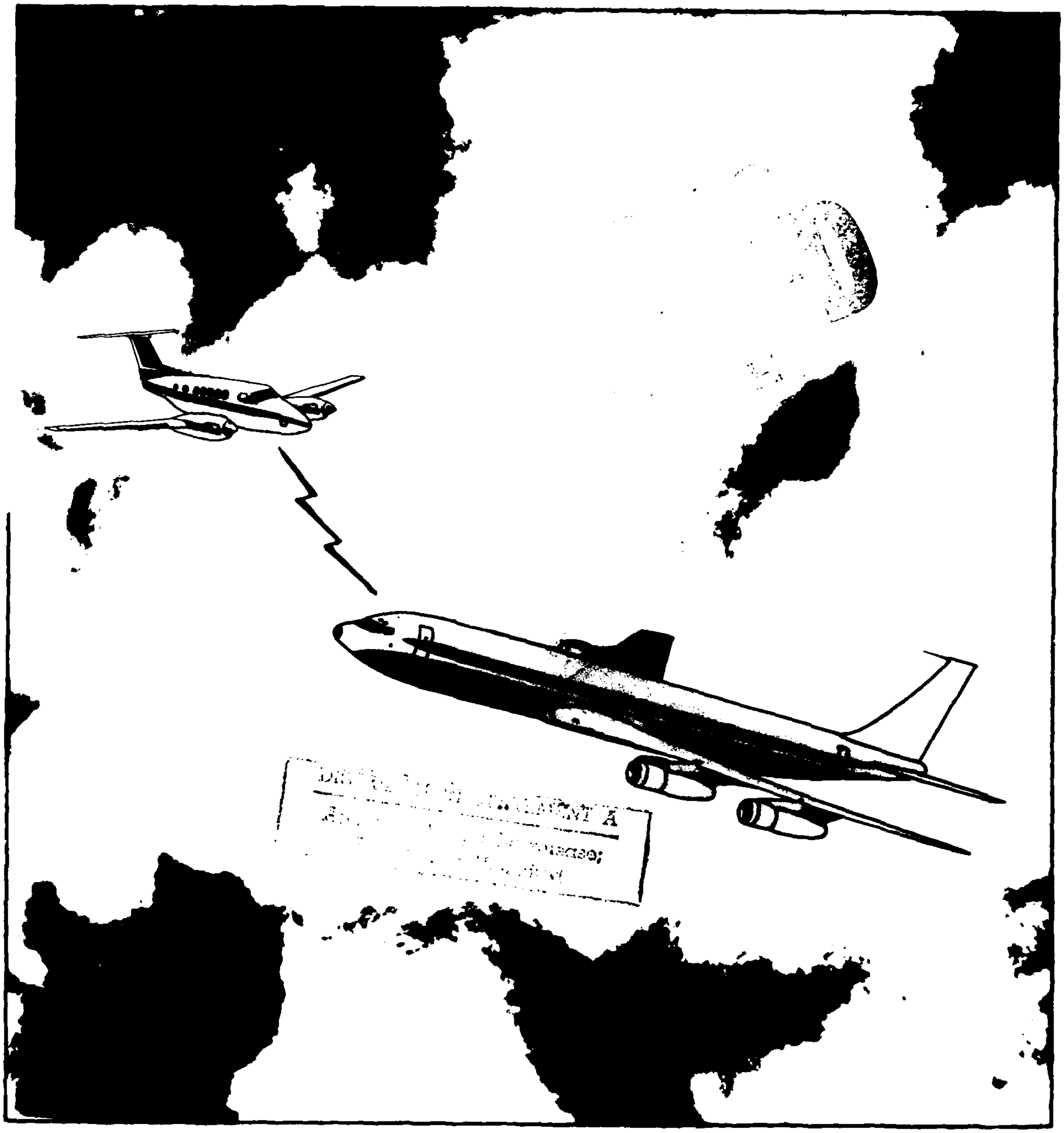
TCAS

Threat Alert and Collision Avoidance System

Symposium .

DOT/FAA/RD-81/76

July 22, 1981



Technical Report Documentation Page

1. Report No. DOT/FAA/RD-81/76	2. Government Accession No. AD-A104 563	3. Recipient's Catalog No.
4. Title and Subtitle Threat Alert and Collision Avoidance System (TCAS) Symposium		5. Report Date July 22, 1981
		6. Performing Organization Code
		8. Performing Organization Report No.
7. Author(s)		
9. Performing Organization Name and Address Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D. C. 20590		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D. C. 20590		13. Type of Report and Period Covered Symposium
		14. Sponsoring Agency Code ARD-10
15. Supplementary Notes		

16. Abstract

The Federal Aviation Administration held a symposium on Threat Alert and Collision Avoidance System (TCAS) in Washington, D. C., July 22, 1981, which was attended by representatives of 68 organizations and 21 airlines. This report contains the news release announcing the new approach to providing protection against mid-air collisions, 10 presentations and the transcript of the panel discussion.

The TCAS will provide a range of capabilities and costs which will meet the requirements of all airspace users. The least complex part of the system is designed for private pilots and would cost about $2,500. The fully capable, or airline, version would cost between $45,000 and $50,000.

This new concept represents a new capability which draws on all FAA has learned about collision avoidance in its past efforts, extends and simplifies FAA's efforts to date, provides new capabilities to all users, and is fully compatible with international standards and improvement activities on the Secondary Surveillance Radar (SSR).

17. Key Words Threat Alert Collision Avoidance Air Traffic Control Transponders National Airspace System	18. Distribution Statement Document is available to the U. S. public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	175	

Form DOT F 1700.7 (8-72)

TCAS TECHNICAL SYMPOSIUM AGENDA

JULY 22, 1981

CHAIRMAN — ROBERT W. WEDAN, DIRECTOR, SYSTEMS RESEARCH AND DEVELOPMENT SERVICE, FEDERAL AVIATION ADMINISTRATION

7:30 - 9:00	Registration	
9:00 - 9:10	Welcome / Review of Agenda	Robert W. Wedan
9:10 - 9:25	TCAS Concept	Al P. Albrecht
9:25 - 10:00	Future ATC Environment	Edmund Koenke
10:00 - 10:30	Definition of TCAS I and TCAS II Characteristics	Norman Solat
10:30 - 11:00	TCAS II	Clyde Miller
11:00 - 11:15	COFFEE BREAK	
11:15 - 11:45	TCAS I	Clyde Miller
11:45 - 12:15	Development Program	Clyde Miller
12:15 - 12:45	Relationship to the Community	Robert W. Wedan
12:45 - 2:00	LUNCH	
2:00 - 2:15	Operational Considerations	Kenneth Hunt
2:15 - 2:30	Airworthiness Considerations	Craig Beard
2:30 -	Question and Answer Panel	

MODERATOR: Al P. Albrecht

PANEL MEMBERS:

Ray Alvarez	Clyde Miller
Craig Beard	Sieg Poritzky
Kenneth Hunt	Norman Solat
Edmund Koenke	Robert Wedan

TCAS SYMPOSIUM

July 22, 1981

Transport Canada
GAMA
NASA Headquarters
AOPA
MITRE
Bendix
ALPA
Republic Electronics
PDX Corporation
COSSOR Electronics
New Zealand Government (Embassy)
E-Systems
U. S. Air Force
ATA
Donaldson, Lufkin & Jenrette
Dalmo Victor
United Kingdom (British Embassy)
Netherlands (Embassy)
Rockwell-Collins
U. S. Army
McDonnell-Douglas
NTSB
International Air Transport Assoc.
Teledyne Avionics
Battelle
Litchford Systems
Aviation Consumer Action Project
Lincoln Laboratory
Aeronautical Radio Inc.
Sperry Flight Systems
Johnston, Lemon & Co., Inc.
ARINC
Boeing Commercial Airplane Co.
Lockheed Calif. Co.
RCA Corporation
Aircraft Electronics Assoc.
NARCO Avionics Inc.
Office of Inspector General
Allied Pilots Assoc.
Department of Commerce
Cardion Electronics
Hazeltine
WC Steber Assoc.

LSI/Astronics
DGAC/CENA (France)
House Science & Technology Committee
Phaneuf Assoc.
Garrett/Airsearch Corporation
NBAA
ECAC
DOT/TSC
AOPA
Hulland Engineering
U. S. Navy
Collins Avionics
RTCA
PATCO
NTIA
King Radio
Experimental Aircraft
Helicopter Association Intl.
Systems Control Inc.
H H Aerospace
John W. Klotz, Inc.
Cessna Aircraft
Telephonics Corporation

AIRLINES:

Western
Air New Zeland
Delta
Frontier
Swiss Air
British
Piedmont
US Air
Northwest
American
All Nippon
Trans World
Eastern
United

Republic
Pan Am
Ozark
Air France
Southwest
Japan
Lufthansa German

TCAS SYMPOSIUM

July 22, 1981

PRESS:

The Journal of ATC
B/CA Magazine
AOPA Pilot
Avionics Magazine
Aviation Week
NY Times
Aviation Convention News
Flying Magazine
Business Aviation Weekly
Government Executive Magazine
FAA General Aviation News

U.S. Department of Transportation
news:

Office of Public Affairs
Washington, D.C. 20590

FOR RELEASE TUESDAY
June 23, 1981

FAA
Contact: Fred Farrar
Tel.: 202/426-8521

FAA PICKS THREAT ALERT AND
COLLISION AVOIDANCE SYSTEM

The Federal Aviation Administration today announced a decision on a new approach to providing protection against mid-air collisions. It will provide valuable new services to the growing number of aircraft in the National Airspace System while significantly improving aviation safety.

Known as the Threat Alert and Collision Avoidance System (TCAS), the system will provide a range of capabilities and costs which will meet the requirements of all airspace users. The least complex part of the system is designed for private pilots and would cost about $2,500. The fully capable, or airline, version would cost between $45,000 and $50,000.

This new concept represents a new capability which draws on all FAA has learned about collision avoidance in its past efforts, extends and simplifies FAA's efforts to date, provides new capabilities to all users, and is fully compatible with international standards and improvement activities on the Secondary Surveillance Radar (SSR).

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The system works in conjunction with altitude-reporting Air Traffic Control Radar Beacon System (ATCRBS) transponders which are in wide use in the Nation's air fleet, and which are required in many airspace areas. These transponders reply to ground interrogations with coded radio signals that provide aircraft position, identity, and altitude information to the ATC system.

There will be two basic types of threat alert and collision avoidance systems, TCAS I and TCAS II.

TCAS I will provide the following capabilities:

- o Normal transponder operations in the present Air Traffic Control Radar Beacon System (ATCRBS).
- o Proper responses to interrogations by the improved Radar Beacon System known as Mode S so as to give it the capability to work compatibly with the current and the evolving ATC system.
- o Periodic Mode S-format unrequested or squitter transmissions on the normal SSR reply frequency of 1090 MHz.
- o The ability to receive and display traffic advisory information, range, bearing and differential altitude (above or below information) from TCAS-II-equipped aircraft.
- o The ability to receive, altitude-sort, and display proximity information from other aircraft equipped with TCAS-I.
- o Ability to receive non-altitude-filtered proximity information from conventional ATCRBS Mode A and limited altitude filtering on altitude reporting transponders within coverage of ATC Radar Beacon System interrogator ground stations.
- o Ability to work compatibly with the current and evolving ground Air Traffic Control system because of the use of the standardized Mode S as the air-to-air communications exchange medium.

In its simplest form, TCAS I, in addition to its normal transponder function, will provide proximity warning only, a visual or audible alarm activated to alert the pilot that he is in proximity to another aircraft carrying the same TCAS-I system, or to an aircraft carrying a conventional ATCRBS transponder (with or without an encoding altimeter). This system is estimated to cost approximately $2,500 and is the basic building block of the future improved Mode S-based Beacon system.

For greater protection, the system will--at a slight increase in price--advise the pilot whether the altitude-reporting threat aircraft is higher or lower in altitude. With yet additional capability, the system will provide a display showing the "o'clock position" and range of threat aircraft equipped with TCAS-II collision avoidance equipment.

It is FAA's intent to set minimum requirements for TCAS-I, including the standards for the SSR Mode S communications medium, and then give industry creativity and free-market forces the opportunity to make the system better, with more features.

TCAS-II is a collision avoidance system similar to, but more capable than, the systems heretofore developed and flown by FAA and the industry. TCAS-II will have the ability to provide the pilot with traffic advisory information in all airspace independently from the ground ATC system. It will provide information and protection from conventional altitude-reporting transponders and from Mode S transponder-equipped aircraft (range, bearing, and altitude) and will provide protection (range and bearing) from Mode A-only equipped aircraft.

- It will have the ability to transmit to others (TCAS-I and TCAS-II equipped aircraft) traffic advisory information (range, bearing, differential altitude, above/below information).

- It will provide collision avoidance protection independently from the ground ATC system using vertical maneuvers, with potential expansion to horizontal maneuvers should technical and economic feasibility be demonstrated.

- It will have an integral scanning directional antenna with direction-finding accuracy capable of supporting a cockpit display of traffic information.

- Like TCAS-I, it will have an integral transponder capable of responding on Modes A, C, and S.

- Like TCAS-I, it will have the ability to work compatibly with the current and evolving ATC system.

- TCAS-II will provide alert and advisory information to aircraft equipped only with TCAS-I, while in the case of two aircraft equipped with TCAS-II, coordinated advisories would be provided.

The threat alert and collision avoidance system defined by FAA overcomes a major drawback of the omnidirectional

- more -

Beacon Collision Avoidance System (BCAS) as previously structured, in that it can operate in all airspace, from the least dense to the most congested.

In announcing this decision on the Threat Alert and Collision Avoidance System, Administrator Helms noted that:

- Collision prevention systems must be an integral part of, and linked to, the total ATC system, but must also operate independently of any ground system.

- They must not constrain, but must permit cost-effective improvements to the total ATC system.

- The minimum system must provide new services to both general aviation and air carriers, but with costs which are sensible for both classes of users.

- The minimum capabilities described by FAA must not stifle innovation by industry to provide enhanced capabilities and innovative designs.

Private business firms have confirmed the FAA estimate that the TCAS-I and II units can be in volume production in 36 and 48 months respectively.

# # #

A. P. ALBRECHT

TCAS TECHNICAL SYMPOSIUM

JULY 22, 1981

GOOD MORNING AND WELCOME TO THE FAA TCAS SYMPOSIUM.

THIRTY DAYS AGO, AT AN AERO CLUB LUNCHEON, MR. HELMS MADE A SIGNIFICANT ANNOUNCEMENT FOR THE AVIATION WORLD. IN THAT ANNOUNCEMENT HE OUTLINED A MAJOR DECISION AND A SIGNIFICANT STEP FORWARD IN THE AREA OF COLLISION AVOIDANCE, MAKING REFERENCE TO THE SYSTEM HE DUBBED THE THREAT ALERT AND COLLISION AVOIDANCE SYSTEM, TCAS. HE MADE A FIRM PLEDGE TO HAVE THAT SYSTEM IN BEING BEFORE HE LEFT OFFICE.

ALTHOUGH THE ANNOUNCEMENT WAS ACCOMPANIED BY A PRESS RELEASE, AND MR. HELMS REMAINED TO ANSWER QUESTIONS, IN THE 30 DAYS SINCE THAT ANNOUNCEMENT, OUR PHONES HAVE BEEN RINGING OFF THE HOOK WITH REQUESTS FOR FURTHER DETAILS.

THERE IS NO DOUBT THAT THE INTEREST IN TCAS IS INTENSE. THERE IS ALSO VERY LITTLE DOUBT THAT THE AVIATION COMMUNITY IS PROBING THE IMPACT AND THE RAMIFICATIONS OF THAT SYSTEM IN DEPTH, IN AN EFFORT TO FULLY APPRECIATE ITS OPERATION AND ITS CONSEQUENCES. EVERYONE CAN AGREE THAT SOMETHING IMPORTANT HAS TRANSPIRED--AND AS ALWAYS HAPPENS WHEN INTELLIGENT PEOPLE REFLECT ON NEW EVENTS AND BALANCE

THEM AGAINST THE PERSPECTIVE OF WHAT THEY ALREADY KNOW AND WHAT THEIR COMMON SENSE AND TECHNICAL JUDGMENT TELLS THEM, IT IS INEVITABLE THAT MANY QUESTIONS ARISE, AND FOR EACH ANSWER, A NEW QUESTION ARRIVES TO TAKE IT S PLACE. THE PURPOSE OF THIS SYMPOSIUM IS TO ANSWER AS MANY OF THEM AS WE CAN.

LET'S TALK FIRST ABOUT THE CRITERIA THE ADMINISTRATOR DESCRIBED THAT THE TCAS CONCEPT MUST MEET. PARAPHRASING HIS JUNE 23RD SPEECH, THEY ARE: A) CAPABLE OF OPERATING WITHOUT DEPENDENCE ON ANY GROUND EQUIPMENT; B) INEXPENSIVE ENOUGH TO MEET THE NEEDS OF GENERAL AVIATION AND PROVIDE HIGHER ORDER SERVICES AND FUNCTIONS DESIRED BY LARGER AIRPLANE USERS; C) FULL COMPATIBILITY WITH THE ATC SYSTEM; AND D) AVAILABLE, <u>IN PRODUCTION</u>, IN 36 TO 48 MONTHS.

ONCE UNDERSTANDING THOSE CRITERIA, THE TCAS PHILOSOPHY AND CONCEPT, AND ITS TECHNICAL REQUIREMENTS BEGIN TO TAKE SHAPE. IT IS IMPORTANT TO RECOGNIZE THAT IN REFERRING TO TCAS, WE ARE REFERRING TO A <u>SYSTEM</u> - ONE COMPRISED OF MANY ELEMENTS. THE PHILOSOPHY IS BASED ON OUR RECOGNITION THAT WE CANNOT AFFORD TO SIT BACK AND WAIT FOR PERFECTION - WE NEED TO GO AHEAD AS RAPIDLY AS POSSIBLE TO PROVIDE NEEDED LEVELS OF PROTECTION TO ALL AIRSPACE USERS. TO PROVIDE THIS RAPID PROTECTION FOR USERS, WE HAVE EVOLVED THE TWO LEVEL TCAS SYSTEM WHICH MR. HELMS SPOKE OF.

THE PHILOSOPHY FOR TCAS 1 IS CLEARLY TO PROVIDE EQUIPMENT AT THE LOWEST POSSIBLE COST FOR A GIVEN LEVEL OF PROTECTION. IMPLIED IN THAT STATEMENT, OF COURSE, IS THE ABILITY OF EACH USER TO EQUIP WITH ENHANCED LEVELS OF PROTECTION AT INCREMENTALLY GREATER COSTS.

FOR TCAS 11, THE PHILOSOPHY IS SOMEWHAT DIFFERENT. HERE WE SEEK TO DEFINE A SYSTEM WHICH WILL PROVIDE THE MAXIMUM PROTECTION ACHIEVABLE FOR ALL ENVIRONMENTS FOR ALL EQUIPPED USERS. TACITLY IMPLIED IN THAT STATEMENT AS WELL, IS THE CONCEPT OF ENHANCEMENTS TO BE ADDED AT USER DISCRETION WHEN TECHNOLOGY AND THE MARKET-PLACE SUPPORT THOSE ENHANCEMENTS.

IT IS GERMANE TO SAY AT THE OUTSET THAT THE TCAS CONCEPT IS AN OUTGROWTH OF THE YEARS OF FAA, INDUSTRY, AND USER PARTICIPATION IN THE DEVELOPMENT, TEST AND EVALUATION OF AIRCRAFT SEPARATION ASSURANCE SYSTEMS--MOST ESPECIALLY THE DEVELOPMENTS KNOWN AS BCAS, BOTH ACTIVE AND FULL BCAS. THE COURSE OF THIS OUTGROWTH, FROM THE SUCCESSFUL DEVELOPMENT AND DEMONSTRATION OF THE ACTIVE BCAS SYSTEM WHICH WAS REPORTED IN OUR CONFERENCE OF LAST JANUARY, HAS BEEN IN TWO DIRECTIONS.

THE NEED FOR GROWTH IN TWO DIRECTIONS IS APPARENT FROM THE PHILOSOPHY AND THE CRITERIA I JUST CITED. FIRST, IT IS CLEAR THAT ACTIVE BCAS NEEDED TO CHANGE UPWARDELY, SINCE IT WORKED VERY WELL--BUT DIDN'T WORK EVERYWHERE. HENCE, TCAS 11.

SECOND, IT NEEDED TO CHANGE IN THE OTHER DIRECTION, SINCE THE PROBABLE COST OF PRODUCTION ACTIVE BCAS UNITS OFFERED NO ASSURANCE THAT SMALLER GENERAL AVIATION AIRCRAFT OWNERS WOULD HAVE THE INCENTIVE TO EQUIP. HENCE, TCAS 1.

ESSENTIALLY, THEN, THE RATIONALE BEHIND THE TCAS DECISION IS EMINENTLY SOUND--PROVIDE COMPATIBLE EQUIPMENT FOR THE SPECTRUM OF AIR SPACE USERS, ACCORDING TO THEIR NEEDS, AND ACCORDING TO THEIR POCKETBOOKS. THUS, TCAS 1 AT THE LOW END OF THE SPECTRUM AT A LOW COST, AND A TCAS 11, AT THE HIGH END OF THE SPECTRUM AT A COST AFFORDABLE BY THE MORE SOPHISTICATED AIRSPACE USERS.

THE DESCRIPTION I'VE JUST GIVEN ITSELF OPENS UP A HOST OF RELATED QUESTIONS. GIVEN THAT WE HAVE DEFINED A HIGH END AND A LOW END OF THE SPECTRUM, WHAT ABOUT THE REGION IN BETWEEN? WHAT ENHANCEMENTS MAY INDUSTRY PROVIDE AND THE USERS PROCURE, AND HOW WILL THOSE ENHANCEMENTS BE STANDARDIZED AND CONTROLLED? THOSE ISSUES WILL BE THE TOPIC OF SEVERAL OF OUR TALKS TODAY.

THE SECOND MAJOR AREA WHERE WE EXPECT YOU HAVE SOME QUESTIONS IS IN THE AREA OF

IMPLEMENTATION--OF TCAS 1 AND ITS ENHANCEMENTS, AND OF TCAS 11 AND ITS ENHANCEMENTS. A HOST OF QUESTIONS IN THIS AREA COME TO MIND, AND I SUSPECT MANY MORE ARE IN YOUR MINDS.

IN THE AREA OF TECHNICAL SPECIFICATIONS ARE THE QUESTIONS OF NATIONAL STANDARDS, MINIMUM OPERATIONAL AND PERFORMANCE SPECIFICATIONS, OR MOPS, AND AVIONICS CERTIFICATION. IT'S FAIR TO ASK WHAT THE FAA INTENDS IN THOSE AREAS, AND THIS AFTERNOON, WALT LUFFSEY'S PEOPLE WILL BE DISCUSSING FAA VIEWS. OUR CURRENT THINKING ON TSO AUTHORIZATION, STC'S, FLIGHT OPERATIONS AND OTHER QUESTIONS WILL ALSO BE COVERED.

THE ADMINISTRATOR IS MOST ANXIOUS, TRUTHFULLY HE IS ADAMANT, THAT WE DEVELOP UNTIL WE CAN FIRM UP THE MINIMUM STANDARDS AND THEN TURN THE JOB OVER TO INDUSTRY AND USERS TO PRODUCE, INSTALL AND IMPROVE/ENHANCE. THAT, WE WILL DO.

BEFORE I TURN THE PODIUM OVER TO THE DAY'S PRINCIPAL SPEAKERS, I KNOW THERE IS ANOTHER QUESTION ON YOUR MINDS--WHERE DO DABS AND ATARS FIT IN ALL THIS? TO ANSWER THAT QUESTION HONESTLY, I WOULD HAVE TO SAY THAT THE ADMINISTRATOR IS STILL IN THE PROCESS OF REVIEWING THOSE IMPLEMENTATION PLANS, AND NO FINAL DECISION HAS BEEN MADE AS YET. HOWEVER, AS YOU WILL LEARN TODAY, OR PROBABLY ALREADY KNOW, BOTH

TCAS 1 AND TCAS 11 CARRY, AS A MINIMUM, A MODE S TRANSPONDER--AND MOST OF YOU ALREADY KNOW THAT IN ITS SIMPLEST FORM, MODE S IS THE INTERNATIONALLY ADOPTED TERM FOR WHAT WE IN THE UNITED STATES HAVE CALLED THE DABS SIGNAL FORMATS.

WITH REGARD TO ATARS, IT SHOULD BE CLEAR THAT THE MODE S TRANSPONDER AND THE DISPLAY REQUIREMENTS OF TCAS 1 AND 11 MAKE THEM FULLY CAPABLE OF SUPPORTING A DECISION TO IMPLEMENT ATARS, AS WELL AS ANY OTHER DATA LINK SERVICES, SHOULD THAT DECISION BE MADE.

THERE IS ANOTHER QUESTION WHICH HAS BEEN ASKED OVER AND OVER AGAIN SINCE MR. HELMS' SPEECH: "IS TCAS REALLY A DRAMATIC CHANGE OF FAA DIRECTION?". THE ANSWER IS THAT AN IMPORTANT DECISION HAS BEEN MADE. IT IS A DECISION WHICH DOES NOT CHANGE THE DIRECTION, BUT ENHANCES THE WORK WHICH WE HAVE BEEN DOING.

TCAS 11 IS THE BCAS ON WHICH WE HAVE BEEN WORKING, WITH TWO ENHANCEMENTS, THE INTRODUCTION OF DIRECTIONAL INTERROGATION AND A RECEIVE DIRECTION-FINDING CAPABILITY TO PERMIT OPERATION IN HIGH-DENSITY AIRSPACE AND TO GIVE A SENSE OF DIRECTION TO THE THREATS. SECOND, AN IMPORTANT NEW TCAS 11 CAPABILITY TO TRANSMIT TO TCAS 1 AIRCRAFT

INFORMATION ABOUT THE TCAS 11 AND ITS INTENTIONS.

TCAS 1 IS A NEW SERVICE, BUT IT HAS AS ITS HEART THE TRANSPONDER CAPABLE OF MODE A, C, AND S THAT WE AND THE COMMUNITY HAVE BEEN WORKING ON. IT HAS TWO ADDITIONAL FEATURES: THE ABILITY TO RECEIVE AND DISPLAY INFORMATION <u>FROM</u> THE TCAS 11, AND THE ABILITY TO PROVIDE WARNING ON THE PROXIMITY OF OTHER TCAS AND ALL OTHER TRANSPONDER EQUIPPED AIRPLANES. SO, WHILE THE DECISION IS IMPORTANT, AND THERE ARE NEW FEATURES, WHAT WE ARE DISCUSSING TODAY DOES NOT INVOLVE A DRAMATIC DEPARTURE FROM WHERE WE HAVE BEEN, BUT BUILDS ON EVERYTHING THAT HAS BEEN DONE. THAT IS TRUE ALSO IN THE INTERNATIONAL ARENA. WE BELIEVE THAT WHAT WE HAVE DONE IS IN FULL CONSONANCE WITH WHAT HAS BEEN DONE ALREADY BY ICAO.

WHEN WILL WE HAVE TCAS'S IN THE OPERATIONAL FLEET? MR. HELMS SAID 36 MONTHS FOR TCAS 1 AND 48 MONTHS FOR TCAS 11. THAT MEANS WE WILL HAVE TO HAVE ALL THE TESTING DONE, AND THE DOCUMENTATION IN PLACE IN 2 YEARS FOR TCAS 1 AND 3 YEARS FOR TCAS 11. THERE IS A LOT OF WORK TO BE DONE TO MEET THOSE DATES, AND IT WILL TAKE A STRONG CONTINUING EFFORT ON BOTH OUR PARTS AND THAT OF INDUSTRY. TO THAT END, WE EXPECT TO ESTABLISH REGULAR SCHEDULED REVIEW SESSIONS WITH YOU TO PROVIDE A REGULAR

POSITIVE ENVIRONMENT FOR COMMUNICATIONS ON THIS CRITICAL PROGRAM. WE'RE STILL FIRMING PLANS FOR THESE MEETINGS BUT EVERY 45 DAYS OR SO SEEMS REASONABLE AT THIS TIME. WE'LL BE IN TOUCH VERY SHORTLY ON THIS SUBJECT.

JUST ONE FINAL REMARK, IN HIS SPEECH OF JUNE 23, MR. HELMS ASKED FOR YOUR SUPPORT. I TAKE IT FROM THE FACT THAT SO MANY OF YOU HAVE SEEN FIT TO BE HERE TODAY, THAT WE HAVE THAT SUPPORT. WE INTEND TO MOVE OUT SMARTLY. IT IS OUR CONVICTION THAT CLOSE AND FREQUENT TECHNICAL COORDINATION BETWEEN THE FAA AND INDUSTRY WILL RESULT IN THE EARLIEST IMPLEMENTATION, AND WE INTEND TO MAINTAIN THAT COORDINATION THROUGHOUT THIS PROGRAM.

IN CLOSING, THEN, LET ME AGAIN PARAPHRASE MR. HELMS. THE TIME FOR IMPLEMENTING A DECISION HAS COME. I INVITE YOU TO COME ALONG THE ROAD WITH US.

THANK YOU FOR YOUR ATTENTION. I'LL TURN THE PODIUM BACK TO BOB AND I'LL SEE YOU AT THE QUESTIONS AND ANSWER SESSION THIS AFTERNOON.

ATC ENVIRONMENTAL EFFECTS

ON

COLLISION AVOIDANCE SYSTEM DESIGN

E. J. KOENKE
7/22/81

COLLISION AVOIDANCE SYSTEM FUNCTIONS

- <u>SURVEILLANCE</u> - DETERMINE RELATIVE POSITION OF AIRCRAFT
- <u>THREAT DETECTION</u> - DETERMINE COLLISION THREAT POTENTIAL OF AIRCRAFT
- <u>RESOLUTION</u> - DETERMINE SAFE EVASIVE MANEUVER
- <u>COORDINATION</u> - COORDINATE MANEUVER WITH OTHER TCAS; DISPLAY MANEUVER TO PILOT; FUNCTION COMPATIBLY WITH ATC
- <u>TRAFFIC ADVISORY</u> - DISPLAY PROXIMATE TRAFFIC TO PILOT
  - TRANSMIT TRAFFIC ADVISORIES TO OTHERS

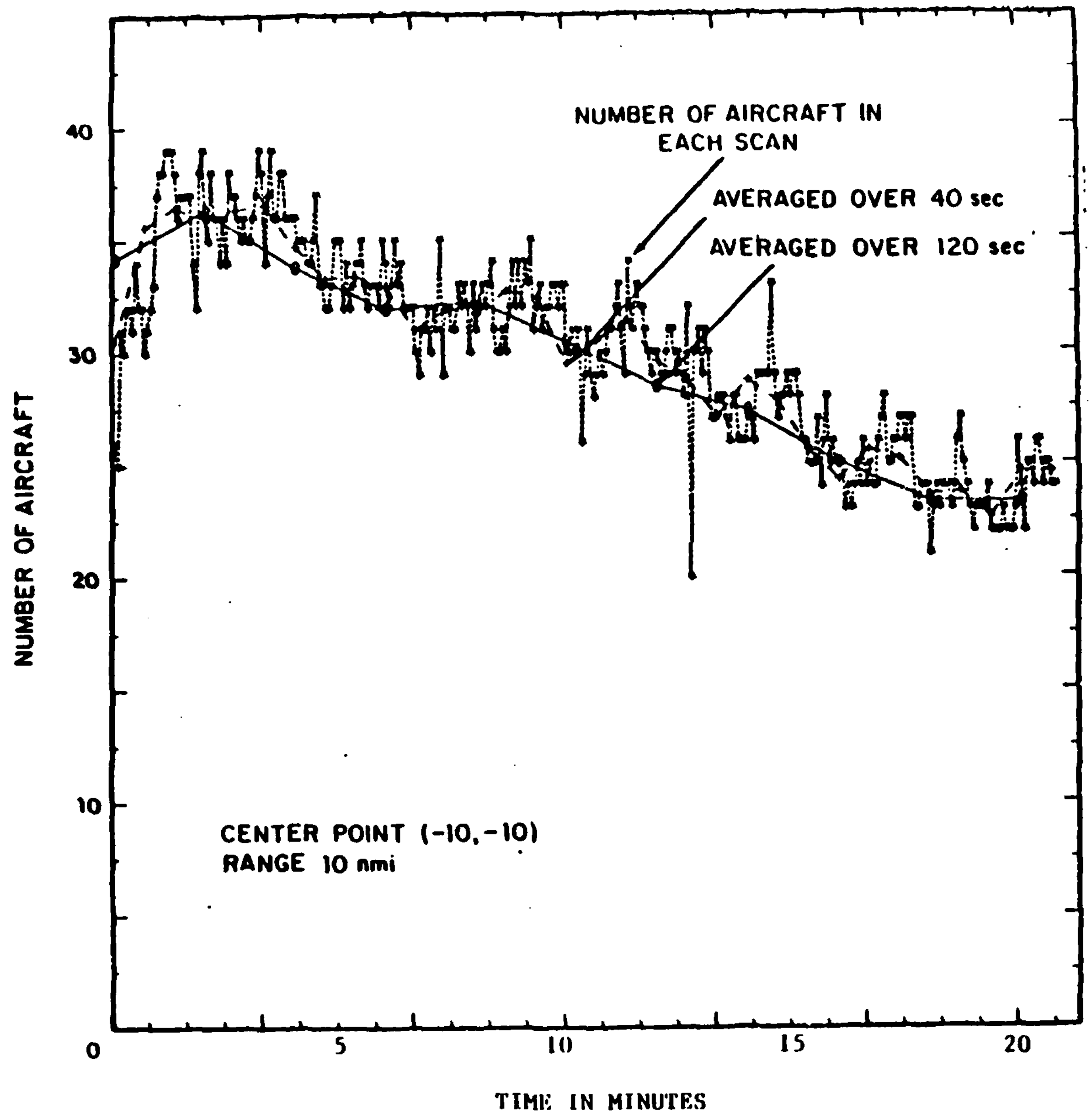
SENSITIVITY OF FUNCTIONS TO ENVIRONMENT

- <u>SURVEILLANCE</u> - HIGH DENSITY ENVIRONMENTS CAN CAUSE INTERFERENCE RESULTING IN FALSE AND/OR MISSED TRACKS
- <u>THREAT DETECTION</u> - FALSE TRACKS CAN RESULT IN FALSE DECLARATION OF A THREAT WHILE MISSED TRACKS CAN RESULT IN LATE OR MISSED DETECTION OF A THREAT
- <u>RESOLUTION</u> - FALSE DECLARATION OF A THREAT CAN LEAD TO THE COMPUTATION OF AN UNNECESSARY ALERT. MISSED THREAT DETECTION CAN RESULT IN THE LACK OF COMPUTATION OF A NECESSARY ALERT
- <u>COORDINATION</u> - DISPLAY OF EXCESSIVE FALSE OR UNNECESSARY ALERTS CAN DESTROY PILOT CONFIDENCE AND, IF FOLLOWED, CAN CAUSE DISRUPTION OF THE ATC PROCESS.

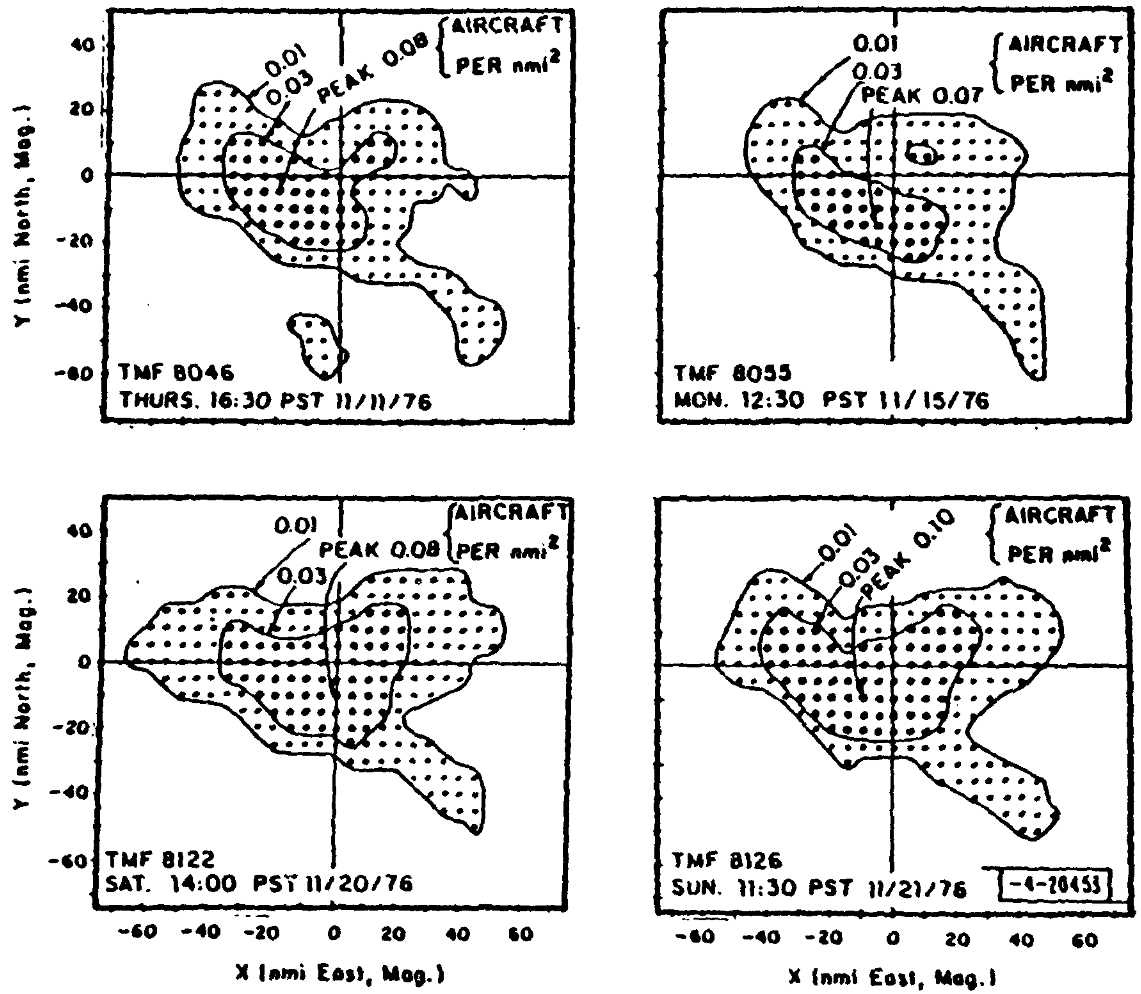
- o <u>COORDINATION</u> (CONT'D)- DISPLAY OF LATE COMMANDS OR NO COMMAND WHEN NECESSARY CAN BE A SAFETY HAZARD.
  - HIGH DENSITY ENVIRONMENTS CAN CAUSE INTERFERENCE RESULTING IN LACK OF MANEUVER COORDINATION.
  - INTERFERENCE TO ATC SURVEILLANCE THROUGH OVER INTERROGATION OR SUPPRESSION OF AIRCRAFT TRANSPONDERS IS POSSIBLE PARTICULARLY IN HIGH DENSITY.
- o <u>TRAFFIC ADVISORIES</u>
  - HIGH DENSITY ENVIRONMENTS CAN CAUSE INTERFERENCE RESULTING IN LOST RECEPTION OF TCAS-II TO TCAS-I ADVISORIES.
  - HIGH DENSITY ENVIRONMENTS CAN RESULT IN DEGRADATION OF THE VALUE OF PROXIMITY WARNING FOR EITHER TCAS-I OR TCAS-II.

POTENTIAL PROBLEM	PRIMARY CAUSE	ALTERNATIVE SOLUTIONS
LATE/MISSED ALERTS	SYNCHRONOUS GARBLE	WHISPER/SHOUT; DIRECTIONAL INTERROGATION; DEGARBLING OF OVERLAPPING REPLIES
FALSE ALERTS	MULTI-PATH	WHISPER/SHOUT; TOP & BOTTOM ANTENNAS; MISS-DISTANCE FILTERING
ATC INTERFERENCE - OPERATIONAL - SURVEILLANCE	FALSE ALERTS OVER INTERROGATION/ SUPPRESSION	WHISPER/SHOUT; TOP & BOTTOM ANTENNAS; DESENTIZATION; MISS-DISTANCE FILTERING; ENVIRONMENTAL SENSING; SEARCH MODE CONTROL
NUMEROUS TARGETS	HIGH DENSITY	ALTITUDE FILTERING; DIRECTIONAL ANTENNAS
DEGRADED DATA LINK	FRUIT	DISCRETE ADDRESSING, MODULATION, CODING

THE ENVIRONMENT



Time variation, traffic in the LA area - peak location
(From Report No. FAA-RD-78-45.)



Day-to-day comparison of LA Basin traffic
(From Report No. FAA-RD-78-45)

NOTE: Each dot represents a density averaged over 20 minutes and over a 10 nmi range.

THE PROJECTED ENVIRONMENT

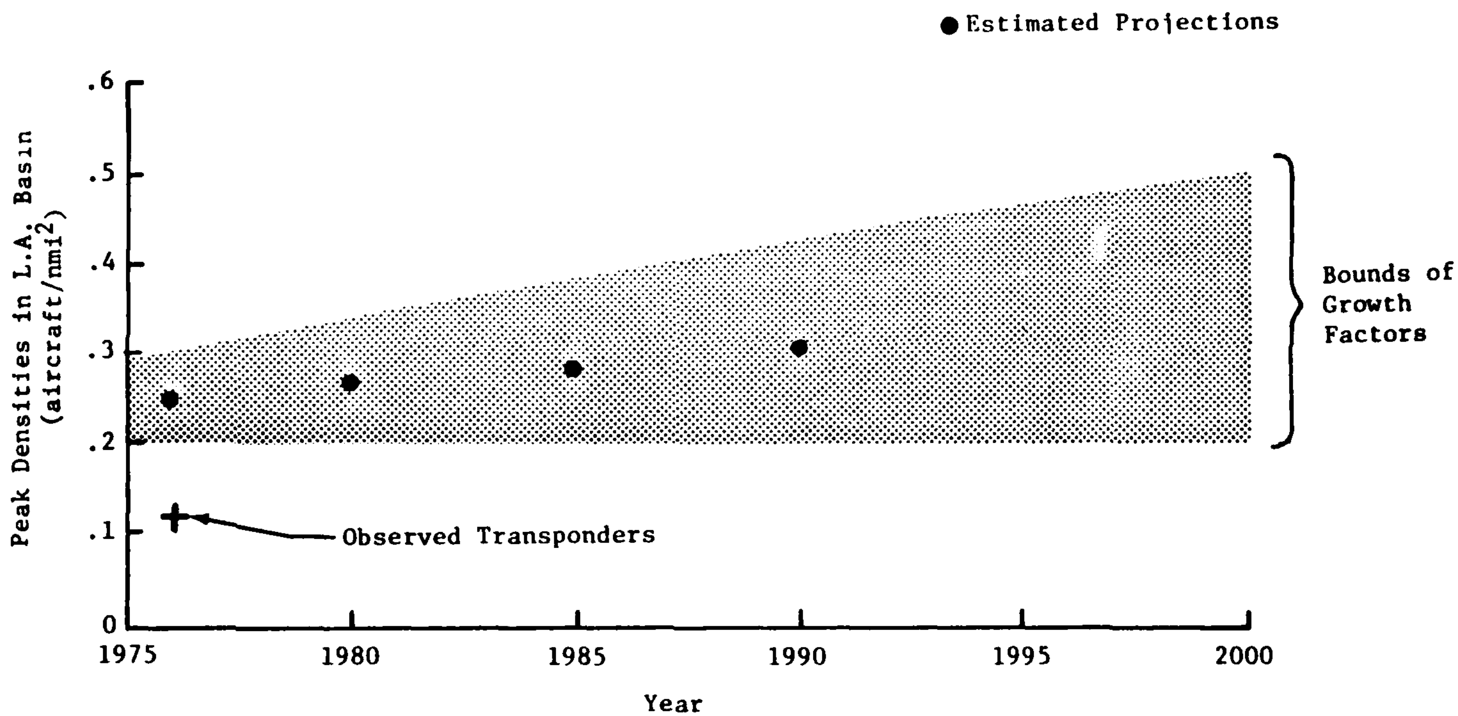
DENSITY (AC/NM^2)

TOTAL A/C

	XPNDRS	TOTAL OPS	IFR OPS	REGISTERED AC
1976	0.10 MEASURED*	.25 EST	.17 EST	.17 EST
1980	.13	.27	.21	.21
1985	.15	.28	.25	.25
1990	.18	.30	.32	.30
1995	.21	--	.35	.35
2000	.24	--	.4	.4

* LARGEST MEASURED WAS 0.12 TRANSPONDERS IN 1976

PEAK DAY ESTIMATE 0.15 IN 1976



ESTIMATED PEAK DENSITY OF AIRCRAFT IN LOS ANGELES BASIN

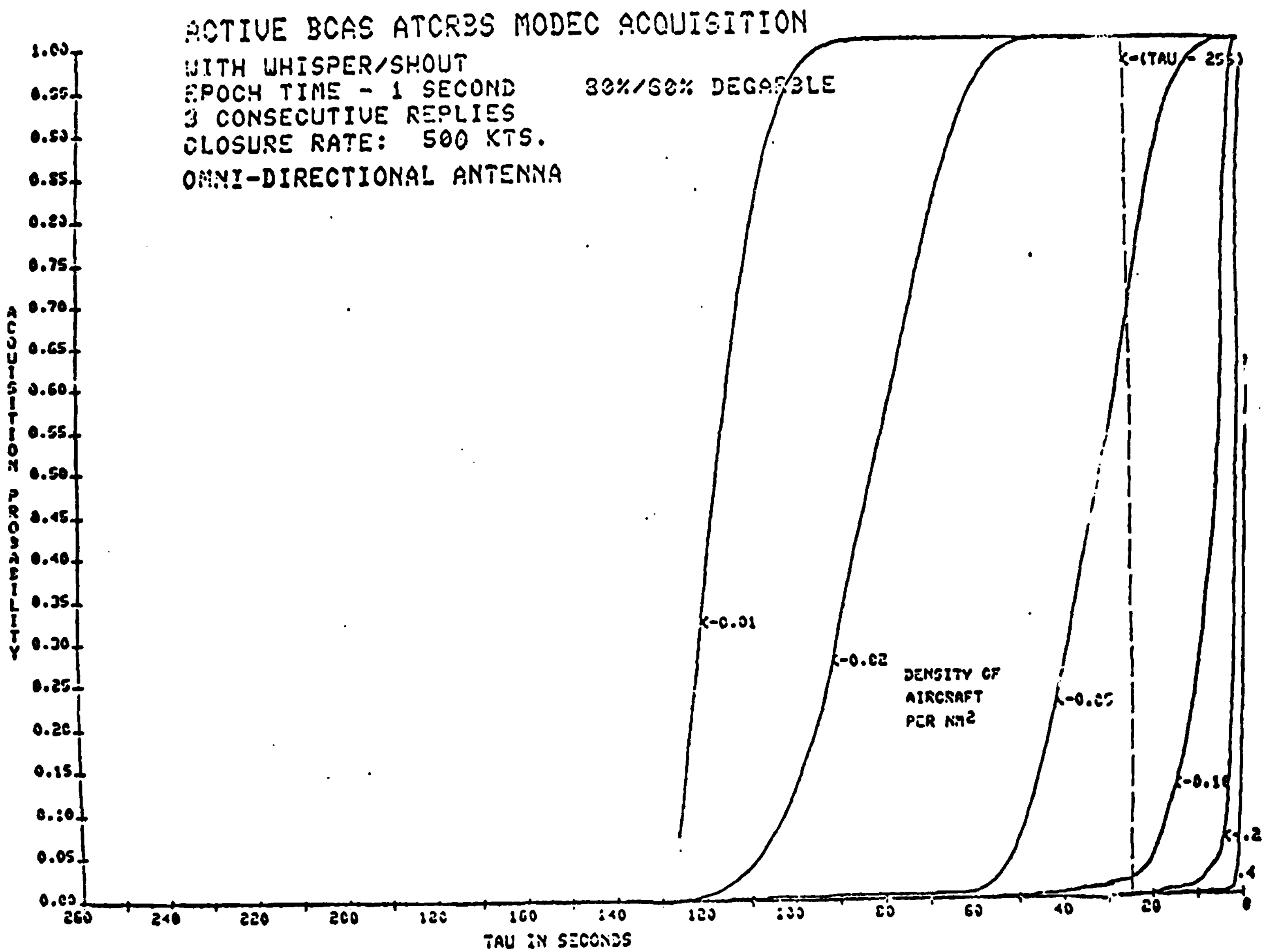
CONCLUSION

- TRANSPONDER EQUIPPED AIRCRAFT DENSITIES OF 0.12 AC/NM^2 WERE MEASURED IN 1976 AND TOTAL AIRCRAFT DENSITIES OF 0.3 BY 1990 AND 0.4 BY 2000 ARE HIGHLY PROBABLE.

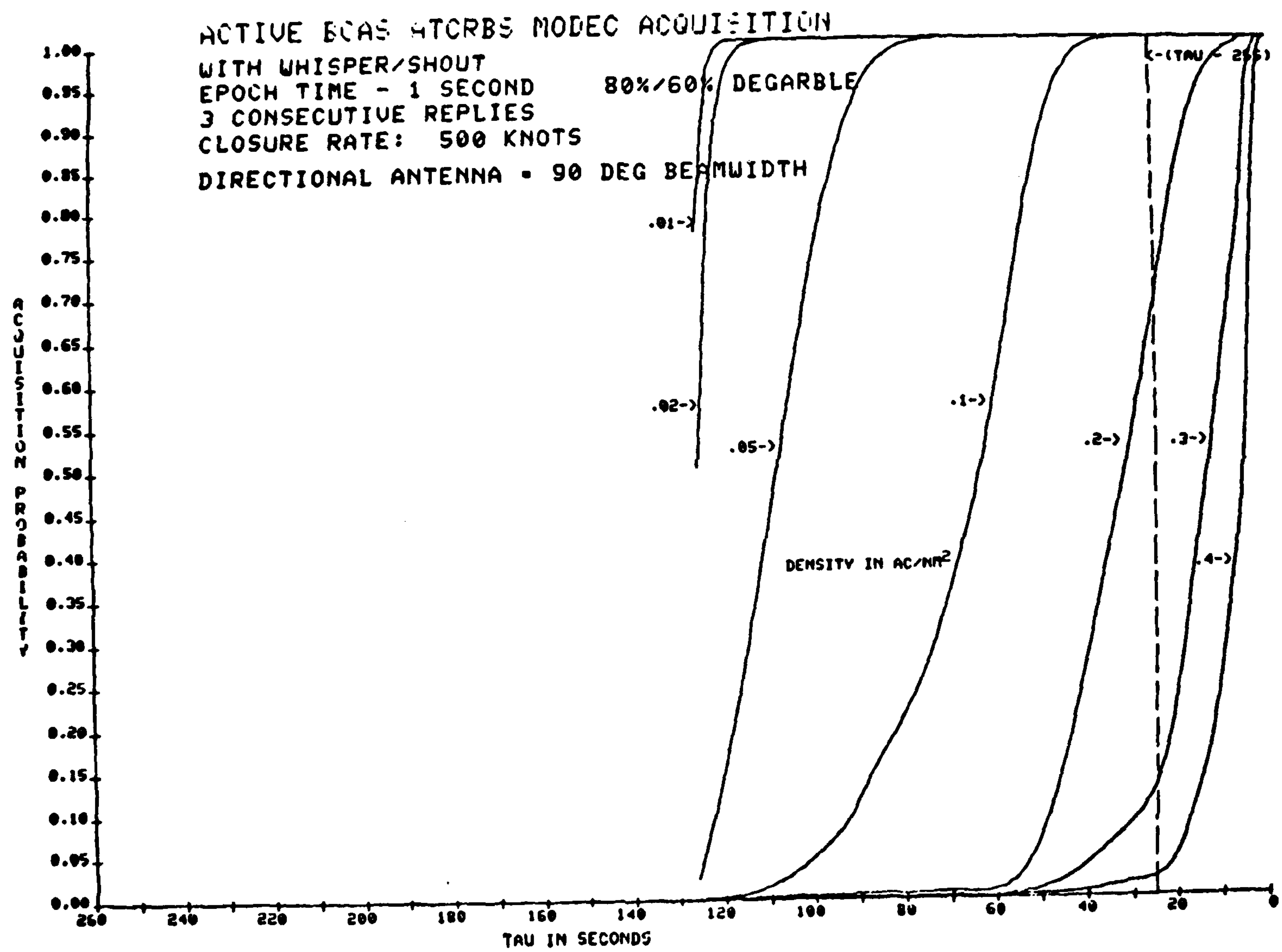
<u>LATE OR MISSED</u>

<u>FALSE OR UNNECESSARY</u>

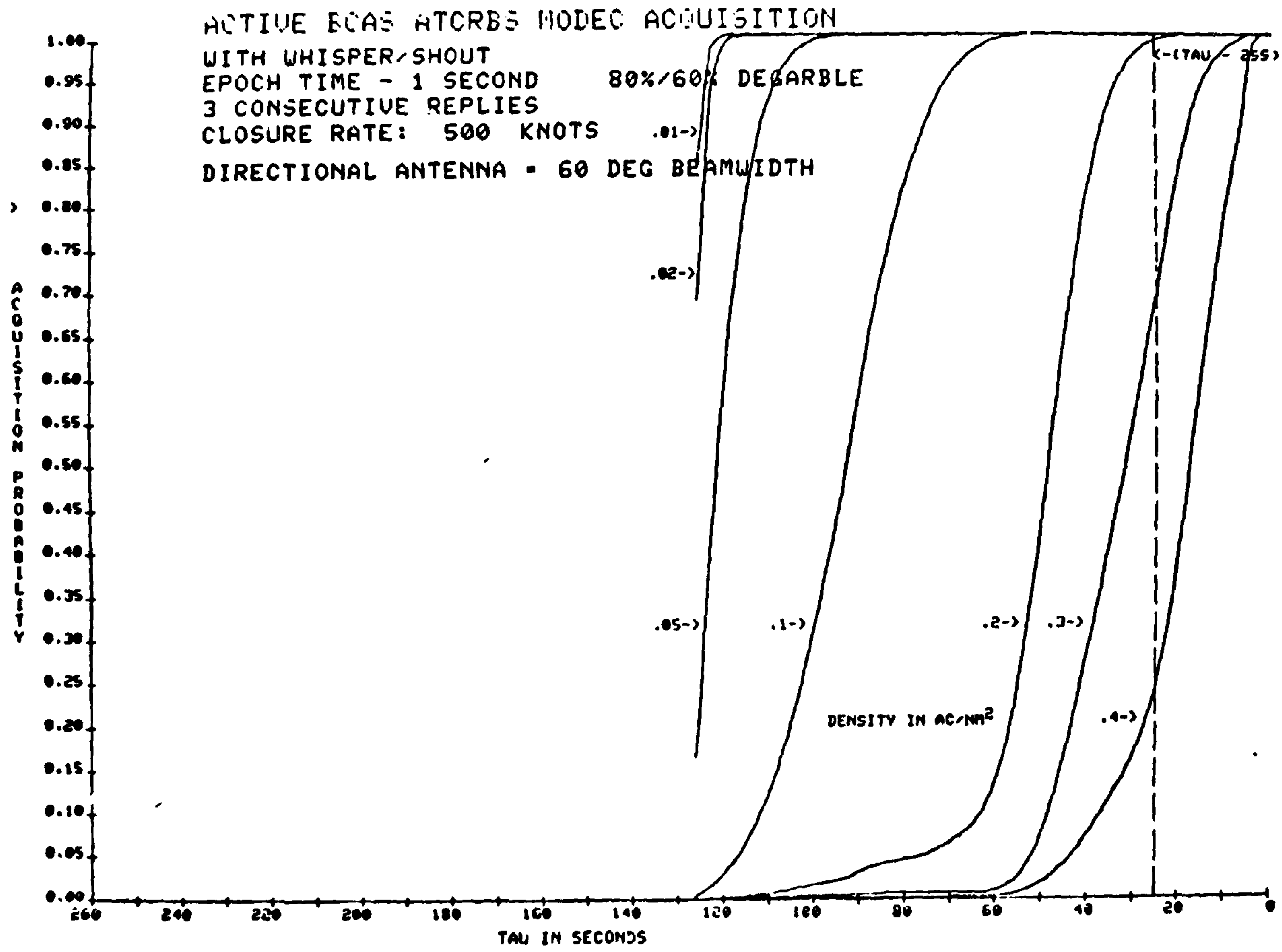
<u>ALERTS</u>



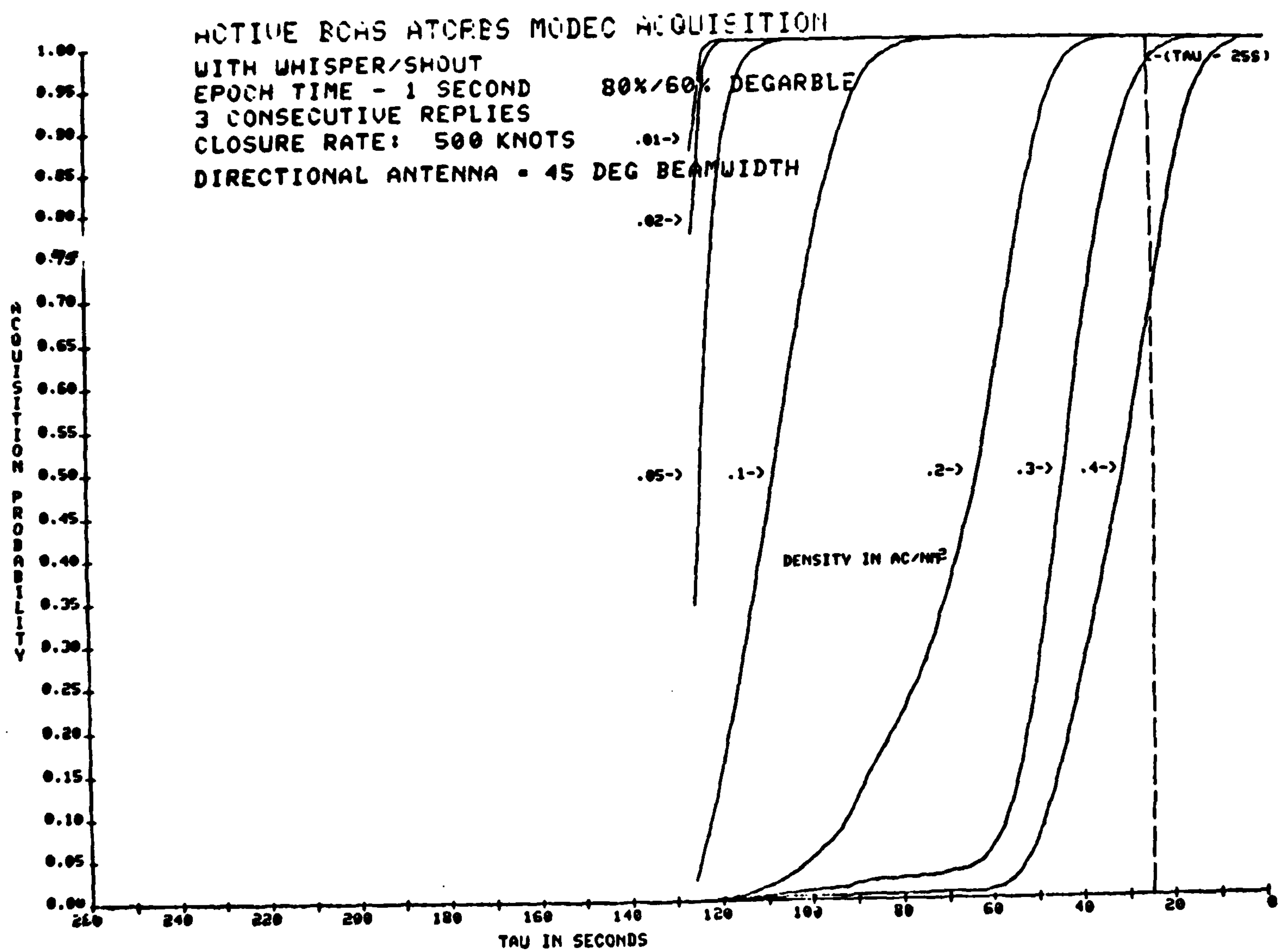
ACTIVE BCAS ATCRBS MODEC ACQUISITION
WITH WHISPER/SHOUT
EPOCH TIME - 1 SECOND
80%/60% DEGARBLE
3 CONSECUTIVE REPLIES
CLOSURE RATE: 500 KTS.
OMNI-DIRECTIONAL ANTENNA
ACQUISITION PROBABILITY
TAU IN SECONDS
DENSITY OF AIRCRAFT PER NM2
←0.01
←0.02
←0.05
←0.10
←.2
.4
←(TAU = 25)



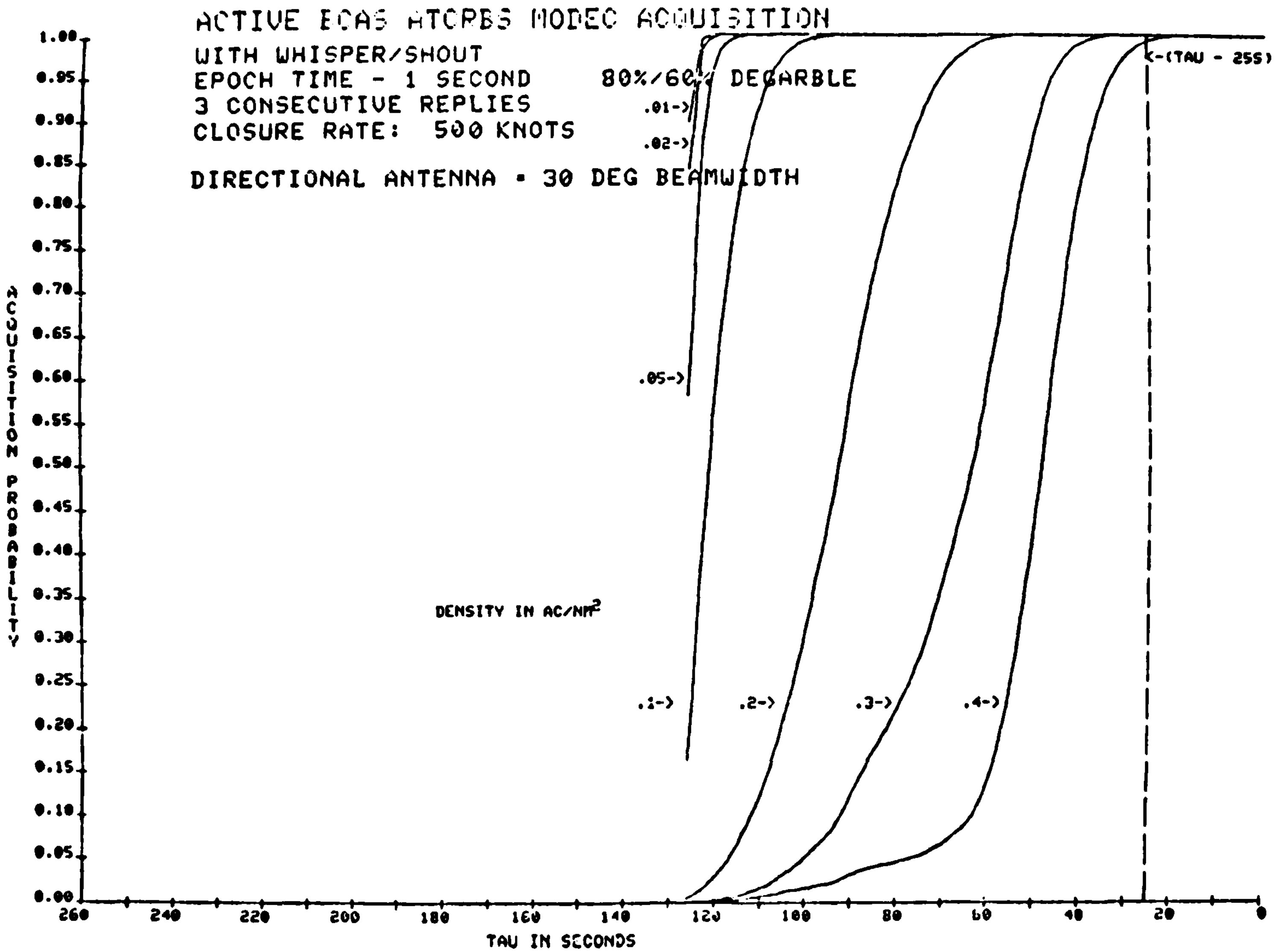
ACTIVE BCAS ATCRBS MODEC ACQUISITION
WITH WHISPER/SHOUT
EPOCH TIME - 1 SECOND
80%/60% DEGARBLE
3 CONSECUTIVE REPLIES
CLOSURE RATE: 500 KNOTS
DIRECTIONAL ANTENNA = 90 DEG BEAMWIDTH
ACQUISITION PROBABILITY
TAU IN SECONDS
DENSITY IN AC/NM2
.01->
.02->
.05->
.1->
.2->
.3->
.4->

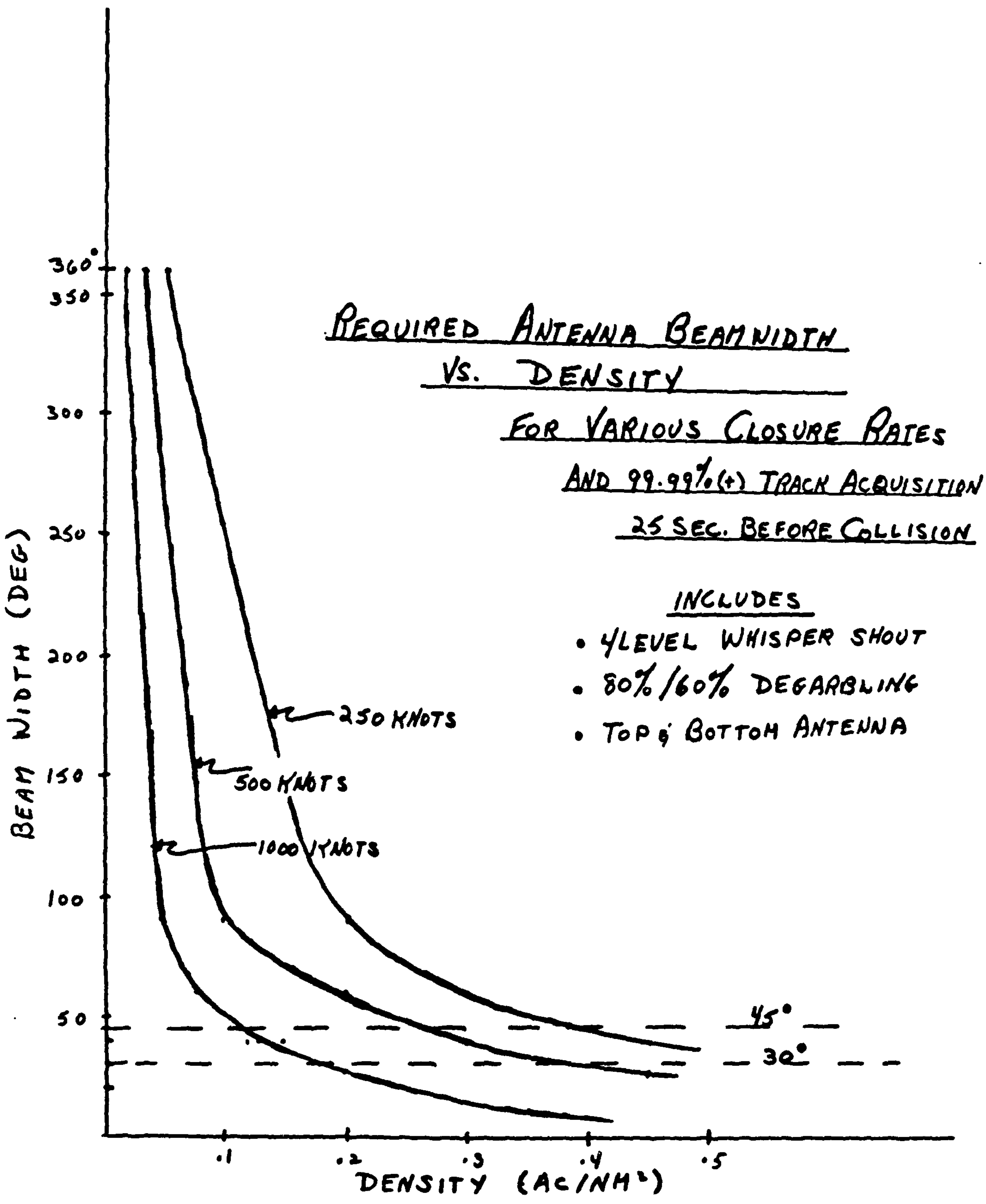


ACTIVE BCAS ATCRBS MODEC ACQUISITION
WITH WHISPER/SHOUT
EPOCH TIME - 1 SECOND
80%/60% DEGARBLE
3 CONSECUTIVE REPLIES
CLOSURE RATE: 500 KNOTS
DIRECTIONAL ANTENNA = 60 DEG BEAMWIDTH
ACQUISITION PROBABILITY
TAU IN SECONDS
DENSITY IN AC/NM2
.01->
.02->
.05->
.1->
.2->
.3->
.4->
<-(TAU = 25S)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
260
240
220
200
180
160
140
120
100
80
60
40
20
0

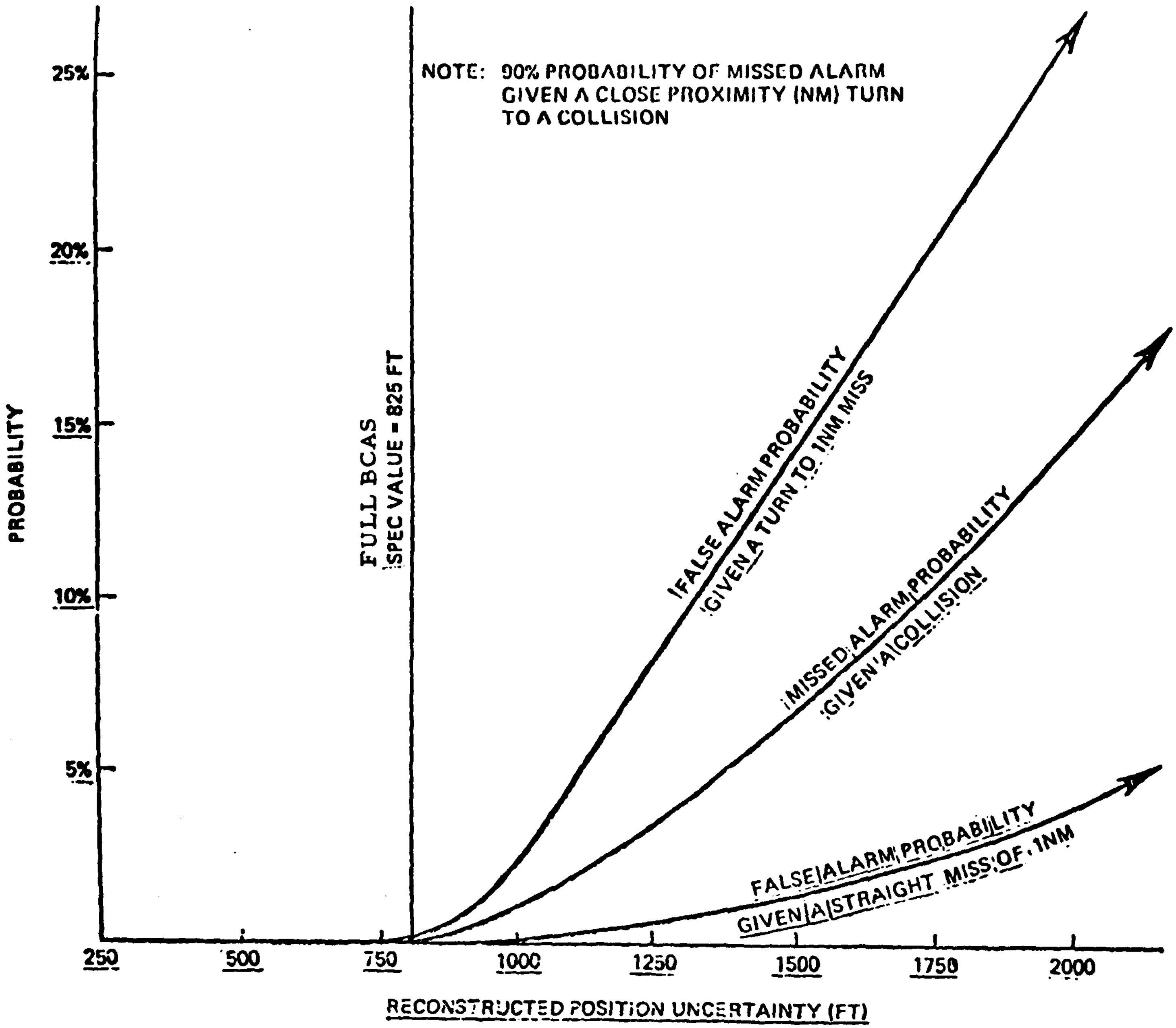


ACTIVE BCAS ATCRBS MODEC ACQUISITION
WITH WHISPER/SHOUT
EPOCH TIME - 1 SECOND
80%/60% DEGARBLE
3 CONSECUTIVE REPLIES
CLOSURE RATE: 500 KNOTS
DIRECTIONAL ANTENNA = 45 DEG BEAMWIDTH
ACQUISITION PROBABILITY
TAU IN SECONDS
DENSITY IN AC/NM²
.01->
.02->
.05->
.1->
.2->
.3->
.4->
<-(TAU = 25S)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
260
240
220
200
180
160
140
120
100
80
60
40
20
0

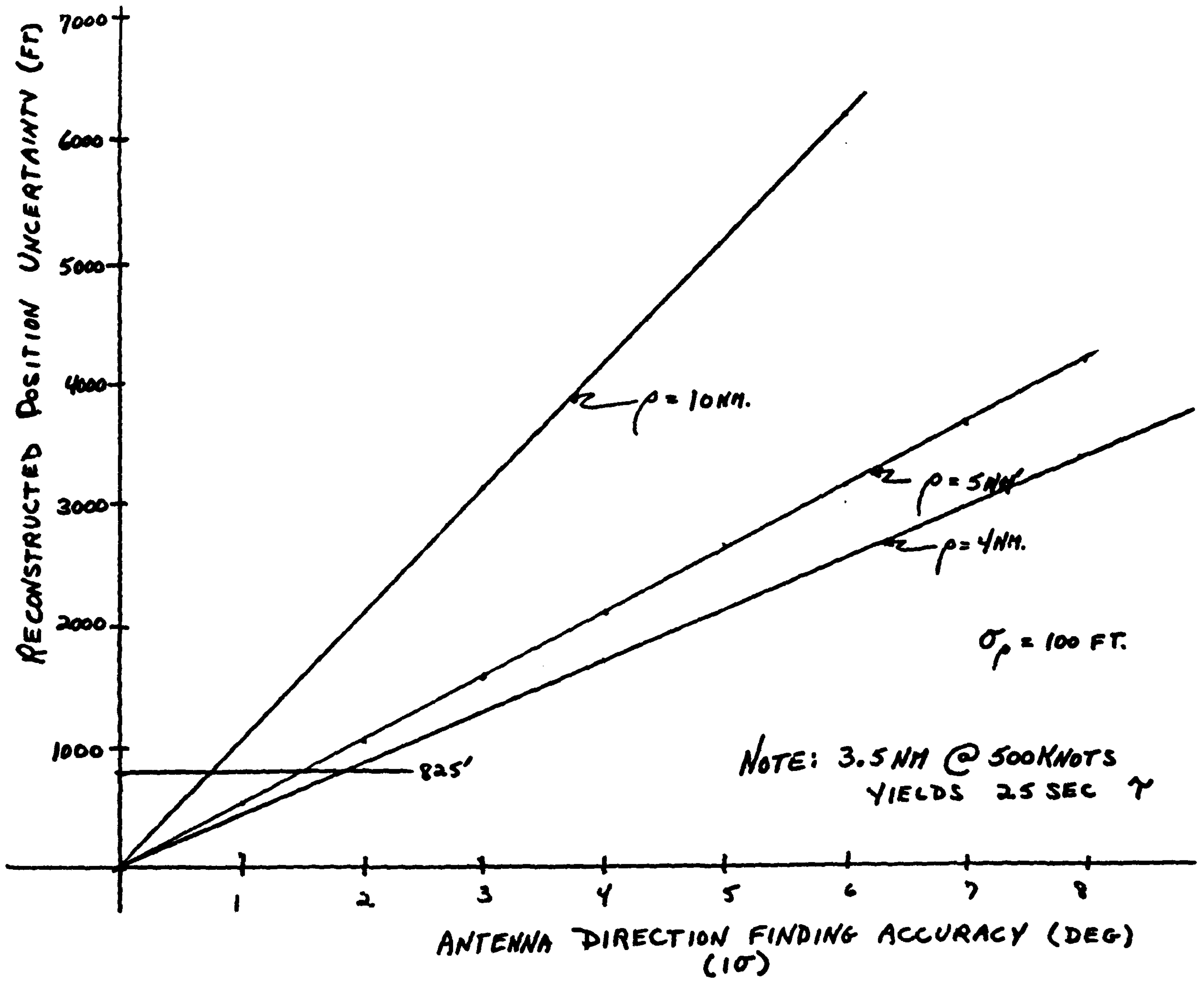

ACTIVE ECAS ATCRBS MODEC ACQUISITION
WITH WHISPER/SHOUT
EPOCH TIME - 1 SECOND
80%/60% DEGARBLE
3 CONSECUTIVE REPLIES
CLOSURE RATE: 500 KNOTS
DIRECTIONAL ANTENNA = 30 DEG BEAMWIDTH
<-(TAU - 25S)
.01->
.02->
.05->
.1->
.2->
.3->
.4->
DENSITY IN AC/NM2
ACQUISITION PROBABILITY
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
260
240
220
200
180
160
140
120
100
80
60
40
20
0
TAU IN SECONDS



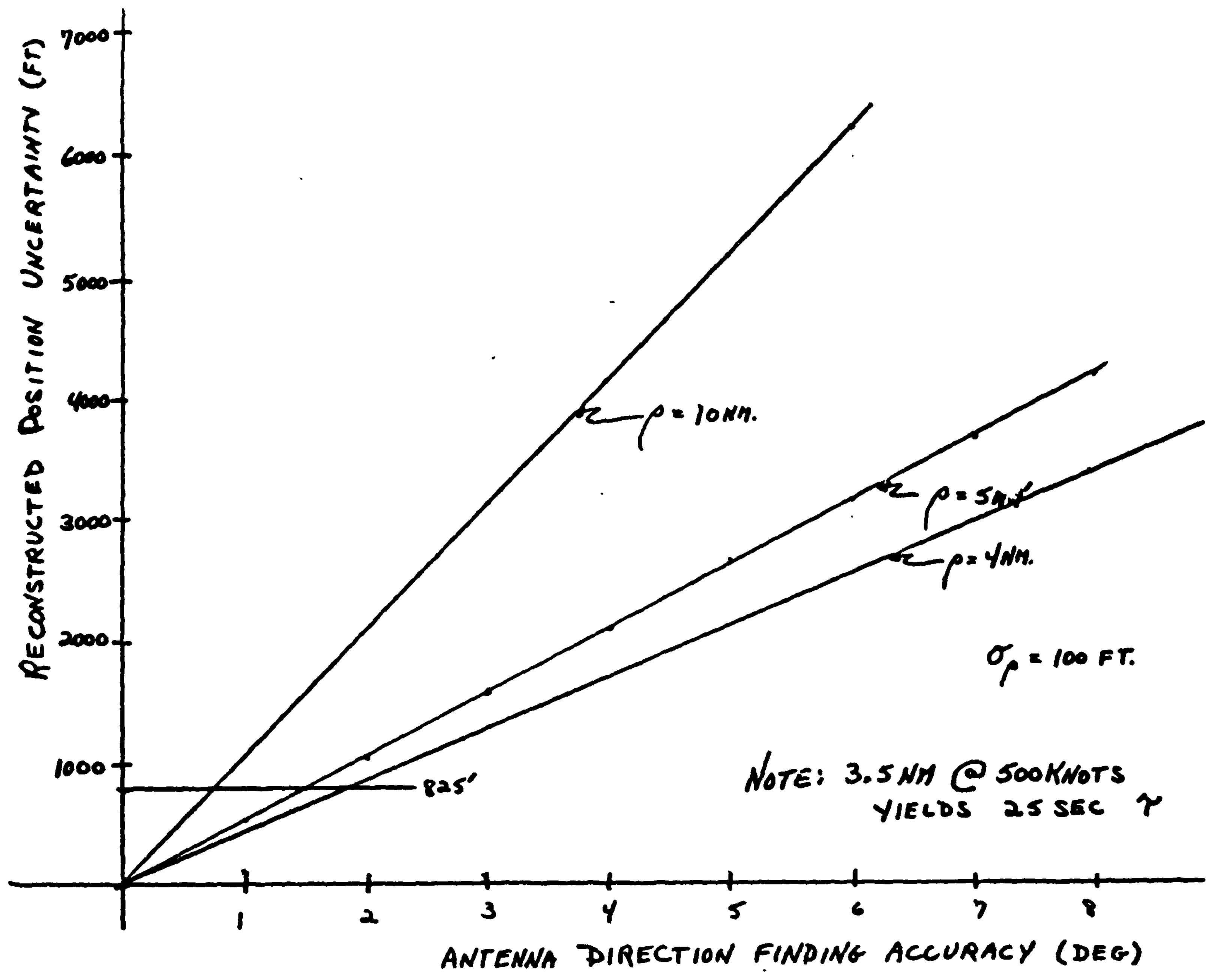
REQUIRED ANTENNA BEAMWIDTH
VS. DENSITY
FOR VARIOUS CLOSURE RATES
AND 99.99%(+) TRACK ACQUISITION
25 SEC. BEFORE COLLISION
INCLUDES
• 4 LEVEL WHISPER SHOUT
• 80%/60% DEGARBLING
• TOP & BOTTOM ANTENNA
250 KNOTS
500 KNOTS
1000 KNOTS
45°
30°
360°
350
300
250
200
150
100
50
BEAM WIDTH (DEG)
.1
.2
.3
.4
.5
DENSITY (AC/NM²)



NOTE: 90% PROBABILITY OF MISSED ALARM
GIVEN A CLOSE PROXIMITY (NM) TURN
TO A COLLISION
FULL BCAS
SPEC VALUE = 825 FT
FALSE ALARM PROBABILITY
GIVEN A TURN TO 1NM MISS
MISSED ALARM PROBABILITY
GIVEN A COLLISION
FALSE ALARM PROBABILITY
GIVEN A STRAIGHT MISS OF 1NM
PROBABILITY
25%
20%
15%
10%
5%
250
500
750
1000
1250
1500
1750
2000
RECONSTRUCTED POSITION UNCERTAINTY (FT)



RECONSTRUCTED POSITION UNCERTAINTY (FT)
7000
6000
5000
4000
3000
2000
1000
825'
ρ = 10NM.
ρ = 5NM
ρ = 4NM.
σρ = 100 FT.
NOTE: 3.5NM @ 500KNOTS
YIELDS 25 SEC τ
1
2
3
4
5
6
7
8
ANTENNA DIRECTION FINDING ACCURACY (DEG)
(1σ)



7000
6000
5000
4000
3000
2000
1000
RECONSTRUCTED POSITION UNCERTAINTY (FT)
825'
ρ = 10NM.
ρ = 5NM
ρ = 4NM.
σρ = 100 FT.
NOTE: 3.5 NM @ 500KNOTS
YIELDS 25 SEC
1
2
3
4
5
6
7
8
ANTENNA DIRECTION FINDING ACCURACY (DEG)

PAIRS OF AIRCRAFT WITH CAS ALERTS IN 65 HOURS OF HOUSTON DATA

LOGIC	ALERTS AT ALL RANGES		ALERTS AT MORE THAN 3 NMI FROM CLOSEST AIRPORT							
			PAIRS WITH BOTH 1200 CODES		MIXED PAIRS		PAIRS WITH BOTH ATC CODES		ALL PAIRS	
	TOTAL ALERTS	POSITIVE COMMANDS	TOTAL ALERTS	POSITIVE COMMANDS	TOTAL ALERTS	POSITIVE COMMANDS	TOTAL ALERTS	POSITIVE COMMANDS	TOTAL ALERTS	POSITIVE COMMANDS
ACTIVE BCAS NO MD FILTER	274	200	22	20	67	31	67	44	156	95
ACTIVE BCAS 0.5 NMI MD FILTER	274	110	22	6	67	22	67	19	156	47
ANTC-117	2379	250	159	23	455	65	1043	46	1657	134

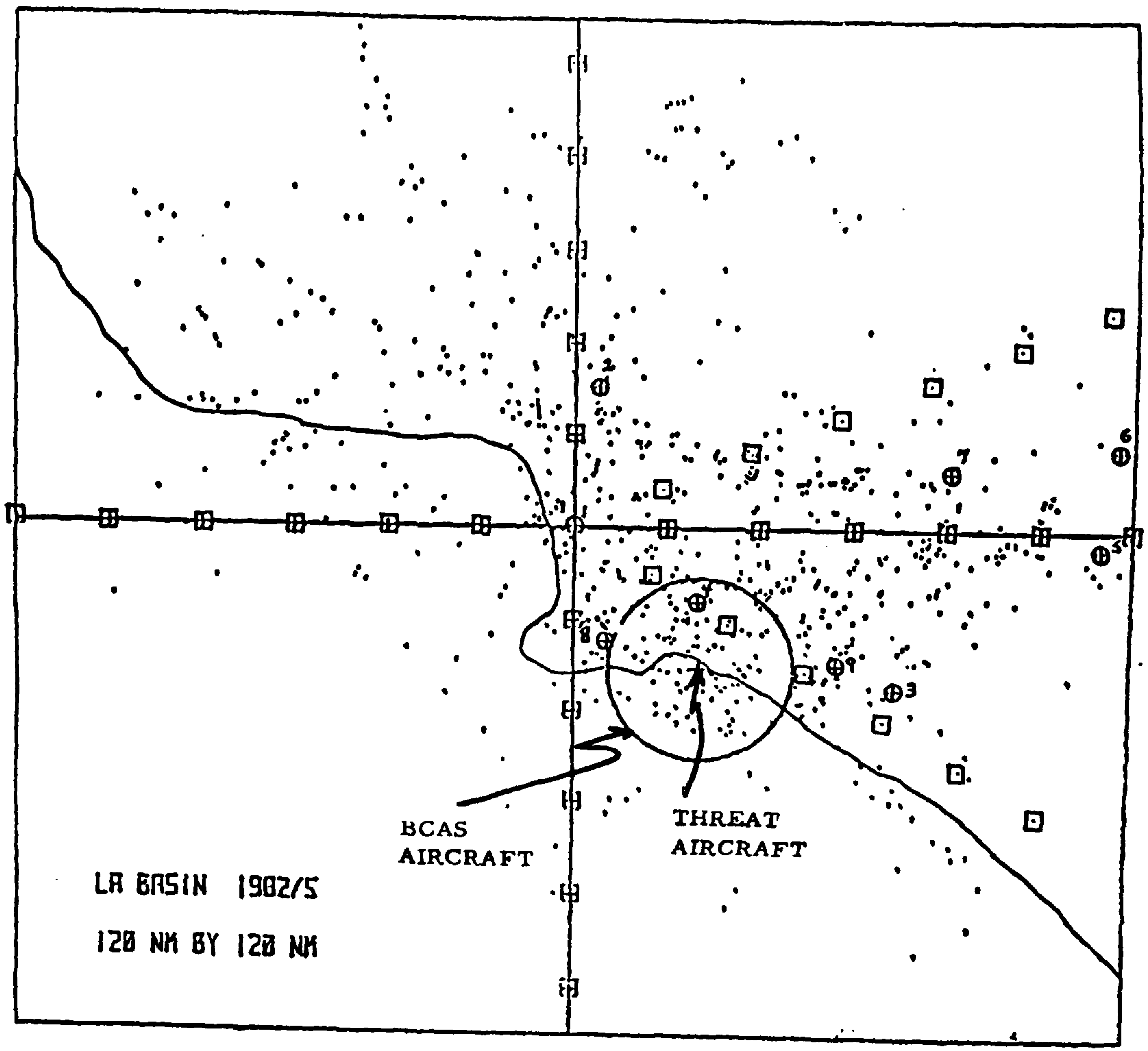
AVERAGE PER-AIRCRAFT ALERT RATES FOR DIFFERENT TYPES OF AIRCRAFT
WHEN BCAS ALERTS ARE INHIBITED WITHIN 3 NMI OF AN AIRPORT

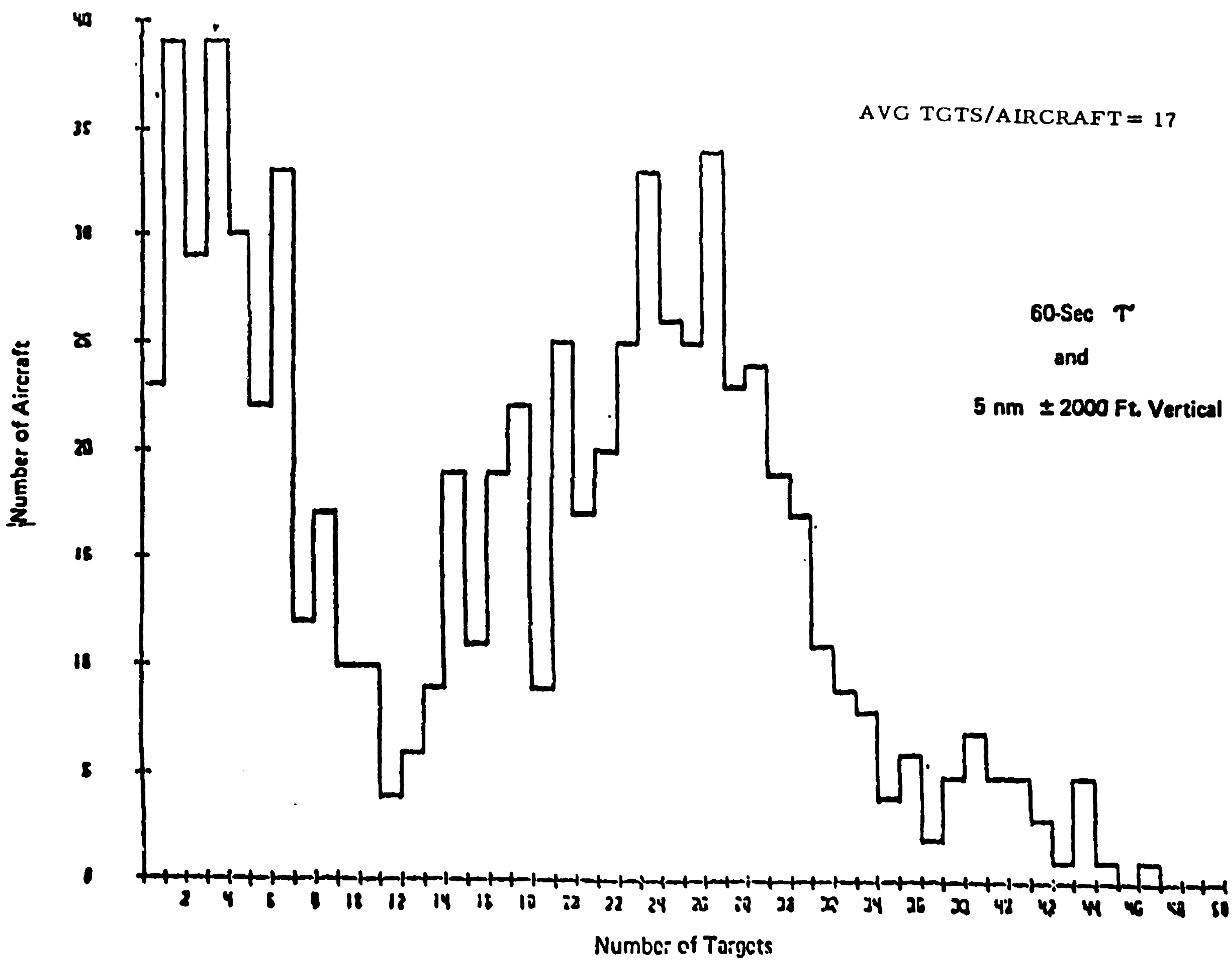
LOGIC	COMPOSITE RATE FOR ALL AIRCRAFT		RATE FOR AIRCRAFT WITH ATC CODES		RATE FOR AIRCRAFT WITH 1200 CODES	
	TOTAL ALERTS	POSITIVE COMMANDS	TOTAL ALERTS	POSITIVE COMMANDS	TOTAL ALERTS	POSITIVE COMMANDS
ACTIVE BCAS NO MD FILTER	1 ALERT IN 5 HRS	1 ALERT IN 8 HRS	1 ALERT IN 7 HRS	1 ALERT IN 12 HRS	1 ALERT IN 2 HRS	1 ALERT IN 3 HRS
ACTIVE BCAS 0.5 NMI MD	1 ALERT IN 5 HRS	1 ALERT IN 17 HRS	1 ALERT IN 7 HRS	1 ALERT IN 23 HRS	1 ALERT IN 2 HRS	1 ALERT IN 6 HRS
ANTC-117 LOGIC	2 ALERTS PER HR	1 ALERT IN 6 HRS	2 ALERTS PER HR	1 ALERT IN 9 HRS	4 ALERTS PER HR	1 ALERT IN 2 HRS

CONCLUSION

- TECHNIQUES EXIST WHICH WILL PERMIT COLLISION AVOIDANCE EQUIPMENTS TO OPERATE IN HIGH DENSITY AIRSPACE.

NUMEROUS TARGETS


BCAS
AIRCRAFT
THREAT
AIRCRAFT
LA BASIN 1982/5
120 NM BY 120 NM

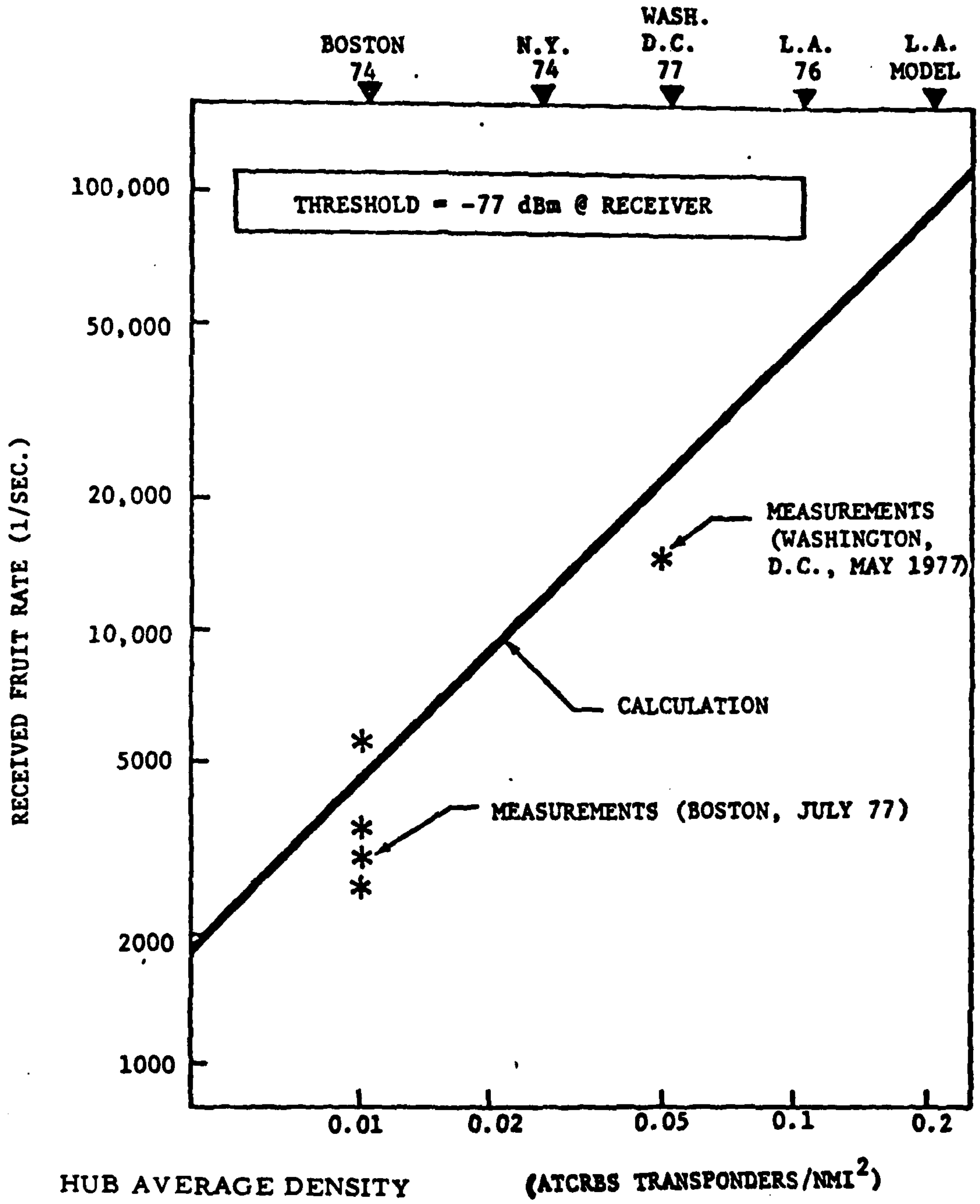


Target Track Requirements

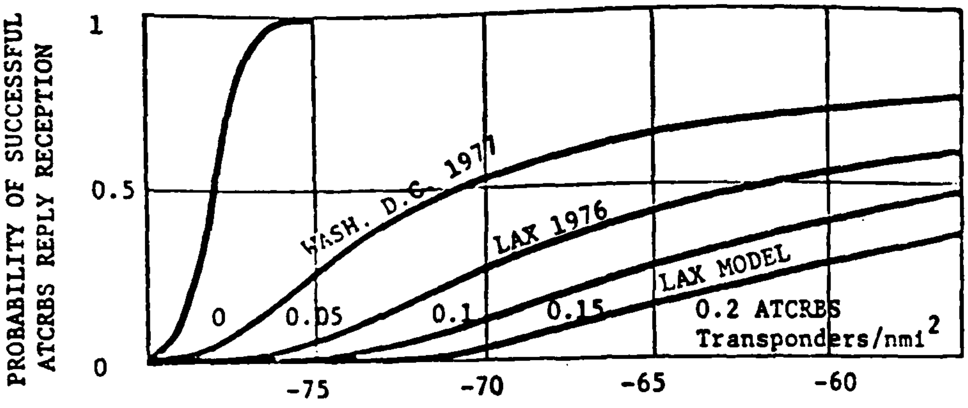
CONCLUSION

- TECHNIQUES FOR MINIMIZING THE NUMBER OF THREAT ALERT TARGETS SUCH AS ALTITUDE AND RANGE FILTERING MUST BE SOUGHT IN ORDER TO IMPROVE THE VALUE OF PROVIDING THE FUNCTION IN HIGH DENSITY.

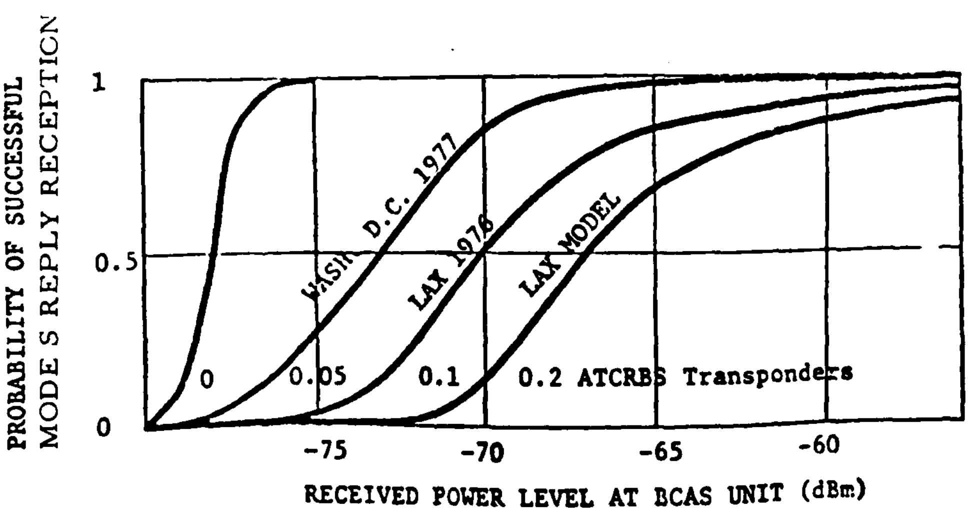
DATA LINK PERFORMANCE



AIRBORNE FRUIT RATE

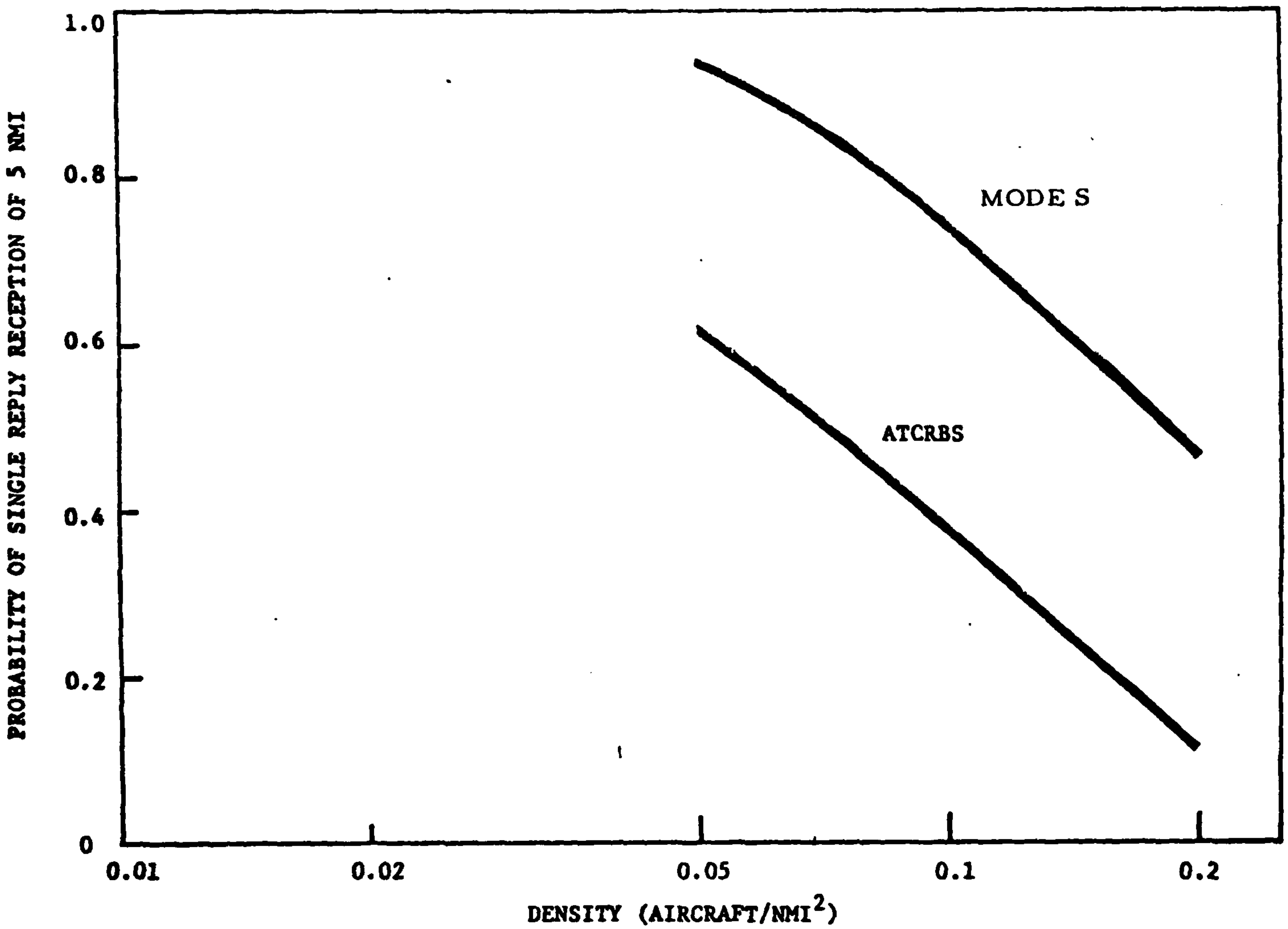


(a) ATCRBS

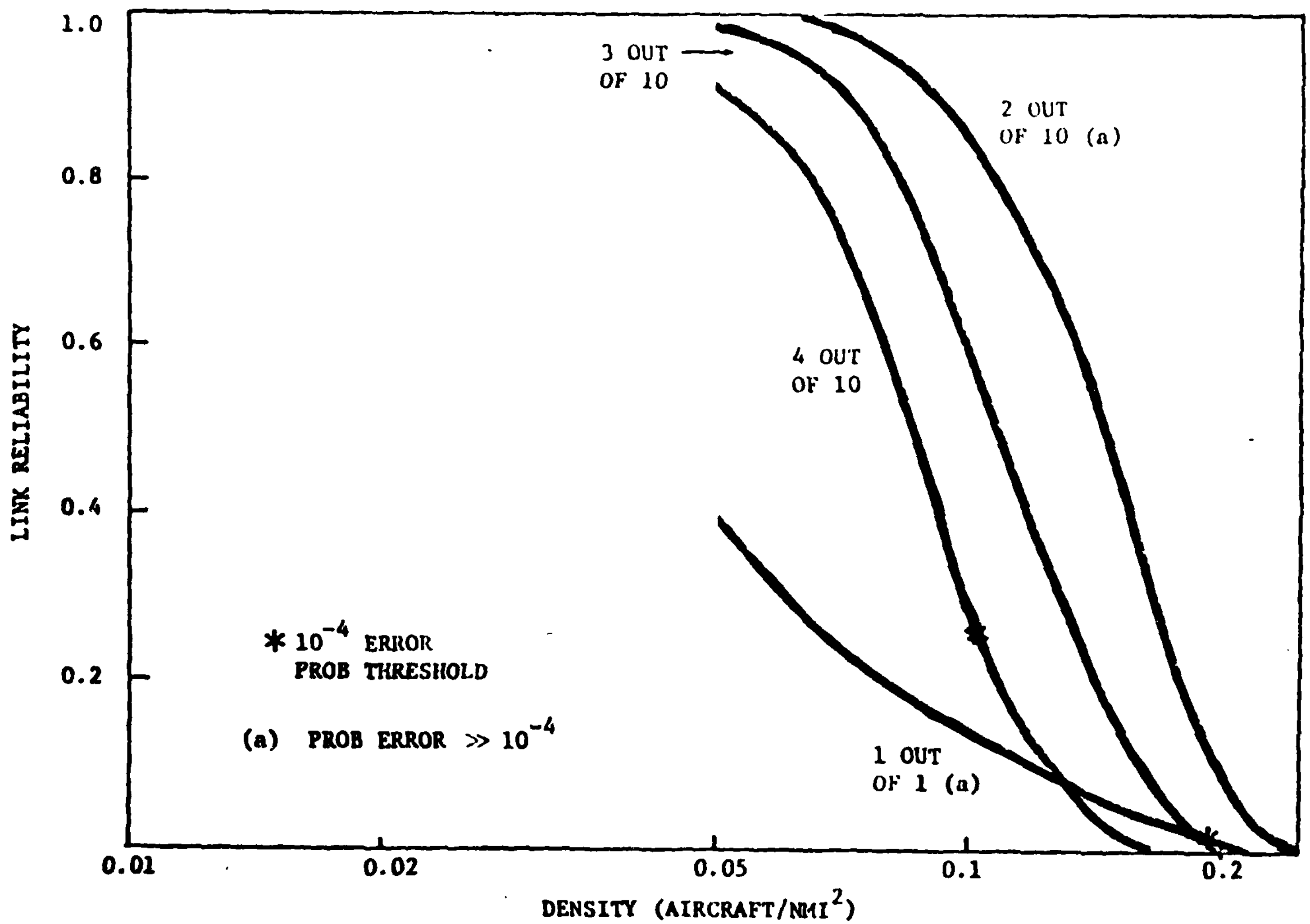


(b) MODE S

ATCRBS AND MODE S REPLY PROCESSOR PERFORMANCE IN A FRUIT ENVIRONMENT



PROBABILITY OF RECEIVING A SINGLE REPLY VS. DENSITY



BCAS/ATCRBS DATA LINK PERFORMANCE - BROADCAST MODE

MANEUVER COORDINATION
(2 WAY)

	RELIABILITY IN LAX	
MODE S	80%(1)	95%(2)
MODE A SPECIAL CODE	5%(1)	80%(10)
MODE D	5%(1)	40%(10)
HIGHEST DISCRETE CODE	7%(1)	52%(10)

CONCLUSION

- o MODE S DATA LINK CAN PERFORM THE NECESSARY COLLISION AVOIDANCE SYSTEM FUNCTIONS IN HIGH DENSITY AIRSPACE BETTER THAN OTHER METHODS THAT HAVE BEEN PUT FORWARD

SUMMARY

- TOTAL AIRCRAFT DENSITIES OF 0.3 BY 1990 AND 0.4 BY 2000 ARE HIGHLY PROBABLE.
- TECHNIQUES EXIST WHICH PERMIT OPERATION OF COLLISION AVOIDANCE SYSTEMS IN HIGH DENSITY AIRSPACE.
- RANGE AND ALTITUDE FILTERING FOR THREAT ALERTING IS HIGHLY DESIRABLE IN HIGH DENSITY AIRSPACE.
- MODE S DATA LINK OUTPERFORMS OTHER DATA LINK CANDIDATES IN HIGH DENSITY AIRSPACE.
- ADAPTIVE DIRECTIONAL (SECTOR) INTERROGATION CONTROL TO MINIMIZE DEGRADATION OF GROUND SURVEILLANCE IS ESSENTIAL.

SOME RELATED REPORTS

THEORY OF AIRCRAFT COLLISION-AVOIDANCE SYSTEM DESIGN & EVALUATION - DOT-TSC-OST-71-4 - KOENKE 1971

'82 LAX - STATISTICAL SUMMARY OF THE 1982 LA BASIN STANDARD TRAFFIC MODEL, VOL. I, MTR 6387, S. COHEN, T. F. MAGINNIS APRIL 1973

'72 LAX - NAFEC 1972 LA BASIN STANDARD AIR TRAFFIC MODEL - FRANCES M. WILLET, JR. - FAA RD 73-90 SEPTEMBER 1973

'95 AATMS 1995 LA BASIN TRAFFIC MODEL - VOL. I, MTR 6419, SERIES 4A. MUNDRA MARCH 1974

A PRELIMINARY EVALUATION OF THE ATCRBS SIGNAL FORMAT FOR THE BCAS DATA LINK - FAA-EM-77-9 - KOENKE ETAL 1977

FAA BCAS CONCEPT - FAA-EM-78-5, 4 VOL. - KOENKE ET AL 1978

AIR TRAFFIC DENSITY AND DISTRIBUTION MEASUREMENTS - W. H. HARMAN - FAA RD-78-45 - 1979

ACTIVE BCAS PERFORMANCE IN A GARBLE ENVIRONMENT - FAA-EM-80-1 - KOENKE 1980

THE EFFECT OF WHISPER SHOUT ON ACTIVE BCAS PERFORMANCE - KOENKE/BOCZENOWSKI - FAA-EM-80-5 - 1980

INTERIM RESULTS OF ANALYSIS OF ACTIVE BCAS ALERT RATES USING REAL HOUSTON TRAFFIC - MTR 79-N293 - MCFARLAND 1980

1100 - LA BASIN 1100 A/C TRAFFIC MODEL - FAA RD-81-39 - A. MUNDRA - JANUARY 1981 (1995 MODEL)

TCAS SYSTEM CHARACTERISTICS
NORMAN SOLAT
JULY 22, 1981

TCAS SYSTEM CHARACTERISTICS
NORMAN SOLAT
JULY 22, 1981

VU GRAPH 1

THIS BRIEFING PROVIDES A GENERAL DESCRIPTION OF FUNCTIONAL AND EQUIPMENT CHARACTERISTICS OF BOTH TCAS I AND TCAS II. FIRST, THE UNIVERSAL PROPERTIES OF BOTH TCAS I AND II ARE DESCRIBED, TO PROVIDE AN OVERVIEW OF HOW BOTH THESE DEVICES FUNCTION AS A SYSTEM. DESCRIPTIONS OF THE FUNCTIONAL REQUIREMENTS OF TCAS I AND II ARE THEN RELATED TO THEIR BASIC EQUIPMENT CHARACTERISTICS.

VU GRAPH 2

FROM THE OVERALL SYSTEM VIEWPOINT THERE ARE SEVERAL COMMON THREADS AMONG ALL ELEMENTS OF THE TCAS SYSTEM. THE PRINCIPAL ONE IS THE PROPERTY THAT THEY ARE ABLE TO OPERATE INDEPENDENTLY OF THE GROUND, WHILE AT THE SAME TIME BEING COMPATIBLE WITH TODAY'S AIR TRAFFIC CONTROL SYSTEM AND WITH THE EVOLUTIONARY ENHANCEMENTS TO THAT SYSTEM WHICH ARE ENVISIONED OVER THE NEXT SEVERAL DECADES. THIS COMPATIBILITY IS ACHIEVED BY BASING THE TCAS SYSTEM ON THE INTERNATIONALLY STANDARDIZED ATC RADAR BEACON SYSTEM, SO THAT ALL AIRCRAFT EQUIPPED WITH TRANSPONDERS ARE CAPABLE OF PROVIDING DATA TO AIRCRAFT EQUIPPED WITH TCAS UNITS.

THE ELEMENT OF THE TCAS APPROACH WHICH DISTINGUISHES IT FROM THE WORK REPORTED IN THE PAST IS THE IDENTIFICATION OF A RANGE OF CAPABILITIES FOR THE EQUIPMENT. THIS PERMITS THE IMPLEMENTATION OF EQUIPMENT WHICH CAN BE TAILORED TO THE NEEDS OF THE USER COMMUNITY IN THE SHORTEST POSSIBLE TIME FRAME. TODAY WE ARE IDENTIFYING AND DESCRIBING TWO SPECIFIC CAPABILITIES -- TCAS I, INTENDED TO PROVIDE A LOW COST MEANS OF IMPLEMENTING A GIVEN LEVEL OF PROTECTION, AND TCAS II, INTENDED, TO PROVIDE FULL PROTECTION FOR ALL EQUIPPED USERS IN THE HIGH DENSITY ENVIRONMENTS WHICH WE PREDICT FOR THE FUTURE.

VU GRAPH 3

DEPICTED HERE IS THE OVERALL TCAS CONCEPT. WE WILL BE DESCRIBING CERTAIN MINIMUM REQUIREMENTS FOR TCAS I AND II WHICH ARE ACHIEVABLE WITH TODAY'S TECHNOLOGY. ENHANCEMENTS TO BOTH SYSTEMS ARE FEASIBLE, AND CERTAIN OF THOSE ENHANCEMENTS ARE UNDER DEVELOPMENT. THEY WILL BE MENTIONED AT THE APPROPRIATE PLACES IN THIS BRIEFING.

VU GRAPH 4

IN TALKING ABOUT THE INDIVIDUAL TCAS I AND II SYSTEMS TODAY, IT IS CONVENIENT TO RELATE THE CHARACTERISTICS OF THE EQUIPMENT TO THE FOUR PRINCIPAL FUNCTIONS OF A SYSTEM OF THIS KIND -- SURVEILLANCE, OR THE ABILITY TO EFFECTIVELY DETERMINE WHAT AIRCRAFT ARE IN THE VICINITY; THE DETERMINATION OF WHICH OF THOSE AIRCRAFT REPRESENT POTENTIAL THREATS AND THE DISPLAY OF THAT INFORMATION; THE DETERMINATION AND DISPLAY OF APPROPRIATE MANEUVERS TO RESOLVE THREATS; AND FINALLY, THE ABILITY TO COORDINATE THE ADVISORIES AND MANEUVERS AMONG THE SUITABLY EQUIPPED AIRCRAFT AND TO PROVIDE THE LINK TO THE EVOLUTIONARY GROUND ATC SYSTEM.

VU GRAPH 5

SINCE TCAS II IS BY FAR THE MORE COMPLEX OF THE TWO SYSTEMS, IT WILL SIMPLIFY THE PRESENTATION BY BEGINNING WITH IT.

FUNCTIONALLY, TCAS II HAS THE FOLLOWING MINIMUM CAPABILITIES. FIRST, IT MUST LISTEN TO AND DECODE THE SQUITTERS EMANATING FROM ALL AIRCRAFT EQUIPPED WITH MODE S TRANSPONDERS -- INCLUDING TCAS I AND TCAS II AIRCRAFT. SECONDLY, IT PERFORMS ITS SURVEILLANCE FUNCTION THROUGH THE ACTIVE INTERROGATION OF ALL AIRCRAFT -- IN MODE S USING THE UNIQUE ADDRESS FOR THOSE INTRUDERS WHOSE SQUITTERS IT HAS ACQUIRED, AND USING THE STANDARD MODE C INTERROGATION FOR ALL OTHER AIRCRAFT.

THE OMNI-DIRECTIONAL ACTIVE BCAS EQUIPMENT BUILT AND TESTED PREVIOUSLY WAS DESIGNED FOR OPERATION IN LOW-TO-MEDIUM-DENSITY AIRSPACE. THE PROBLEMS OF SYNCHRONOUS GARBLE IN HIGH DENSITIES WILL PRECLUDE ITS EFFECTIVE OPERATION. TCAS I, THEREFORE, PROVIDES THE CAPABILITY TO OPERATE IN THE PROJECTED HIGH DENSITIES BY INTERROGATING DIRECTIONALLY IN NARROW SECTORS. THROUGH THE USE OF SUITABLE DIRECTION FINDING TECHNIQUES, THE BEARING OF THE INTRUDER IS DETERMINED.

TCAS II USES THE VERTICAL THREAT DETECTION LOGIC SPECIFIED FOR ACTIVE BCAS. BASED ON ANALYSIS AND SIMULATIONS, IT HAS BEEN DETERMINED THAT THE AVAILABILITY OF A RELIABLE COMPUTATION OF HORIZONTAL MISS DISTANCE CAN AFFORT THE OPPORTUNITY TO REDUCE THE INCIDENCE OF ALERTS BY AS MUCH AS 50%, AND THE MEANS TO PROVIDE SUCH AN ENHANCED CAPABILITY ARE UNDER INVESTIGATION.

VU GRAPH 6

TCAS II AIRCRAFT HAVE THE CAPABILITY TO DERIVE AND DISPLAY TRAFFIC ADVISORIES IN RANGE, BEARING, AND RELATIVE ALTITUDE. ADVISORIES FOR RESOLUTION USE THE VERTICAL RESOLUTION LOGIC DEVELOPED FOR ACTIVE BCAS. AS AN ENHANCEMENT, RESOLUTION ADVISORIES CAN BE PROVIDED IN THE HORIZONTAL PLANE, AS WELL.

THE COORDINATION FUNCTON IS PROVIDED VIA AN INTEGRAL MODE S CAPABILITY, WHICH WE REFER TO AS THE CROSS LINK. THIS PERMITS TCAS II AIRCRAFT TO TRANSMIT ADVISORIES TO TCAS I INTRUDERS, ALERTING THOSE AIRCRAFT TO ITS PRESENCE, AND INFORMING THEM OF ITS RELATIVE POSITION. WHEN THE TCAS II AIRCRAFT IS EXECUTING A MANEUVER TO RESOLVE A CONFLICT, THAT INFORMATION IS TRANSMITTED VIA THE CROSSLINK AS AN ADVISORY TO A TCAS I AIRCRAFT, AND FOR COORDINATION, IF THE OTHER AIRCRAFT IS ALSO EQUIPPED WITH TCAS II.

VU GRAPH 7

THE BASIC CHARACTERISTICS OF TCAS II EQUIPMENT RESULTING FROM THOSE FUNCTOAL REQUIREMENTS ARE SHOWN IN THIS AND THE NEXT VU GRAPH. TO PROVIDE NORMAL TRANSPONDER FUNCTIONS, AS WELL AS THOSE FUNCTIONS NECESSARY FOR TCAS OPERATION, AN INTEGRAL MODE A, C, AND S TRANSPONDER IS REQUIRED. THIS TRANSPONDER PROVIDES THE REPLIES TO ALL INTERROGATIONS IN THE APPROPRIATE MODE, PROVIDES THE MODE S SQUITTER NECESSARY TO PERMIT TCAS I AND TCAS II AIRCRAFT TO ACQUIRE ITS UNIQUE MODE S ADDRESS, AND PROVIDES THE CAPABILITY TO RECEIVE CROSSLINK MODE S MESSAGES ADDRESSED TO IT. MOST IMPORTANT IS THE FACT THAT THIS TRANSPONDER PROVIDES THE MEANS BY WHICH THE FUTURE EVOLUTION OF THE ATC SYSTEM WILL BE ACCOMMODATED.

VU GRAPH 7 (CONTINUED)

IN ADDITION TO THE TRANSPONDER, A TCAS II AIRCRAFT MUST INTERROGATE ON 1030 MHz, TO PROVIDE THE SURVEILLANCE OF ATCRBS AIRCRAFT IN MODE C AND OF AIRCRAFT WITH MODE S CAPABILITY IN MODE S. IN ORDER TO OPERATE IN FUTURE HIGH DENSITY AIRSPACE, WHICH WILL REQUIRE RELATIVELY NARROW INTERROGATION SECTORS, A SUITABLE ADAPTIVE MEANS TO PREVENT EXCESS INTERROGATIONS WILL BE NECESSARY, AS WELL AS ADHERENCE TO THE INTERFERENCE LIMITING REQUIREMENT WHICH THE FAA WILL SPECIFY IN ITS STANDARDS.

VU GRAPH 8

THE SCANNING ANTENNA MUST HAVE THE CAPABILITY FOR TRANSMITTING DIRECTIONALLY TO REDUCE THE EQUIPMENT SUSCEPTIBILITY TO SYNCHRONOUS GARBLE. THE ANTENNA ALSO UTILIZES DIRECTION FINDING ON THE ORDER 8°, ONE SIGMA, ON RECEIVE TO PROVIDE INFORMATION TO THE TRAFFIC DISPLAY.

ANTENNAS ARE UNDER DEVELOPMENT WHICH WILL ENABLE THE ACCURATE COMPUTATION OF BEARING RATE TO IMPLEMENT THE MISS DISTANCE ASSESSMENT AND HOPEFULLY THE DERIVATION OF HORIZONTAL MANEUVERS, AS AN ENHANCEMENT.

THE THREAT DETECTION AND RESOLUTION LOGIC IS THE FAA STANDARDIZED VERTICAL LOGIC FOR ACTIVE BCAS. WHEN FEASIBILITY OF HORIZONTAL DETECTION AND MANEUVER ADVISORIES HAS BEEN DETERMINED, THE FAA WILL SPECIFY THAT LOGIC AS WELL.

OTHER EQUIPMENT CHARACTERISTICS WHICH ARE SPECIFIED ARE THE LOGIC FOR AIR-TO-AIR COORDINATION, AND THE MODE S FORMATS FOR ALL INFORMATION EXHANGE.

VU GRAPH 9

TCAS I IS FUNCTIONALLY MUCH SIMPLER THAN TCAS II. FOR ITS SURVEILLANCE FUNCTION IT LISTENS IN TO THE ATCRBS TRANSPONDERS AS THEY REPLY TO MODE A AND C GROUND INTERROGATIONS. AS AN ENHNACEMENT, IT IS DESIRABLE TO REDUCE THE INCIDENCE OF ALARMS THROUGH SUITABILITY FILTERING THE REPLIES AND DISCARDING THOSE RELATING TO ALTITUDES OF NO INTEREST.

TCAS I ALSO LISTENS IN TO THOSE AIRCRAFT WHICH PROVIDE SQUITTERS ON MODE S. THESE INCLUDE OTHER TCAS I AIRCRAFT AND ALL TCAS II AIRCRAFT. SINCE THE MODE S SQUITTER IS NOT DEPENDENT ON GROUND INTERROGATIONS AND ALWAYS CONTAINS THE ALTITUDE CODE, THIS PROVIDES ALTITUDE FILTERED SURVEILLANCE OF EQUIPPED AIRCRAFT IN ALL AIRSPACE. AS AN ENHNACEMENT, A DETERMINATION OF BEARING THROUGH A SUITABLE DIRECTION FINDING ANTENNA MAY BE DESIRABLE.

IN THE MINIMUM TCAS I, THE DETECTION OF THREATS IS BASED ON THE RECEIVED SIGNAL EXCEEDING A PRESET THRESHOLD. SOME NUMBER OF UNNECESSARY ALERTS MAY BE AVOIDED THROUGH THE ABILITY TO FILTER SIGNALS FROM ALTITUDES OF NO INTEREST, IF THE ALTITUDE INFORMATION IS AVAILABLE.

VU GRAPH 10

THE ADVISORY GENERATED ABOARD A TCAS I AIRCRAFT IS DERIVED FROM THE RECEIVED SIGNAL EXCEEDING A GIVEN THRESHOLD, AND THIS INFORMATION MAY BE SIMPLY DISPLAYED BY MEANS OF A LIGHT, FOR EXAMPLE. FOR TCAS I EQUIPMENT ENHANCED TO PROVIDE BEARING INFORMATION, THE BEARING OF THE SIGNAL WHICH EXCEEDS THAT THRESHOLD MAY ALSO BE DETERMINED AND DISPLAYED. BY MEANS OF THE MODE S

VU GRAPH 10 (CONTINUED)

CROSSLINK, TCAS I HAS THE ABILITY TO RECEIVE AND DISPLAY ADVISORIES FROM AIRCRAFT EQUIPPED WITH TCAS II. THE INFORMATION TRANSMITTED FOR DISPLAY CONTAINS THE RANGE, RELATIVE AZIMUTH AND THE RELATIVE ALTITUDE OF THE TCAS II THREAT. WHEN THE TCAS II AIRCRAFT IS MANEUVERING TO AVOID THE TCAS I AIRCRAFT, INFORMATION RELATING TO THAT MANEUVER IS TRANSMITTED ON THE CROSSLINK FOR DISPLAY BY THE TCAS I AIRCRAFT.

VU GRAPH 11

THE MINUMUM EQUIPMENT NECESSARY TO PERFORM THE TCAS I FUNCTIONS JUST DESCRIBED ARE GIVEN HERE.

FIRST AND FOREMOST, IS THE MODE A, C, AND S TRANSPONDER, WITH THE CAPABILITIES PREVIOUSLY DESCRIBED, AND SHOWN BELOW.

ADDITIONALLY, TO DETECT THE PRESENCE OF TRANSPONDER-EQUIPPED TARGETS, TCAS I REQUIRES A RECEIVER TUNED TO 1090 MHz, AN AMPLITUDE MODULATED DETECTOR FOR THE MODE A AND C TRANSPONDER REPLIES, AND A DPSK DETECTOR/DECODER FOR THE MODE S SQUITTERS. INCLUDED ALSO IS THE ABILITY TO FILTER THE MODE C AND MODE S ALTITUDE INFORMATION.

POSSIBLE ENHNACEMENTS, IN ADDITION TO ONBOARD BEARIANG DETERMINATION, ARE POSSIBLE AND ENCOURAGED, SUBJECT TO THEIR ABILITY TO MEET FAA MINIMUM REQUIREMENTS. SUCH ENHANCEMENTS MIGHT INCLUDE, FOR EXAMPLE, THE ABILITY TO INTERROAGATE ON 1030 MHz, THEREBY ENABLING THE ACQUISTION OF MODE A AND C TARGETS OUTSIDE OF ATC COVERAGE AS WELL AS THE ABILITY TO PROVIDE RANGE INFORMATION TO ENHANCE THE PROXIMITY WARNING ASPECTS OF THE DEVICE. THE ADDITION OF SUCH RADIATING EQUIPMENT WILL REQUIRE THE DEMONSTRATION THAT FAA STANDARDS FOR INTERFERENCE LIMITING ARE MET.

IT IS CONCEIVABLE THAT THE INFORMATION RECEIVED THROUGH INTERROGATIONS MIGHT, IN A FURTHER ENHANCEMENT, BE UTILIZED TO DERIVE MANEUVER ADVISORIES. UNDER SUCH CONDITIONS, THE FAA STANDARDS FOR RESOLUTION AND COORDINATION LOGIC WILL HAVE TO BE MET.

TCAS SYSTEM CHARACTERISTICS

NORMAN SOLAT
SYSTEMS RESEARCH & DEVELOPMENT SERVICE
FEDERAL AVIATION ADMINISTRATION

JULY 22, 1981

- TCAS SYSTEM PROPERTIES
- TCAS SYSTEM FUNCTIONAL REQUIREMENTS
  - TCAS II
  - TCAS I
- TCAS EQUIPMENT CHARACTERISTICS
  - TCAS II
  - TCAS I

TCAS SYSTEM PROPERTIES

- INDEPENDENCE FROM THE GROUND
  - CAPABLE OF COMPATIBLE OPERATION WITH CURRENT AND EVOLVING ATC SYSTEM
- BASED ON INTERNATIONALLY STANDARDIZED ATC RADAR BEACON SYSTEM (SSR)
- RANGE OF CAPABILITIES
  - TCAS I - LOWEST COST FOR GIVEN LEVEL OF PROTECTION
  - TCAS II - MAXIMUM PROTECTION FOR ALL ENVIRONMENTS

TCAS SYSTEM CONCEPT

ENHANCEMENTS

- TCAS II - MINIMUM

ENHANCEMENTS

- TCAS I - MINIMUM

TCAS SYSTEM FUNCTIONS

- SURVEILLANCE
- THREAT DETECTION
  - TRAFFIC ADVISORY
- THREAT RESOLUTION
  - RESOLUTION ADVISORY
- COORDINATION

TCAS II FUNCTIONAL REQUIREMENTS

- SURVEILLANCE
  - "LISTEN IN" TO MODE S TRANSPONDER SQUITTERS
  - ACTIVE INTERROGATION OF TRANSPONDERS USING MODE C & MODE S
  - HIGH DENSITY OPERATION THROUGH SCANNING DIRECTIONAL ANTENNA INTERROGATIONS
  - INTRUDER BEARING DETERMINATION THROUGH RECEIVE DIRECTION FINDING ANTENNA
- THREAT DETECTION
  - ACTIVE BCAS VERTICAL THREAT DETECTION LOGIC
  - HORIZONTAL MISS DISTANCE ASSESSMENT TO REDUCE UNWANTED ALARMS AS ENHANCEMENT

TCAS II FUNCTIONAL REQUIREMENTS (CONT'D)

- TRAFFIC ADVISORY GENERATION/DISPLAY
  - INTRUDER RANGE, BEARING, RELATIVE ALTITUDE
- RESOLUTION ADVISORY
  - ACTIVE BCAS VERTICAL RESOLUTION ADVISORY LOGIC
  - HORIZONTAL RESOLUTION ADVISORIES AS ENHANCEMENT
- COORDINATION VIA INTEGRAL MODE S CAPABILITY (CROSSLINK)
  - TRAFFIC ADVISORIES (RANGE, RELATIVE AZIMUTH, RELATIVE ALTITUDE) TRANSMITTED TO TCAS I INTRUDER
  - MANEUVER INFORMATION TRANSMITTED TO TCAS I AND TCAS II INTRUDERS

TCAS II EQUIPMENT CHARACTERISTICS

- MODE S TRANSPONDER WITH ALTITUDE ENCODER
  - REPLIES TO INTERROGATIONS ON 1090 MHz IN MODE A, C OR S AS REQUIRED
  - MODE S PERIODIC SQUITTERS ON 1090 MHz FOR TCAS I AND TCAS II ACQUISITION
  - MODE S RECEPTION ON 1030 MHz OF COORDINATION MESSAGES
  - COMPATIBILITY WITH ATC EVOLUTION THROUGH DATA LINK INTERFACES

- MODE C & S INTERROGATOR (1030 MHz)
  - SURVEILLANCE OF ATCRBS TARGETS (MODE C)
  - SURVEILLANCE OF TCAS I, II, AND OTHER MODE S EQUIPPED TARGETS (MODE S)
  - ADAPTIVE INTERROGATION FOR HIGH DENSITY OPERATION
  - INTERFERENCE LIMITING AS SPECIFIED BY FAA

TCAS II EQUIPMENT CHARACTERISTICS (CONT'D)

- SCANNING ANTENNA
  - DIRECTIONAL TRANSMIT FOR GARBLE REDUCTION IN HIGH DENSITIES
  - DIRECTION FINDING RECEIVE FOR TRAFFIC DISPLAY
  - ENHANCEMENTS UNDER DEVELOPMENT
    - HIGH ACCURACY BEARING DETERMINATION
    - BEARING RATE DETERMINATION FOR HORIZONTAL MISS DISTANCE ASSESSMENT AND HORIZONTAL MANEUVERS
- THREAT DETECTION & RESOLUTION LOGIC
  - VERTICAL LOGIC AS SPECIFIED BY FAA
  - HORIZONTAL LOGIC, IF FEASIBLE, TO BE SPECIFIED BY FAA
- OTHER
  - COORDINATION LOGIC
  - MODE S FORMATS

  } TO BE SPECIFIED BY FAA

TCAS I FUNCTIONAL REQUIREMENTS

- SURVEILLANCE
  - LISTEN IN TO MODE A & C REPLIES TO GROUND INTERROGATION
    - ALTITUDE FILTERING AS ENHANCEMENT
  - LISTEN IN TO MODE S SQUITTERS FROM OTHER TCAS I, TCAS II OR MODE S AIRCRAFT
    - ALL AIRSPACE
    - ALTITUDE FILTERED
  - BEARING DETERMINATION THROUGH DIRECTIONAL RECEIVE ANTENNA AS AN ENHANCEMENT
- THREAT DETECTION
  - ALERT BASED ON SIGNAL STRENGTH AND ALTITUDE COINCIDENCE (WHEN KNOWN)

TCAS I FUNCTIONAL REQUIREMENTS (CONT'D)

- TRAFFIC ADVISORY GENERATION (OWN AIRCRAFT)
  - BASED ON SENSITIVITY
  - THREAT BEARING FROM DIRECTIONAL RECEIVE ANTENNA AS AN ENHANCEMENT
- TRAFFIC ADVISORY RECEPTION (FROM TCAS II AIRCRAFT)
  - VIA MODE S CROSSLINK
  - RANGE, RELATIVE AZIMUTH, RELATIVE ALTITUDE
  - MANEUVER INFORMATION

TCAS I EQUIPMENT CHARACTERISTICS

- MODE S TRANSPONDER WITH ALTITUDE ENCODER
  - REPLIES TO MODE A, C & S INTERROGATIONS
  - PERIODIC SQUITTER ON MODE S
  - MODE S RECEPTION OF CROSSLINK MESSAGES
  - COMPATIBILITY WITH ATC EVOLUTION
- RECEIVER/DETECTOR ON 1090 MHz
  - PASSIVE TRANSPONDER DETECTION OF MODES A & C
  - DETECTION OF MODE S SQUITTERS
  - ALTITUDE FILTER
- POSSIBLE ENHANCEMENTS - REQUIRE FAA SPECIFICATIONS
  - INTERROGATION ON 1030 MHz TO ACQUIRE MODE A & C TARGETS OUTSIDE ATC COVERAGE
  - RANGING/RANGE TRACKING FOR ENHANCED PWI
  - MANEUVER ADVISORIES

TCAS DEVELOPMENT PROGRAM

Dr. Clyde A. Miller
July 22, 1981

Separation Systems Branch
Systems Research and Development Service
Federal Aviation Administration
Washington, D. C. 20591

SLIDE 1

The FAA program for the development of TCAS can be divided into three categories. Engineering development activities include the efforts to design and fabricate engineering model equipments, to test and evaluate the engineering characteristics of these equipments in flight tests and to document the characteristics of the units evaluated

Once engineering performance is established, operational tests are undertaken to assess the effectiveness of TCAS in the operational environment. These evaluations involve cockpit simulations, tests in FAA aircraft configured as normal air carriers, and tests on in-service air carrier aircraft.

Standards of more than one type are involved in the implementation of systems such as TCAS. National Aviation Standards are published for public comment. The purpose of such national standards is limited to defining areas of compatibility for mutual operation of TCAS equipments and operation of TCAS equipments within the National Airspace System. When a national standard is reasonably well established, a special committee of the Radio Technical Committee for Aeronautics can be convened to establish minimum operational performance standards (the "MOPS"). This document states the minimum requirements of the equipments and defines the test methodologies whereby equipment performance can be established in terms of these requirements.

SLIDE 2

Much of the technology associated with TCAS, especially TCAS II, was developed under the earlier BCAS program. MIT Lincoln Laboratory delivered second-generation Active BCAS avionics units to FAA in early 1980. These units were extensively evaluated in more than 250 hours of flight tests during 1980 to include a short operational evaluation in the FAA Boeing 727 test aircraft.

The technical performance of the Lincoln Laboratory Active BCAS equipments was substantially better than had been anticipated and provides the cornerstone of our confidence that minimum TCAS II equipments can be in production in the near future. The results of our evaluations of these Lincoln Laboratory equipments were summarized at a public conference last January.

In March 1980 a contract was awarded to Dalmo Victor Operations of Bell Aerospace TEXTRON, Belmont, California, for three each Active BCAS units based on the Lincoln Laboratory design but packaged as air carrier avionics units. Our objective was to involve an avionics manufacturing organization in fabricating Active BCAS units in order to determine whether or not the large-scale production of our design would be straightforward. We also wanted air carrier quality units for operational evaluation on in-service air carrier aircraft. This evaluation will get under way when the technical validation of the Dalmo Victor units has been completed at the FAA Technical Center in Atlantic City, New Jersey.

In the meantime, Lincoln Laboratory has been developing an Active BCAS design appropriate for the relatively low speed general aviation environment. The cost objective for this unit is at the level of a general aviation DME.

Techniques for reducing the cost of the general aviation design, as compared to the design implemented in the Dalmo Victor air carrier units, include lower transmitter power, simplified signal processing as permitted by the lower aircraft speeds anticipated and the implementation of reply processing in software as compared to the hardwired reply processors used in the air carrier units. It is anticipated that the general aviation design will be validated early next year.

SLIDE 3

While our evaluations during 1980 established most of the basic techniques required for Active BCAS, and many of the techniques required for TCAS, several principal areas of work remain. The coordination logic whereby equipped aircraft in conflict communicate for the purpose of ensuring compatible avoidance maneuvers has been designed by MITRE Corporation. Simulation studies, which are the principal means for validating the performance of this logic, are nearly completed. In-flight validation of the logic should be completed by the middle of next year.

We have been experimenting with small aircraft antennas that can generate relatively coarse estimates of the bearing of intruding aircraft. A Lincoln Laboratory evaluation of such an antenna has been in process for several months and should be completed by the end of the summer. The technology inherent in this antenna is applicable to simple TCAS equipments that would sense the bearing of intruders based on the passive detection of transponder transmissions, and is also appropriate for minimum TCAS II equipments that would display intruder bearing data in proximity warning indications.

Finally, we are experimenting with techniques for generating proximity warning indications with respect to intruding aircraft that are equipped with transponders that do not report altitude through their transponders. The generation of resolution advisories for such non-Mode C intruders is not warranted since, without altitude data, it is not possible to reliably differentiate between those aircraft which are collision threats and those which are not. It may be possible, however, to reliably generate proximity warnings that display intruder range and bearing, thereby aiding the pilot in visually acquiring the intruder.

SLIDE 4

The Communications Division of Bendix Corporation is currently designing TCAS II equipments for fabrication, test and evaluation. The development is in two steps, the delivery of Model A (minimum TCAS II) equipments followed by the delivery of Model B (enhanced TCAS II) equipments. The Model A equipments will provide sector interrogation to ensure reliable surveillance in high density airspace, and will have a direction finding capability on receive so that proximity warning indications can include the display of intruder bearing. The bearing data from the Model A antenna is not used, however, for horizontal miss distance assessment nor will an effort be made to provide horizontal resolution advisories based on such data.

Model A may be viewed as an effort to design and fabricate a minimum TCAS II on an accelerated schedule without addressing the technically risky enhancements that attempt to use bearing data for miss distance assessment and horizontal resolution. These issues will be taken up in the follow-on Model B activities.

SLIDE 5

It is anticipated that Model A engineering models will be delivered in September 1982 for flight test and evaluation over the following 10 months. These equipments will include the hardware and most of the software required for the Model B evaluation program so that upgrading Model A units to the enhanced Model B units will be largely a matter of providing a revised software module. On this basis, Model B activities will proceed within 6 months of the earlier Model A efforts.

Based on our Active BCAS work, there is substantial confidence in the schedule for Model A (minimum TCAS II). The enhanced TCAS (Model B) involves some new technical challenges and hence the schedule risk is higher.

SLIDE 6

In parallel with the Bendix effort, there will be 3 principal support activities directed toward the development of techniques for TCAS II.

Lincoln Laboratory will extend their earlier BCAS studies to identify and evaluate advanced signal processing techniques that would support reliable TCAS II surveillance in high density airspace. Much of this work will be based on in-flight data gathering schedule for next month in the densely travelled Los Angeles Basin.

Electromagnetic compatibility analyses are necessary to assure that transmissions from TCAS equipments do not degrade the operation of ground-based surveillance radars that support conventional air traffic control operations. Work in this area builds upon extensive analyses conducted over the past several years as part of our development efforts for Mode S and collision avoidance.

Finally, the enhanced TCAS II which would assess horizontal miss distance and provide horizontal resolution advisories, requires carefully designed computer algorithms for correctly employing the TCAS II bearing data for these purposes. It is anticipated that the initial logic would be validated by simulation at MITRE Corporation in August of next year, and supplied to Bendix for delivery in Model B in early 1983.

SLIDE 7

We do not anticipate an extensive development program for the minimum TCAS I comprising the Mode S transponder, the TCAS II crosslink feature, and the passive transponder detector. Nonetheless, our extensive development experience in the area of beacon signaling suggests that there may be opportunities for improving the performance of passive transponder detectors. We intend to publish a series of two reports on this subject over the next several months.

SLIDE 8

Operational evaluations are an effort to determine the effectiveness of TCAS options in environments that are as realistic as possible. In particular, the cockpit would be configured to represent the cockpit of a representative TCAS aircraft and flight procedures would be in place stipulating crew responsibilities in the event of a TCAS alarm. The aircraft would then be operated either in intentional close encounters to assess the degree of collision protection afforded, or in normal airspace to assess the rate and effect of alarms that occur when, in fact, no collision is imminent. We intend to approach the full-scale operational evaluation, just described, in three steps.

As a first step, we will evaluate the Dalmo Victor units described earlier on in-service Piedmont Boeing 727 aircraft. The displays will not be visible to any member of the crew but will be evaluated, instead, by an observer riding in the jump seat. There will, of course, be no intentional close encounters flown with these aircraft. The objective of this effort is to assess the probable impact of alarms encountered during normal traffic operations. In particular, alarms will be assessed to estimate the impact they would have had on flight path, crew workload, and overall safety had the display unit been in the pilot's position and had the pilot followed the command.

These evaluations should be finished in the early part of next year.

SLIDE 9

It is difficult to evaluate even a limited array of display devices in operational aircraft, and it is similarly difficult to perform comprehensive workload analyses since the variety of flight scenarios is necessarily limited by safety considerations. In order to better address these issues in the air carrier context, two cockpit simulation efforts are planned.

A relatively simple developmental simulator will be used to evaluate display media and other display characteristics. Effective display options and appropriate TCAS flight operations procedures will then be evaluated in a fully operational simulator for an assessment of workload. This effort will shed new light on the effectiveness of bearing data in proximity warning indications, the effectiveness of proximity warnings as procursors for resolution advisories, the workload associated with non-Mode C proximity warnings in dense airspace, and flight crew procedures for manual control of TCAS unit sensitivity. This simulation work should be finished in the early part of next year.

SLIDE 10

Results from the Piedmont evaluations and the simulation studies will be integrated into an FAA aircraft during the first quarter of 1982. The objective of this activity is to provide a fully operational TCAS test bed representative of an air carrier. The test bed will be carefully evaluated with respect to equipment characteristics, flight procedures, and overall effectiveness, and will then be available for demonstration to interested parties.

SLIDE 11

The National Standard for Active BCAS published in the Federal Register last October will serve as the basis for the draft national standard for the minimum TCAS II. We expect to publish this draft national standard for public comment in January. We further expect to finalize the minimum TCAS II standard by June of 1982, and to follow this with the publication of the national standards for the enhanced version of TCAS II. The national standards for the enhanced TCAS II would describe how intruder bearing data would be used for horizontal miss distance assessment and the generation of horizontal resolution advisories.

We are proposing an ambitious schedule for the publication of the MOPS for minimum TCAS II equipments. Given what we have learned from Active BCAS, the Bendix TCAS II development effort, the continuing contributions of MIT Lincoln Laboratory and Mitre Corporation, and other contractor efforts that will get under way in the near future, we believe that it is possible to have the minimum TCAS II MOPS in hand by June of next year.

This schedule is not possible without the earnest support of many of the people here today, but with your help, we can be successful.

Thank you.

CATEGORIES OF ACTIVITIES

- ENGINEERING DEVELOPMENT
- OPERATIONAL TEST AND EVALUATION
- STANDARDS
  - NATIONAL STANDARDS
  - MOPS

ENGINEERING DEVELOPMENT: TCAS TECHNOLOGY

- LINCOLN BCAS EXPERIMENTAL UNITS
  - 2/80 DELIVERED TO FAA
  - 12/80 IN-FLIGHT T&E COMPLETED
- DALMO VICTOR AIR CARRIER UNITS
  - 4/81 BASIC UNIT DELIVERED
  - 9/81 COMPLETE VALIDATION
- GENERAL AVIATION BCAS EXPERIMENTAL UNIT
  - 1/82 GROUND TESTS COMPLETE
  - 4/82 COMPLETE IN-FLIGHT T&E

SLIDE 2

ENGINEERING DEVELOPMENT: TCAS TECHNOLOGY

- o COORDINATION LOGIC DEVELOPMENT
  - * 8/81 SIMULATION STUDIES COMPLETE
  - * 6/82 IN-FLIGHT EVALUATION COMPLETE
- o BEARING PWI EVALUATION
  - * 10/81 IN-FLIGHT EVALUATION COMPLETE
- o NON MODE C PWI EVALUATION
  - * 6/82 IN-FLIGHT EVALUATION COMPLETE

ENGINEERING DEVELOPMENT: TCAS II

- o BENDIX MODEL A
  - * SECTOR INTERROGATION FOR HIGH DENSITIES
  - * CROSS LINK FOR TCAS I INTRUDERS
  - * BEARING DATA FOR PWI
- o BENDIX MODEL B
  - * BEARING DATA FOR HORIZONTAL MISS ASSESSMENT
  - * BEARING DATA FOR HORIZONTAL RESOLUTION

ENGINEERING DEVELOPMENT: TCAS II

- o BENDIX MODEL A
  - * 9/82 DELIVER FIRST UNIT
  - * 7/83 COMPLETE IN-FLIGHT T&E
- o BENDIX MODEL B
  - * 2/83 DELIVER FIRST UNIT
  - * 12/83 COMPLETE IN-FLIGHT T&E

ENGINEERING DEVELOPMENT: TCAS II

- o SURVEILLANCE TECHNIQUES FOR HIGH DENSITY AIRSPACE
  - * 8/81 FLIGHT TESTS IN LAX
  - * 6/82 COMPLETE TECHNIQUE DEVELOPMENT
- o EMC ANALYSES
  - * 5/82 IMPACTS OF TCAS II ANALYZED
- o HORIZONTAL LOGIC
  - * 8/82 COMPLETE INITIAL SIMULATION EVALUATIONS

ENGINEERING DEVELOPMENT: TCAS I

- DESIGN GUIDELINES FOR PASSIVE TRANSPONDER DETECTORS
  - * 1/82 INTERIM REPORT
  - * 4/82 FINAL REPORT

OPERATIONAL EVALUATION: IN-SERVICE AIR CARRIER

- ASSESS IMPACTS OF COLLISION AVOIDANCE EQUIPMENTS
  - 10/81 BEGIN EVALUATION
  - 3/82 EVALUATION COMPLETE

OPERATIONAL EVALUATION: COCKPIT SIMULATORS

- DEVELOPMENTAL SIMULATION (DISPLAY CHARACTERISTICS)
  - 11/82 SELECT DISPLAYS FOR FLIGHT EVALUATION
- OPERATIONAL SIMULATION (WORKLOAD)
  - 1/82 SELECT OPS PROCEDURES FOR EVALUATION

OPERATIONAL EVALUATION: FAA TEST AIRCRAFT

o OPERATE FAA AIRCRAFT AS EQUIPPED AIR CARRIER

  * 3/82 COMPLETE IN-FLIGHT EVALUATIONS
  * 5/82 PROVIDE DEMONSTRATIONS

STANDARDS

- NATIONAL STANDARDS
  - 10/80 ACTIVE BCAS
  - 1/82 TCAS II (MINIMUM) DRAFT
  - 6/82 TCAS II (MINIMUM) FINAL
  - 6/83 TCAS II (ENHANCED) DRAFT
  - 6/84 TCAS II (ENHANCED) FINAL
- MINIMUM OPERATIONAL PERFORMANCE STANDARDS (RTCA)
  - 6/82 TCAS II (MINIMUM)
  - 6/84 TCAS II (ENHANCED)

TCAS-I

Dr. Clyde A. Miller

July 22, 1981

Separation Systems Branch
Systems Research and Development Service
Federal Aviation Administration
Washington, D.C. 20591

Slide 1

TCAS-I FUNCTIONS AND COMPONENTS

I am going to give you a brief technical overview of the elements of TCAS-I. As indicated in an earlier paper, there are three main characteristics of TCAS-I.

First, TCAS-I is able to respond with encoded altitude to interrogations from the air traffic control system on the ground and from airborne TCAS-II units. Thus it includes a transponder and encoding altimeter.

Second, TCAS-I has a means for alerting the pilot that a TCAS-II aircraft is maneuvering to avoid him. This information is crosslinked from TCAS-II to the transponder in the TCAS-I aircraft. Thus, the transponder must be a Mode A/C/S transponder with an associated pilot display.

Third, TCAS-I has the ability to listen passively for transmissions from nearby transponders and to alert the pilot when the received power of any transmission might indicate that it is a threat.

Although together they make up the TCAS-I system, the equipment used for passive transponder detection is functionally independent of the Mode A/C/S transponder and the display for TCAS-II advisories. I will not dwell further on the technical aspects of the Mode A/C/S transponder and the encoding altimeter since the TCAS concept does not require any changes to the existing Mode S (or DABS) design. The Mode A/C/S transponder as defined by the DABS National Standard is fully capable of serving as the data link modem in the TCAS-I aircraft.

I will first focus briefly on the means for displaying TCAS-II advisories to the TCAS-I pilot. I will then turn to my main topic which is a discussion of the technical aspects of passive transponder detection.

Slide 2

MEANS OF DISPLAYING TCAS-II ADVISORIES

It is a simple matter to make use of the inherent communications capability of the Mode S link to drive a display in the TCAS-I aircraft on receipt of a message from the TCAS-II aircraft. When a maneuver advisory caused by a TCAS-I aircraft is displayed to the pilot of the TCAS-II aircraft, a message is included in the next regular surveillance interrogation to the TCAS-I aircraft. The air-to-air message alerts the TCAS-I pilot where the TCAS-II aircraft will be relative to him at the point of closest approach. For example, the "above" message is used when the TCAS-II tells its pilot either to climb or to limit his rate of descent. The crosslink message also includes a traffic advisory, that is, information on the range, relative altitude, and the relative bearing between the two aircraft. In the illustration here, the TCAS-II aircraft will be above the TCAS-I aircraft at closest approach even though it is currently 200 feet below. The range is currently 2.6 nmi and the bearing of the TCAS-II aircraft is 30° relative to magnetic North.

Slide 3

AIR-TO-AIR TRANSFER OF BEARING INFORMATION

There are several options for displaying the bearing of the TCAS-II aircraft to the TCAS-I pilot. This drawing illustrates the implementation of crosslinked bearing that seems to be least expensive for both the TCAS-I and TCAS-II aircraft. The TCAS-II unit measures the bearing to the TCAS-I aircraft and determines its own bearing from magnetic North (to the nearest 30 degrees) as it would be seen from the TCAS-I aircraft. It need not know the heading of the TCAS-I aircraft to do this. This number is crosslinked and displayed directly on a two-digit numeric readout, which could be built into the Mode A/C/S transponder as shown here. The pilot then uses his directional gyro to determine which direction to look for the target. Such a display would allow bearing to be displayed almost as accurately in the TCAS-I aircraft as in the TCAS-II aircraft which makes the measurement. This technique has the advantage that it doesn't require any electrical or mechanical interface between the Mode A/C/S transponder and the instrument used for determining heading in the TCAS-I aircraft. The alternative would be to display the TCAS-II bearing in terms of clock position to the TCAS-I pilot. However, this would require an interface between the transponder and the directional gyro to correct for the TCAS-I heading.

Slide 4

TCAS-I DISPLAY OF TCAS-II ADVISORIES - SUMMARY

In summary, crosslinking of TCAS-II advisories is easily achieved via the Mode-S data link. There is ample capacity on the link for both the maneuver advisory and relative positional information.

This scheme can be implemented and allow for the display of bearing information without requiring costly interfaces between the TCAS-I equipment and other flight instruments on the TCAS-I aircraft.

Slide 5

PASSIVE TRANSPONDER DETECTION

The passive transponder detector is a relatively simple device which listens for ATCRBS replies or MODE S reply or squitter transmissions at 1090 MHz. The device may have one or more selectable sensitivity settings, and it can also include a provision for rejecting replies whose altitude codes indicate that they are from aircraft far above or below own aircraft. An alert light is illuminated for a few seconds each time a reply exceeds the threshold and is found to be close in altitude. The light stays on if another reply is accepted before the light has timed out. The audio alarm sounds when the light is first triggered. The timer on the light prevents slowly scanning interrogators from causing the alert to retrigger each time the interrogator beam scans past.

This technique is capable of detecting ATCRBS transponders only in regions with ATCRBS ground interrogator coverage. However, it works with Mode A/C/S transponders everywhere since it is capable of triggering on spontaneous Mode S squitter transmissions.

Slide 6

PASSIVE TRANSPONDER DETECTOR - POSSIBLE REALIZATION

One possible realization of a Passive Transponder Detector is shown in this figure. A 1090-MHz receiver converts the RF transponder reply pulses into video pulses. These are fed to an amplitude comparator which is used to establish a detection threshold. This comparator can also be used to desensitize the unit each time the transponder on the TCAS-I aircraft transmits so the detector does not alarm on its own transponder replies. It is impossible to continue detecting when the on-board transponder transmits a reply to a ground interrogation. One must either suppress the detector when the transponder replies (as shown here) or alternatively, establish detector listening periods and desensitize the transponder during these periods. To maintain as high a transponder reply probability as possible, it would be necessary for these listening periods to be very brief. Pulses which pass the detection threshold are then fed to ATCRBS and Mode S reply detectors which look for a valid pulse sequence and, if a valid sequence is detected, extract the altitude code from the reply. The altitude code is then compared to own aircraft's code. If the reply altitude is outside of a predetermined altitude band or if it is an invalid altitude code, the reply is rejected. If the reply is in the band, or if the reply comes from an ATCRBS transponder which is not equipped with an encoding altimeter, the reply is accepted and an alarm is triggered. One knows when a reply comes from a transponder not equipped with an encoding altimeter because such transponders respond to Mode C interrogations with bracket pulses only.

The box labeled ALARM LOGIC controls the triggering and duration of the alarm light and the audio tone. The pilot control of sensitivity feeds back to control both the detection threshold sensitivity and the width of the altitude acceptance band.

Slide 7

PASSIVE TRANSPONDER DETECTION - WITH BEARING

It is also possible to include a direction finding capability in the passive transponder detector. This requires some sort of array of antenna elements on the aircraft. The measured bearing can be displayed in a number of ways ranging from a simple ring of lights to a modified plan-position display on a cathode ray tube.

Slide 8

TCAS-I PASSIVE TRANSPONDER DETECTOR - WITH BEARING - POSSIBLE REALIZATION

One possible realization of a passive transponder detector with direction finding capability is shown in this figure.

A four-element array is mounted on the bottom of the aircraft. Behind the array is a passive RF combiner network consisting of stripline hybrid junctions. The output of the hybrid network is a pair of RF lines, labeled Sum (Σ) and Difference (Δ). These lines feed a pair of phase-matched receivers. The IF outputs of the receivers are fed to a phase comparator to determine the angle of the received pulse. The sum-channel receiver has a video output which drives a set of circuits equivalent to those shown in the block diagram for the detector without bearing. Thus everything outside of the upper box in this figure is required for direction finding.

The analog phase signal obtained from the phase comparator is converted to a digital signal in the box labeled ANGLE DECODER. This box includes an analog-to-digital converter and a look-up table for calibrating the phase signal. The angle estimates for individual pulses are associated with replies and averaged to obtain a reply angle estimate. This estimate is then converted into a form appropriate for driving the display.

Slide 9

PASSIVE TRANSPONDER DETECTION - DEVELOPMENT ACTIVITIES

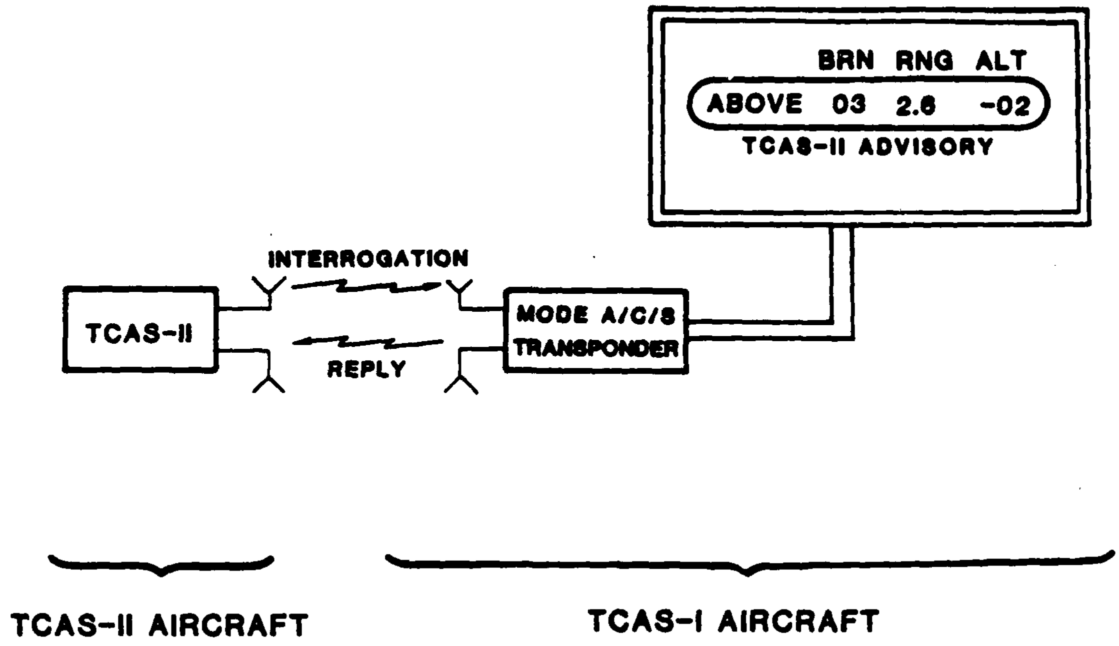
This figure lists some work which needs to be done to determine the performance of the passive transponder detection technique. We need alert rate data for both high and low traffic density airspace. These measurements will be made with various sensitivity thresholds and altitude filtering bands to attempt to determine the most useful settings for these detection parameters in a given airspace. One option for altitude filtering is to distinguish between alerts due to replies with altitude reports and those without altitude, and to provide the pilot with a switch for suppressing the latter. While this would provide less protection, it could be a useful pilot-selected mode for airspace where the alert rate may otherwise be too high.

Another area that needs further study is the direction finding technique used for ATCRBS transponders. We have only demonstrated the ability of a passive transponder detector to determine the bearing of Mode S targets. It is more difficult to determine the bearing of an ATCRBS-equipped aircraft with a passive system of this sort because there is little information available for associating asynchronous ATCRBS replies with targets, particularly if two targets are at the same altitude or are not equipped with encoding altimeters.

Another idea which we will consider is the possible use of measured changes in reply power to determine how much of a collision threat a given target is. All other factors being constant, it is theoretically possible to determine the Tau (or range/range-rate) parameter of a given target by measuring the variations in its received power with time. At the very least, it might be practical to reduce alert rates somewhat by assessing whether a target is closing or opening in range.

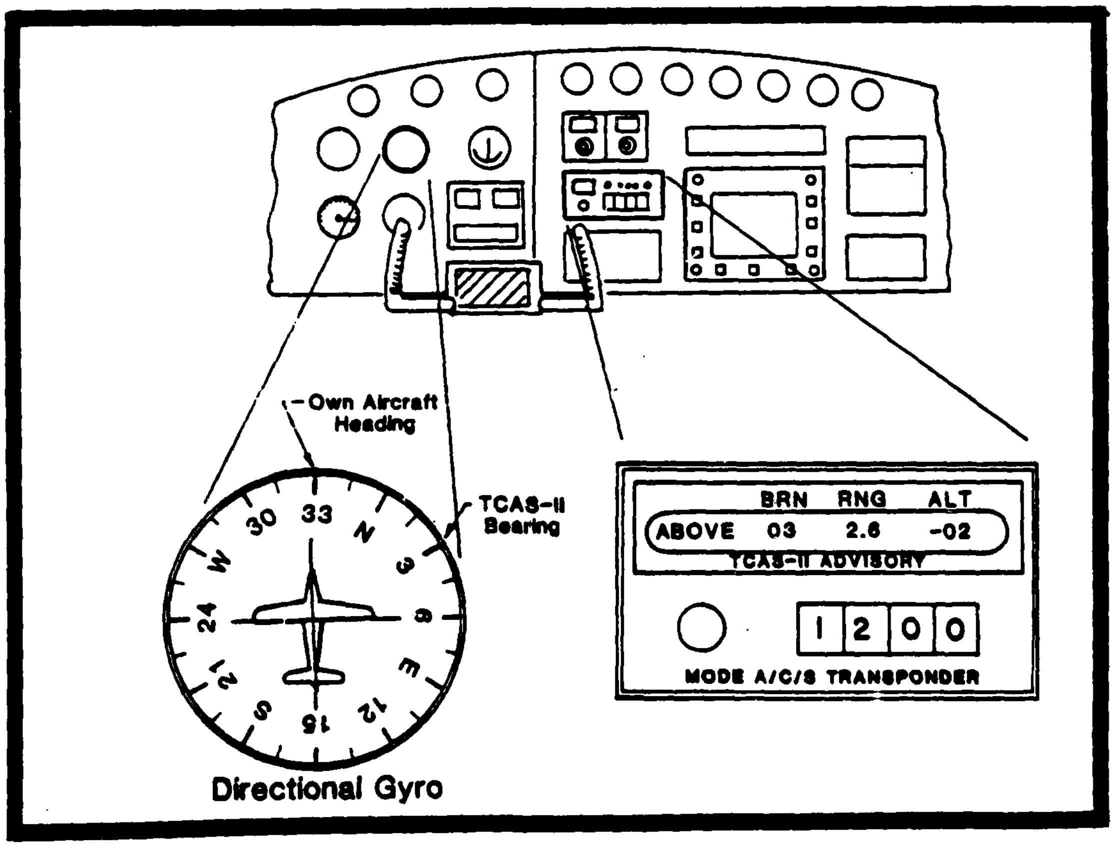
TCAS-I FUNCTIONS AND COMPONENTS

- PROVIDES SURVEILLANCE ELEMENT FOR GROUND ATC AND TCAS-II
  - ▶ TRANSPONDER
  - ▶ ENCODING ALTIMETER
- DISPLAYS MANEUVER INTENT CROSSLINKED FROM TCAS-II
  - ▶ TRANSPONDER MUST BE MODE A/C/S
  - ▶ TCAS-II ADVISORY DISPLAY
- LISTENS FOR TRANSMISSIONS FROM NEARBY TRANSPONDERS
  - ▶ PASSIVE TRANSPONDER DETECTOR



MEANS OF DISPLAYING TCAS-II ADVISORIES

AIR-TO-AIR TRANSFER OF BEARING INFORMATION



AD-A104 563 FEDERAL AVIATION ADMINISTRATION WASHINGTON DC SYSTEM--ETC F/G 1/4
THREAT ALERT AND COLLISION AVOIDANCE SYSTEM (TCAS) SYMPOSIUM.(U)
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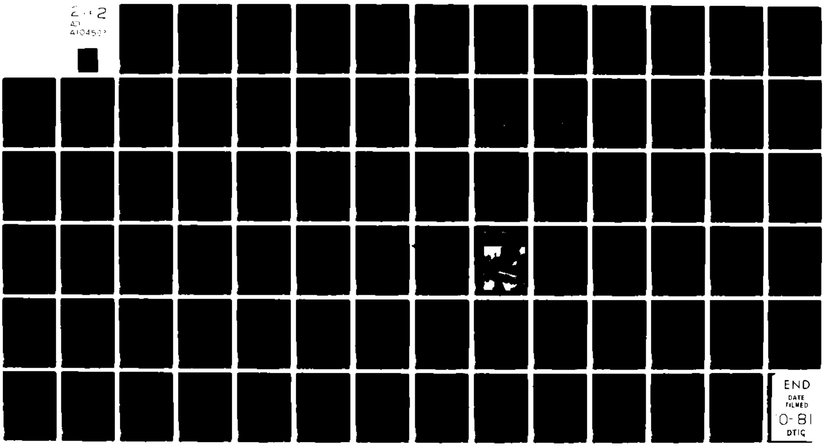
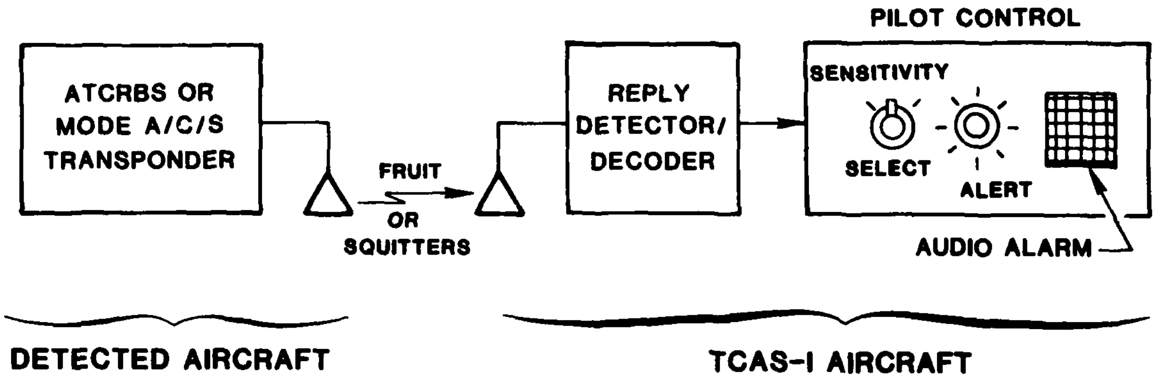


TCAS-I DISPLAY OF TCAS-II ADVISORIES

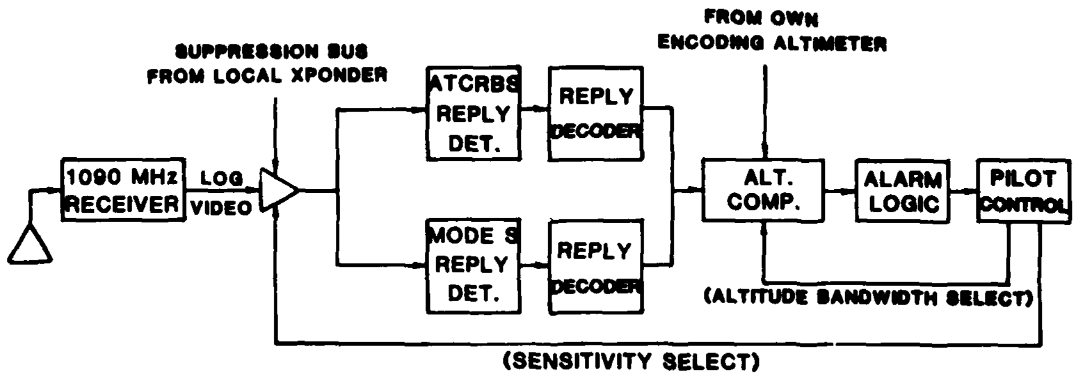
SUMMARY

- AIR-TO-AIR INTERROGATION FORMAT HAS SUFFICIENT CAPACITY FOR ADVISORIES

- INEXPENSIVE ADDITION TO MODE A/C/S TRANSPONDER IF BEARING IS DISPLAYED RELATIVE TO NORTH

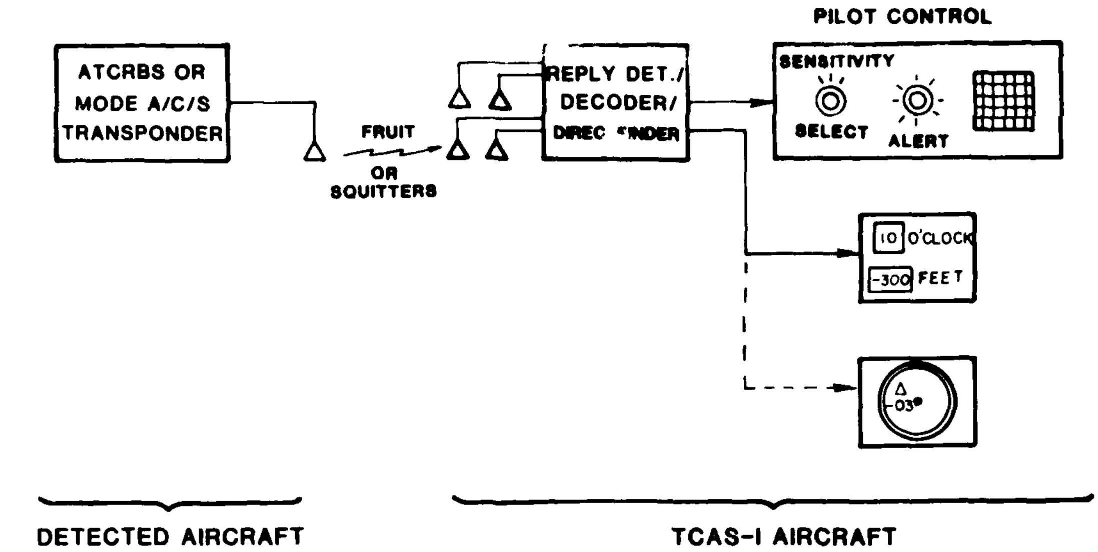


TCAS-I PASSIVE TRANSPONDER DETECTION

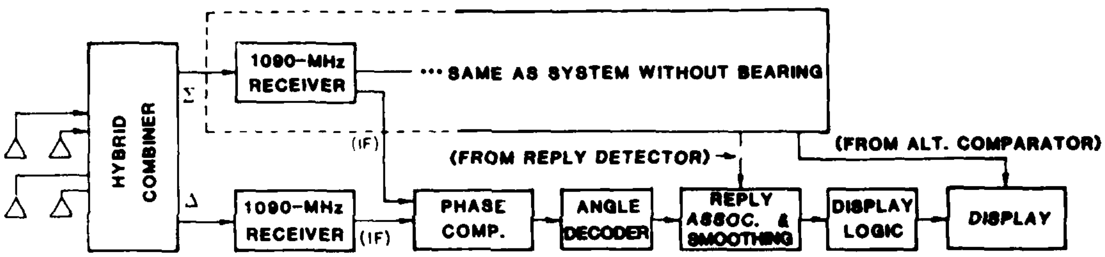


TCAS-I PASSIVE TRANSPONDER DETECTOR

POSSIBLE REALIZATION



TCAS-I PASSIVE TRANSPONDER DETECTION - WITH BEARING



TCAS-I PASSIVE TRANSPONDER DETECTOR - WITH BEARING
POSSIBLE REALIZATION

TCAS-I PASSIVE TRANSPONDER DETECTION DEVELOPMENT ACTIVITIES

- MEASURE ALERT RATES VS DENSITY
- DETERMINE BEST SENSITIVITY SETTINGS
- DETERMINE BEST ALTITUDE FILTERING BANDS
- DESIGN AND TEST ATCRBS DIRECTION FINDING TECHNIQUE
- EXAMINE POWER LEVEL TRACKING

TCAS II

Dr. Clyde A. Miller
July 22, 1981

Separation Systems Branch
Systems Research and Development Service
Federal Aviation Administration
Washington, D. C. 20591

SLIDE 1

Minimum performance requirements for TCAS II include the provision of collision resolution advisories in the vertical plane and reliable operation, independent of ground equipments, in airspace densities as high as 0.3 to 0.4 aircraft per square nautical mile (which corresponds to between 90 and 120 aircraft within 10 nautical miles of the TCAS II aircraft). In addition, intruder bearing data is provided with an acuracy on the order of 8 deg. rms (or better) so that reliable intruder clock position data can be provided in the cockpit. Mode S air-to-air signaling is employed for crosslinking traffic and TCAS II maneuver advisories to TCAS I intruders and for coordinating resolution advisories among TCAS II aircraft in conflict.

The ability of TCAS II to operate in dense airspace without degrading the ground surveillance system is extremely important. TCAS II is, in effect, an airborne secondary surveillance radar that interrogates the transponders in its immediate vicinity. These interrogations compete with interrogations from ground sensors that collect surveillance data for conventional air traffic control operations. Our requirement is to ensure that the sum total of TCAS II interrogations in any environment does not reduce the ability of the ground system to detect transponder replies from proximate aircraft by more than 2 percent on the average.

The principal enhancements envisioned for TCAS II are based on the use of intruder bearing data, available from the TCAS II on-board direction finding antenna, for purposes of horizontal miss distance assessment and the generation of horizontal resolution advisories. Estimating the horizontal miss distance for intruding aircraft is a technique that can reduce the rate of unwanted alarms when accurate miss distance estimates are available. Accurate miss distance estimates require accurate bearing rate data for the intruder which, in turn, requires precision bearing data from the antenna. Antenna data requirements for the generation of horizontal resolution advisories are even more stringent than those for miss distance assessment.

SLIDE 2

Our technical approach in the development of engineering model equipments of TCAS II avionics is based on active interrogation of nearby aircraft using interrogation antenna patterns that successively illuminate narrow azimuth sectors. This spatial selection of proximate aircraft for interrogation and reply processing reduces synchronous reply garbling which occurs when several aircraft are interrogated simultaneously.

The reduction of synchrouous garble is not the only difficulty associated with TCAS II operation in high densities. It is also necessary to limit the interference injected into the ATC environment by TCAS II interrogations. Fortunately, the use of narrow interrogation sectors that can be steered to various azimuths about the TCAS II aircraft suggests some techniques for rationing interrogation energy in those directions where it is most needed. These techniques may substantially reduce the interference levels of TCAS II.

The use of on aircraft antennas for intruder bearing measurements is one of the most interesting and challanging aspects of TCAS II operation. Clearly, relatively coarse measurments to support PWI displays are feasible. More precise mesurements for miss distance assessment and horizontal resolution will not be achieved as easily.

SLIDE 3

I would like to take a few minutes to describe the design that Bendix Corporation is pursuing in accordance with the technical approach outlined above. The technical approach that I have described is probably not the only approach for achieving ground-independent collision avoidance for high density airspace, and the Bendix design is clearly not the only way to pursue the technical approach I have outline. Nonetheless, an overview of some of the salient features of the Bendix design provides insight into how one might approach a TCAS II hardware implementation. The discussion will focus on the antenna with a few references to the RF and computer subsystems.

SLIDE 4

At least to a first order, one may view the minimum TCAS II as an Active BCAS electronics package connected to a relative high performance antenna that has the capability for sectorized interrogations and angle-of-arrival estimation on receive.

The current Bendix approach to the antenna envisions a unit approximately 18 inches in diameter by 1/2 high that would be mounted on the top and bottom of the TCAS II aircraft. It is possible that electronics might be colocated with such antennas ranging from relatively simple beam forming and control circuitry up to the TCAS II transmitters and RF receivers.

It is emphasized that this slide illustrates engineering model equipments with associated data collection and system control hardware. Production equipments would, of course, be far more compact.

SLIDE 5

This sytem block diagram is relatively straightforward and illustrates a modern computer-based design approach whereby virtually all of the TCAS II functions are either performed in or controlled by the control processor through the associated interface modules. Cockpit outputs at the right side of the slide show conventional collision avoidance equipment outputs such as traffic and resolution advisories (CAS advisories and commands) as well as optional traffic advisories on aircraft selected for reasons other than collision avoidance. The additional traffic advisories are sometimes referred to as cockpit display c traffic information (CDTI). It is not proposed to implement any CDTI functions in the TCAS II development program.

SLIDE 6

Returning to the antenna, there are several techniques that will be implemented in the Bendix design which are worthy of discussion.

SLIDE 7

Transmitter beam sharpening is achieved by transmitting on both a sum (sigma) pattern and a difference (delta) pattern. The normal ATCRBS P1-P3 interrogation is transmitted on the sum pattern with the sidelobe suppression (SLS), or P2, pulse transmitted on the difference pattern. Transponders near the axis of the sum pattern sense a P1 - P3 pulse pair that is stronger than the SLS (P2) pulse and respond to the interrogation. Conversely, transponders away from the axis of the sum pattern sense a relatively strong P2 pulse and suppress (don't respond). By selecting the power of the P2 transmission on the difference pattern relative to the power of the P1 and P3 pulses, it is possible to provide an effective interrogation beamwidth substantially smaller than the 3dB beamwidth of the sum pattern. Bendix proposes to provide an effective beamwidth of 22.5 deg. with a sum pattern beamwidth of 65 deg.

SLIDE 8

Given a 22.5 deg. interrogation sector that can be electronically steered in azimuth, one is faced with selecting the scheme for scanning the pattern. A certain amount of overlap is desirable from the standpoint of ensuring that there are no holes in the coverage. It turns out however, that beam overlap also appears to be useful for reducing synchronous garble. For example, in the slide, there may be several aircraft garbling one another in beam number 1, and some of these aircraft may drop out when the beam is moved over to position no. 2. At the moment, we are experimenting with various beam overlap patterns in computer simulation in an effort to identify effective schemes.

SLIDE 9

Several techniques are available for measuring intruder bearing. In the Bendix design, the same sum and difference patterns used for interrogation are also used to receive the elicited replies. By careful control of the sum and difference pattern shapes, an estimate of target position with respect to the axis of the sum pattern can be derived from the ratio of the video signals simultaneously received in the sum and difference patterns.

As suggested in this slide, difference-to-sum ratios that indicate the reply originated from regions outside the 22.5 deg. interrogation beamwidth can be used to reject fruit thereby reducing the signal processing load on the TCAS II computer.

SLIDES 10-12

The next few slides give some indication of how interrogation energy can be controlled as a function of azimuth in order to reduce interference to ATC. The approach illustrated envisions a track while scan scheme that requires TCAS II to periodically search its environment for intruder aircraft. If intruders are detected that could close on the TCAS II aircraft within 55 seconds, these aircraft would be selectively interrogated at a rate adequate to ensure reliable tracking data at the time a collision resolution advisory might be required - say at 30 seconds separation.

The question addressed in slides 11 and 12 is the interrogation rate required for the search function recognizing that one needs to look ahead more frequently than behind because intruders ahead are capable of closing faster. In the example of slide 11, the combined 1250 knot closing speed and the 55 second look ahead time dictate that intruders straight ahead be detected at 19 nmi. Since the system has a range of 20 nmi the interrogation rate ahead requires 1 look every 1 nmi of intruder closure, or 1 interrogation every 3 seconds at 1250 knots. Looking aft, however, the closing speed is only 50 knots suggesting that the interrogation rate could be as low as once every 19 minutes.

Over the 360 azimuth circle, a basic interrogation rate of approximately 5 per second would support the search function even with a four-fold overlap of the 22.5 deg. interrogation sector. This basic rate would be increased by the use of whisper-shout transmissions and top and bottom antennas.

Slide 12 suggest that a basic interrogation rate of 1 every 3 seconds would be sufficient for the search function in low speed terminal airspace.

These results suggest that there are opportunities for intelligently controlling the use of interrogation energy. The design of final interrogation scheduling and interference limiting algorithms is not completed.

SLIDE 13

As described earlier, sum and difference angle-of-arrival estimation is employed for measuring intruder bearing in the Bendix design. While this technology is highly developed in both military and civil applications, it is important to recognize that there are several error souces that must be addressed in addition to the obvious problem of controlling systematic errors that arise in the physical realization of the antenna. TCAS II receiver noise effects and noise-like perturbations of the angle of arrival due to fruit and garble associated with dense traffic areas must be controlled along with target glint or scintillation effects that result from reflections of transponder replies from the airframe of the intruding aircraft. In addition, reflection and diffraction of the arriving signal due to the airframe of the TCAS II aircraft must be taken into account, and TCAS II aircraft attitude variations to include roll angle and yaw motion must be compensated based on data from inertially stabilized reference units.

SLIDE 14

Substantial progress has been made in analyzing the ability of TCAS II to operate reliably in high density airspace. Moreover, some preliminary data on the effects of own aircraft diffraction on the monpulse estimate of intruder bearing have been developed.

SLIDE 15

The analysis of high density performance has focused on the ability of sector interrogation, whisper-shout and interrogation beam interlacing to reliably support TCA II surveillance. The principal difficulty with reliably tracking intruder aircraft in high density areas is that several aircraft may simultaneously respond to a TCAS II interrogation. When these replies overlap in the TCAS VI receiver, it may be difficult or impossible to sort out the individual replies. This phenomena of synchronous garble can degrade TCAS II surveillance at medium and long ranges to the extent that timely resolution advisories for collision avoidance can not be provided. The techniques listed on this slide are designed to separate out individual aircraft, or subsets of aircraft, from the total population in such a way that reply garbling is of manageable proportions.

SLIDE 16

Results of an analysis of a model of Los Angeles Basin traffic that provides a total of 743 aircraft in the Basin are shown in this slide. The 743 aircraft model provides densities of 0.3 aircraft per square nautical mile with some local densities as high as 0.4 aircraft per square nautical mile for some of the aircraft in the model.

If one attempted to operate a simple Active BCAS with an omnidirectional interrogation pattern in this environment, very few of the replies elicited would be in the clear (only 2.3 percent). Even with whisper-shout, fully 79 percent of the replies would be overlapped with 5 or more garbling replies. As the interrogation sector width decreases, the probability of receiving replies in the clear, or with only one or two overlaps, increases substantially. The use of the four-fold interrogation sector overlap further reduces reply garbling as compared to the use of contiguous sectors of the same width.

SLIDE 17

Another way to view the effectiveness of sectorized interrogation is to plot the probability of replies being garbled by N or more overlaps as a function of local airspace density. These data were generated from the 743 aircraft Los Angeles Basin model by analyzing the garble situation for aircraft grouped according to their local airspace density. Hence the data points corresponding to a density of 0.1 aircraft per square nautical mile were determined by analyzing the garble situation for all those aircraft that had this density as determined by counting the number of proximate aircraft over a radius of 20 nautical miles.

SLIDE 18

Lincoln Laboratory has extrapolated Active BCAS data collected last year in an effort to estimate the airspace densities in which reliable surveillance would be available using sectorized interrogations together with signal processing enhancements. For ATCRBS intruders, omnidirectional interrogations appear to be capable of reliably providing 25 seconds warning for 500 knot encounters in airspace densities of 0.4 aircraft per square nautical mile. For intruders equipped with Mode S transponders, omnidirectional interrogations would provide adequate warnings in densities up to 0.3 at which point interference to the ATC system might require interrogation limitations that would degrade TCAS II performance.

At the other extreme, 30 deg. interrogation sectors appear to be capable of providing timely alarms in densities up to 0.4 aircraft per square nautical mile for any combination of ATCRBS and Mode S transponder equipage over the aircraft population.

SLIDES 19 and 20

As pointed out earlier, diffraction from the structure of the TCAS II aircraft is one source of degradation of intruder bearing data provided by an on-aircraft antenna. A somewhat simplified analysis of this effect illustrates the nature of this error source.

The model includes only the effect of the vertical stabilizer which is represented as a simple flat plate 20 inches wide, 100 feet from antenna. No reflected or diffracted waves from other parts of the aircraft are included in the analysis. The sum and difference patterns are steered aft so that the axis of the sum pattern (and the null of the difference pattern) is 5.6 degrees away from the tail. The angle of arrival response of the antenna was then calculated as a function of intruder true bearing angle with the results shown in slide 20. Intruder angle is measured positive clockwise from dead aft so that the axis of the sum pattern corresponds to an intruder bearing of -5.625 degrees. The ripple in the direction error (estimated intruder bearing) is well behaved in the sense that it is small in magnitude. However, miss distance assessment and horizontal resolution are matters of reliably tracking bearing rates on the order of a few tenths of a degree per second.

Slide 20 shows that the effect of diffraction can be indicated bearing rates that contain substantial errors. For example, if the intruder is moving clockwise in the region from -6.0 to -4.0 degrees, the indicated bearing data suggest that the intruder is actually moving in the counter clockwise direction (toward more negative angles).

This preliminary analysis is not given as evidence that useful bearing measurements can not be made. In clean sectors, it may be possible to effectively make such measurements with carefully designed and installed antennas. We intend to find out.

SLIDE 21

There is a high confidence that a TCAS II capable of reliably providing vertical resolution advisories in high density airspace can be available in the near term. Much of the technology for such a device is available from our earlier Active BCAS work, and the antenna techniques required for sectorized interrogations are relatively straightforward. In addition, there are opportunities for reducing TCAS II interrogation energy levels below those that would be required for the simple Active BCAS in such densities.

We intend to pursue the use of on-board direction finding antennas for purposes of intruder bearing measurements for miss distance assessment and horizontal resolution. We recognize that this area involves technical risks not inherent in the minimum TCAS II design but we believe there may be opportunities for TCAS II enhancements in this area.

TCAS II REQUIREMENTS

(SLIDE 1)

<u>MINIMUM</u>

- VERTICAL MANEUVERS
- RELIABLE OPERATION IN HIGH DENSITY AIRSPACE (90 TO 120 A/C W/I 10 NMI)
- INTRUDER BEARING FOR PWI (8 DEG RMS)
- CROSSLINK TRAFFIC AND MANEUVER ADVISORIES TO TCAS I; MANEUVER COORDINATION WITH TCAS II
- LESS THAN 2 PERCENT DEGRADATION OF GROUND SURVEILLANCE

<u>ENHANCEMENTS</u>

- USE OF INTRUDER BEARING DATA FOR HORIZONTAL MISS DISTANCE ASSESSMENT (ALARM REDUCTION)
- USE OF INTRUDER BEARING DATA FOR HORIZONTAL RESOLUTION MANEUVERS

TECHNICAL APPROACH

(SLIDE 2)

- ACTIVE INTERROGATION OF PROXIMATE AIRCRAFT
- STEERABLE NARROW INTERROGATION AZIMUTH PATTERN
- OPTIMIZED ACTIVE INTERROGATION TRANSMISSIONS FOR INTERFERENCE LIMITING
- MODE S SIGNALING FOR SURVEILLANCE, TCAS I CROSSLINK AND TCAS II COORDINATION
- MEASUREMENT OF INTRUDER BEARING USING ON-BOARD ANTENNA

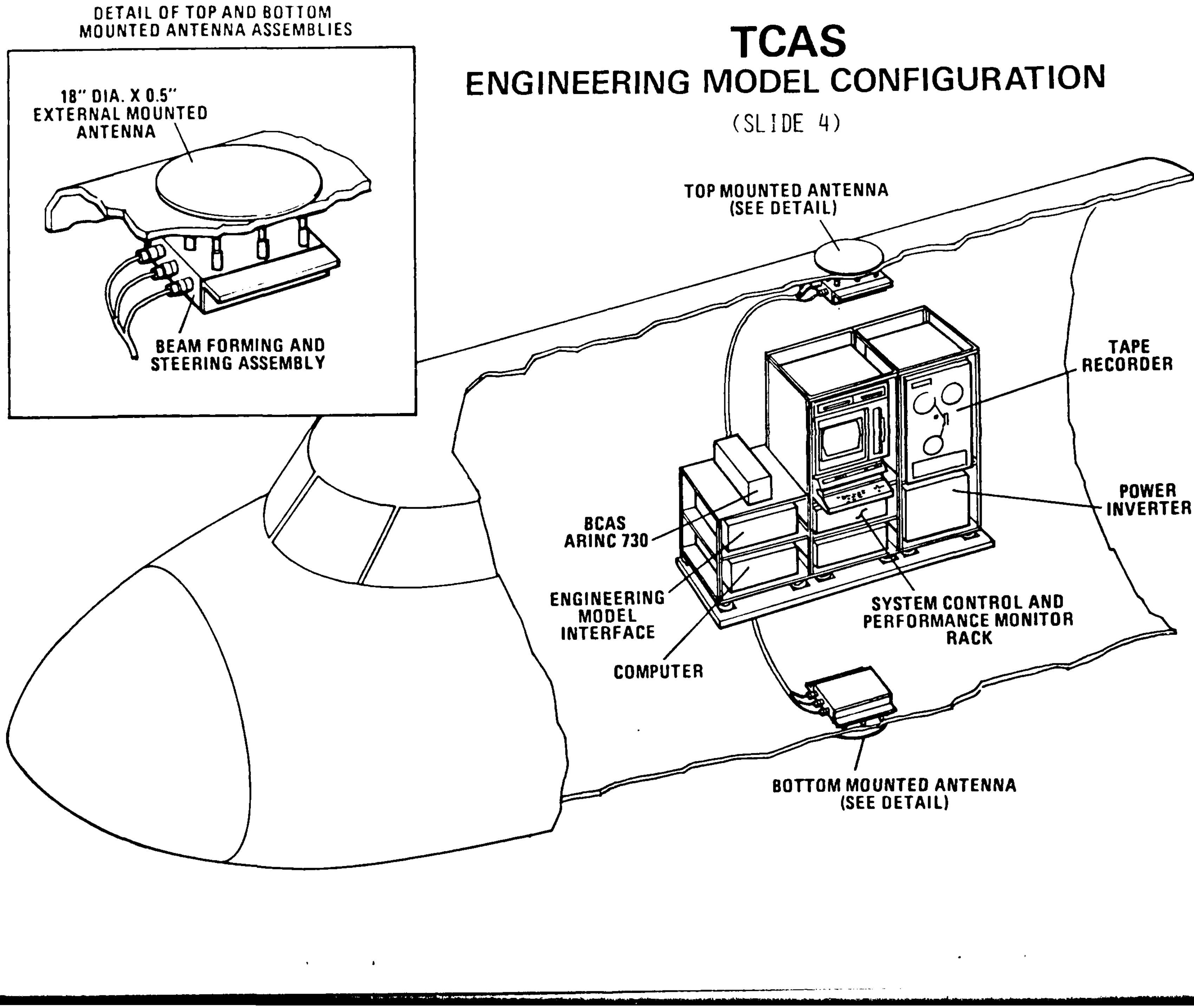
SYSTEM DESCRIPTION

(SLIDE 3)

- ANTENNA SUBSYSTEM
- RF SUBSYSTEM
- COMPUTER FUNCTIONS

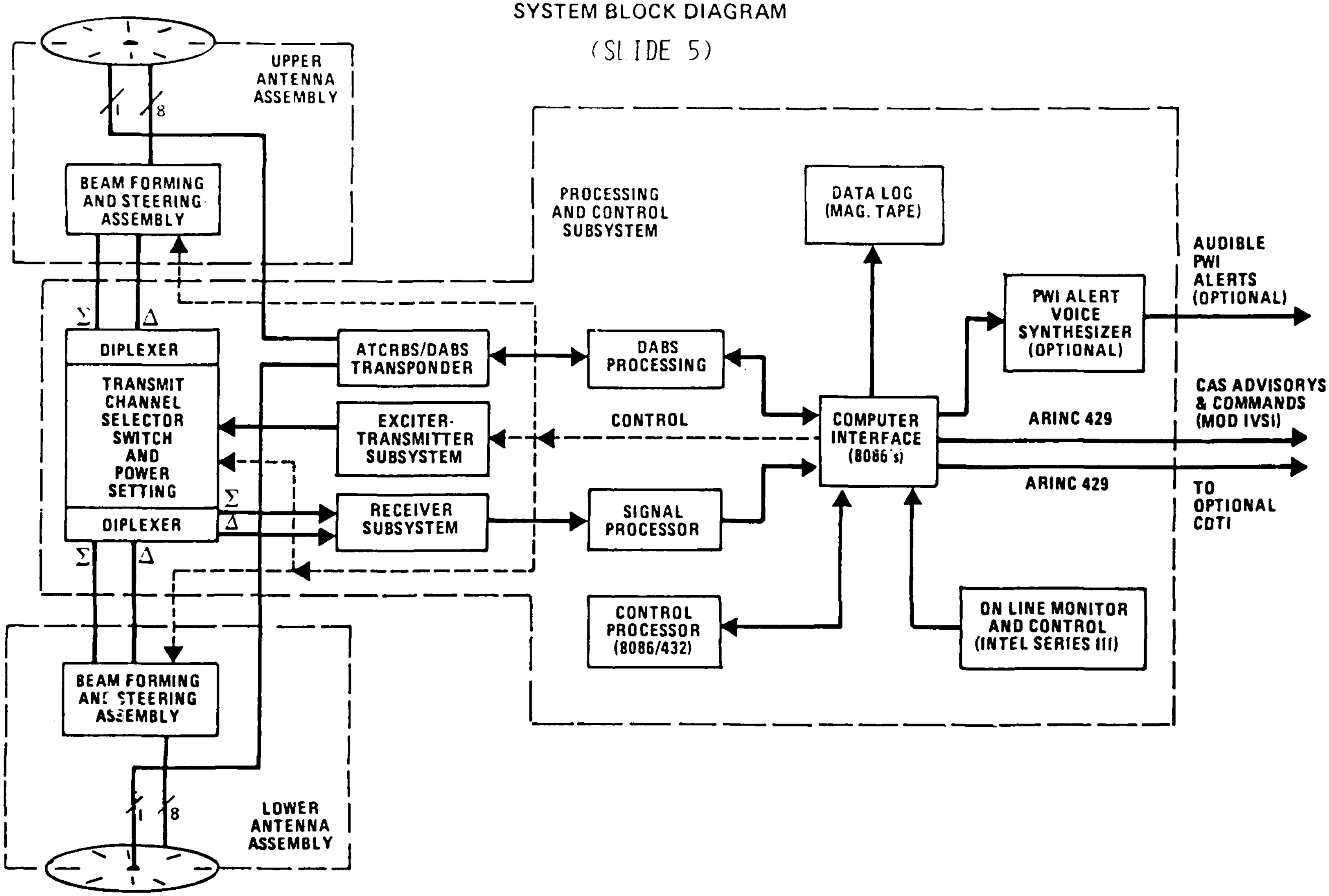
TCAS
ENGINEERING MODEL CONFIGURATION

(SLIDE 4)



TCAS ENGINEERING MODEL
SYSTEM BLOCK DIAGRAM

(SLIDE 5)



ANTENNA SUBSYSTEM

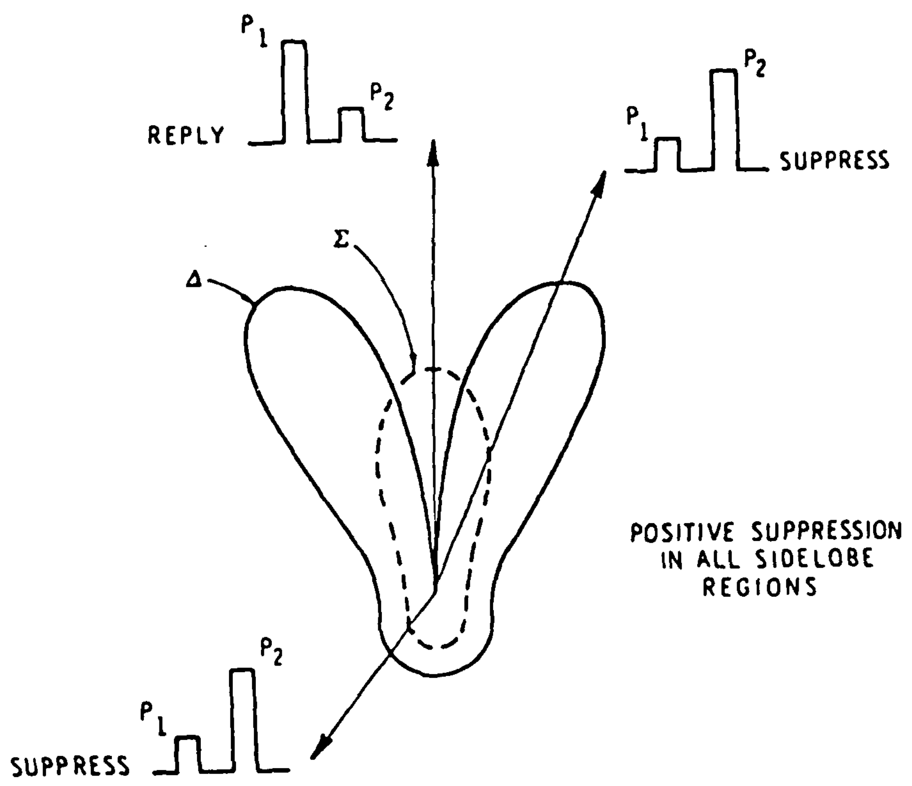
(SLIDE 6)

- SECTOR INTERROGATION
    - * STEERABLE SUM AND DIFFERENCE PATTERNS
    - * BEAM SHARPENING ON TRANSMIT
    - * BEAM INTERLACE FOR GARBLE REDUCTION

- INTRUDER BEARING MEASUREMENT USING SUM AND DIFFERENCE RECEIVE PATTERNS

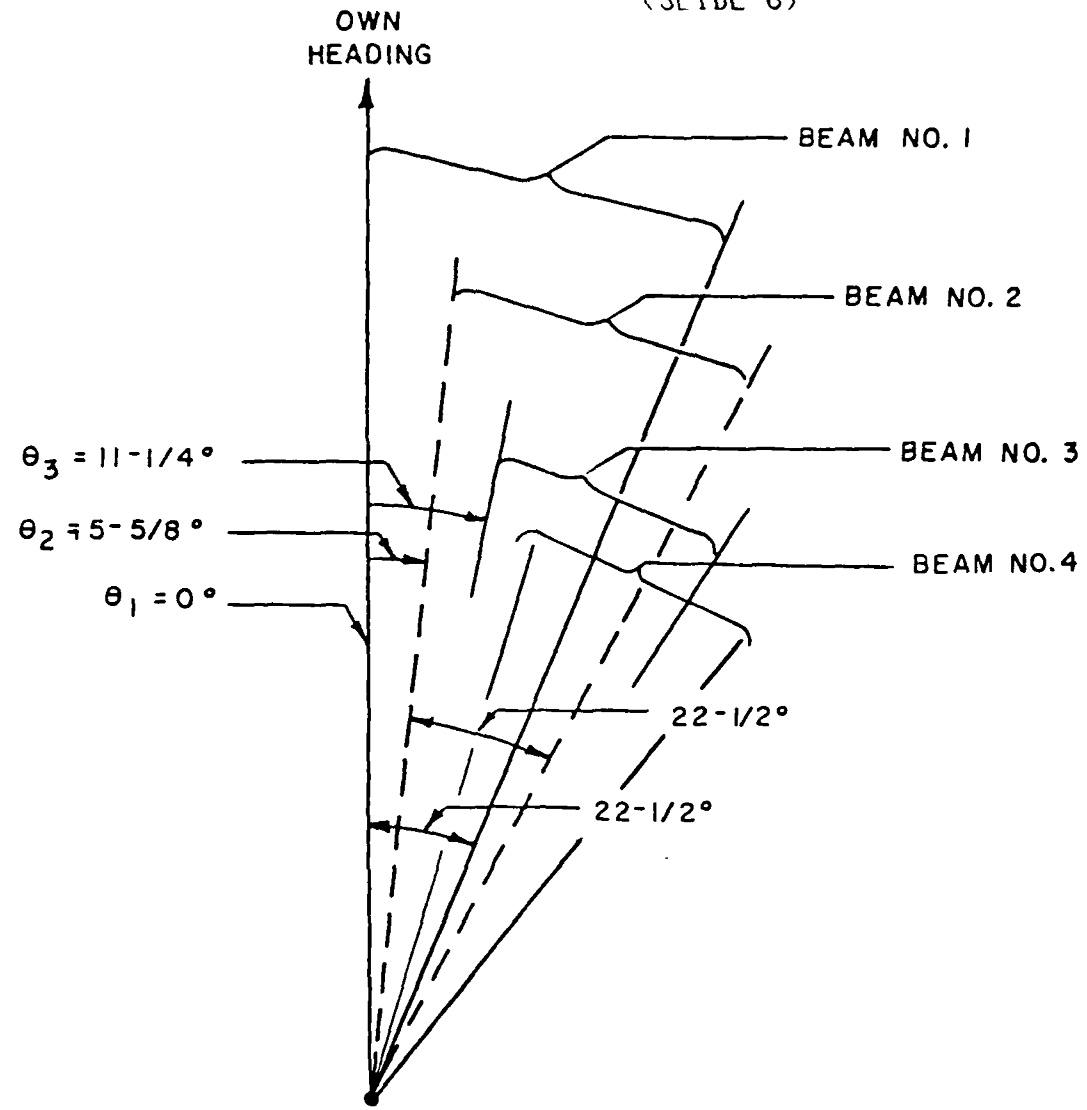
TRANSMITTER BEAM SHARPENING & SLS

(SLIDE 7)



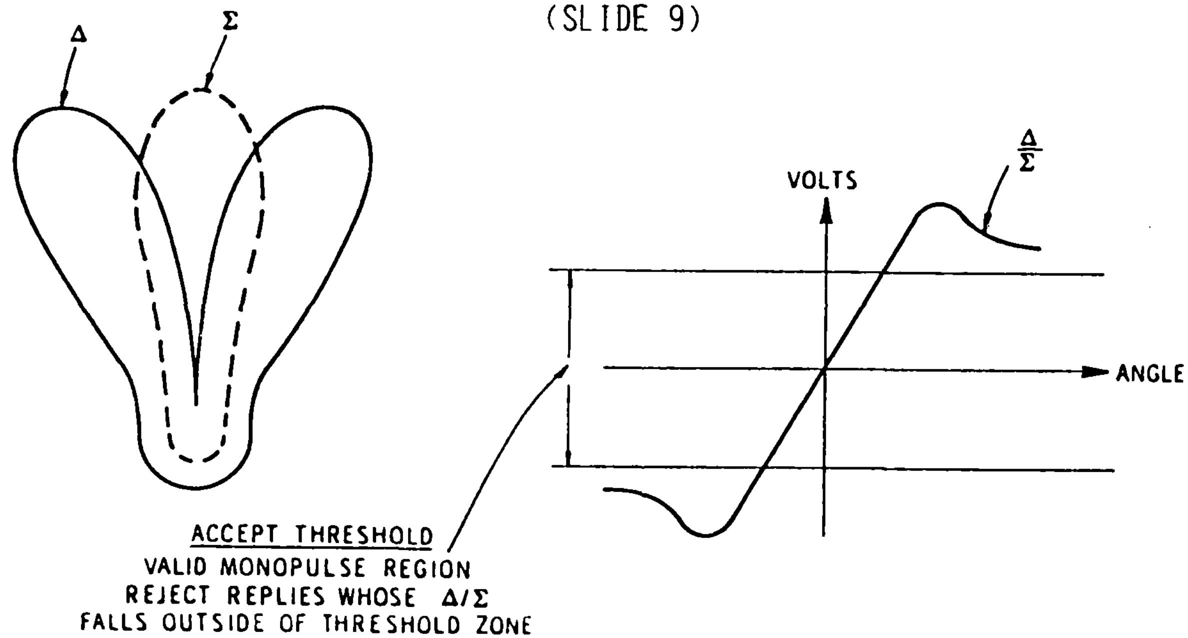
FOURFOLD OVERLAP SEARCH PATTERN

(SLIDE 8)



BEARING MEASUREMENT

(SLIDE 9)



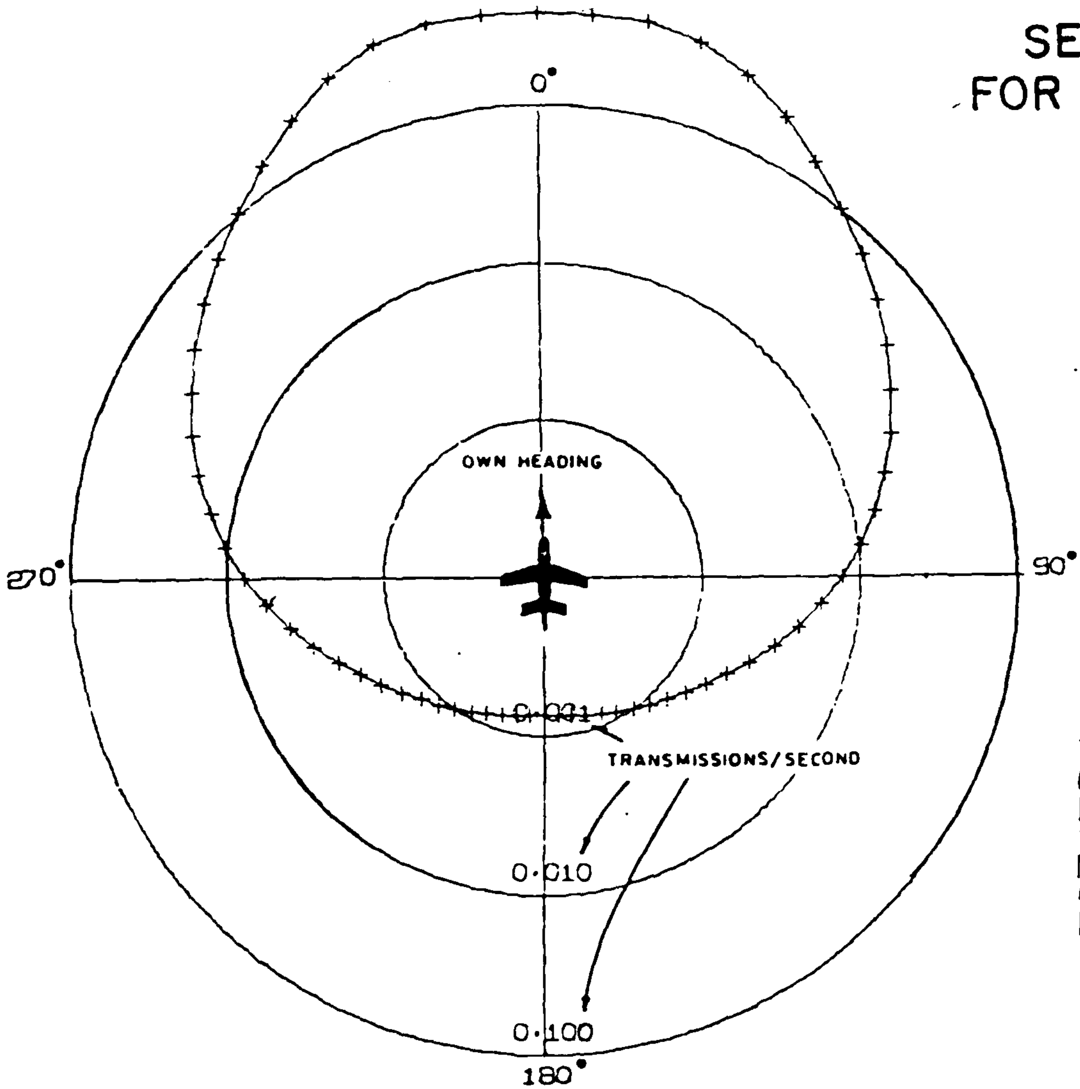
OPTIMIZED ACTIVE INTERROGATION

(SLIDE 10)

- AZIMUTH SEARCH WITH UPDATE RATE RELATED TO CLOSING SPEED
  - HIGH UPDATE RATE LOOKING FORWARD
  - LOW UPDATE RATE LOOKING BACK
- THREAT AIRCRAFT TRACKED WITH HIGH UPDATE RATE

SEARCH RATE VS BEARING FOR HIGH SPEED ENCOUNTERS

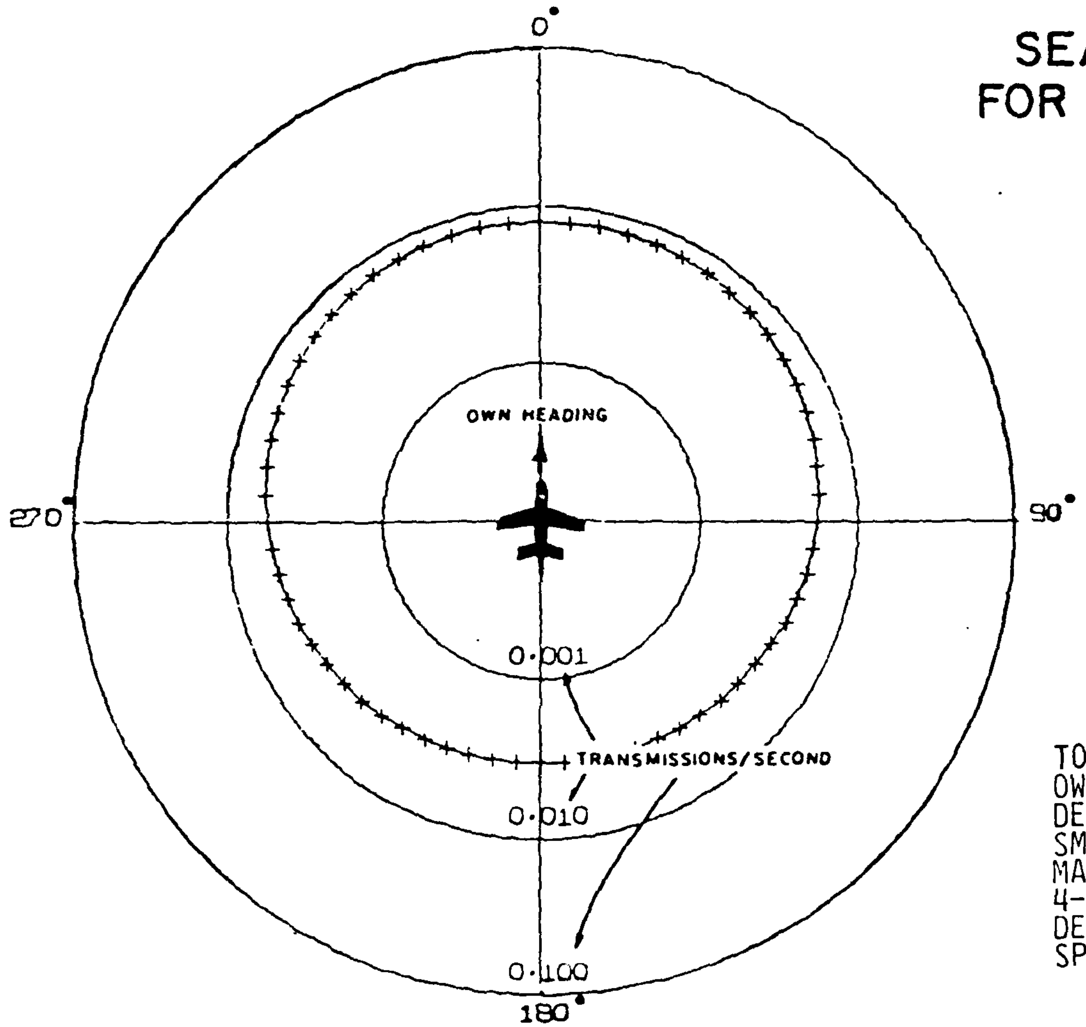
(SLIDE 11)



TOTAL TRANSMISSIONS PER SECOND, NT = 4.69
OWN SPEED, SO = 600. KNOTS
DETECTION RANGE, RD = 20.0 NM
SMOOTHING TIME = 25.00 SECONDS
MANEUVER TIME = 30.0 SECONDS
4-FOLD OVERLAP
DEGREE INTERVAL SEEN PER LOOK = 22.500
SPEED OF TARGET, ST = 300. TO 650. KNOTS

SEARCH RATE VS BEARING FOR SLOW SPEED ENCOUNTERS

(SLIDE 12)



TOTAL TRANSMISSIONS PER SECOND, NT = 0.35
OWN SPEED, SO = 100. KNOTS
DETECTION RANGE, RD = 20.0 NM
SMOOTHING TIME = 25.00 SECONDS
MANEUVER TIME = 30.0 SECONDS
4-FOLD OVERLAP
DEGREE INTERVAL SEEN PER LOOK = 22.500
SPEED OF TARGET, ST = 100. TO 300. KNOTS

MEASUREMENT OF INTRUDER BEARING

(SLIDE 13)

- MONOPULSE ANGLE-OF-ARRIVAL ESTIMATION
- BEARING ACCURACY DEGRADED BY:
  * ANTENNA ERRORS
  * NOISE AND TARGET GLINT
  * OWN AIRCRAFT DIFFRACTION/REFLECTION EFFECTS
  * OWN AIRCRAFT ATTITUDE VARIATIONS

PERFORMANCE ASSESSMENT

(SLIDE 14)

- HIGH DENSITY OPERATION
- OWN AIRCRAFT DIFFRACTION

HIGH DENSITY OPERATION

(SLIDE 15)

- REDUCTION OF GARBLE
  - SECTOR INTERROGATION
  - WHISPER SHOUT
  - BEAM INTERLACE

LA BASIN 743 AIRCRAFT MODEL

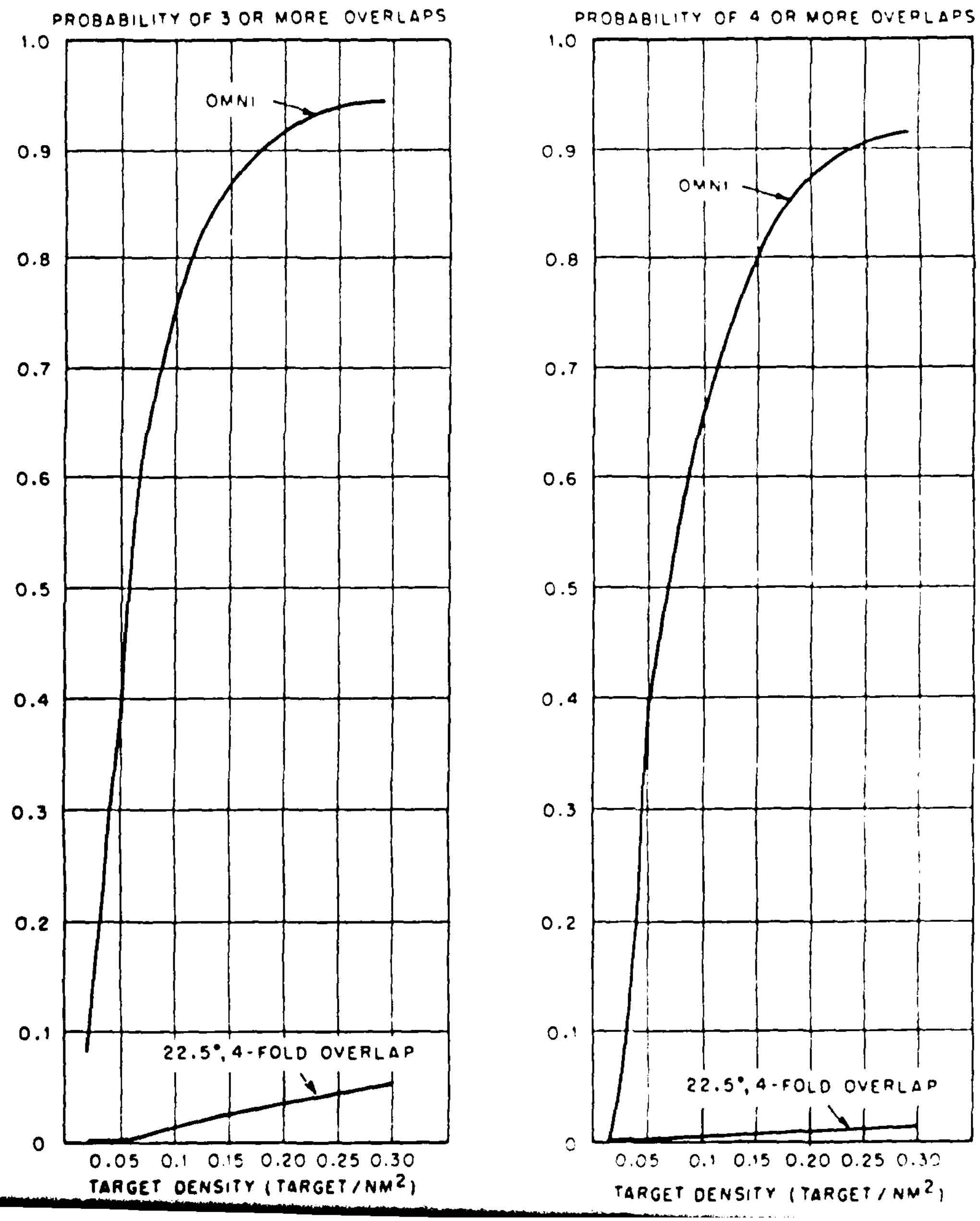
(SLIDE 16)

PERCENT OF TARGETS WITH N OVERLAPS

		INTERROGATION SCHEME			
N	OMNI	90°	45°	22.5°	22.5° W/ 4-FOLD OVERLAP
0	2.3	15.0	26.1	39.6	39.7
1	3.9	14.7	18.8	25.1	39.6
2	5.2	13.7	17.9	16.8	13.2
3	5.1	12.3	12.4	7.2	4.9
4	5.0	10.4	6.3	6.6	1.6
≥ 5	78.5	33.9	18.5	4.7	1.0

(SLIDE 17)

PROBABILITY OF MISSED REPLY



EXTRAPOLATION OF ACTIVE BCAS DATA

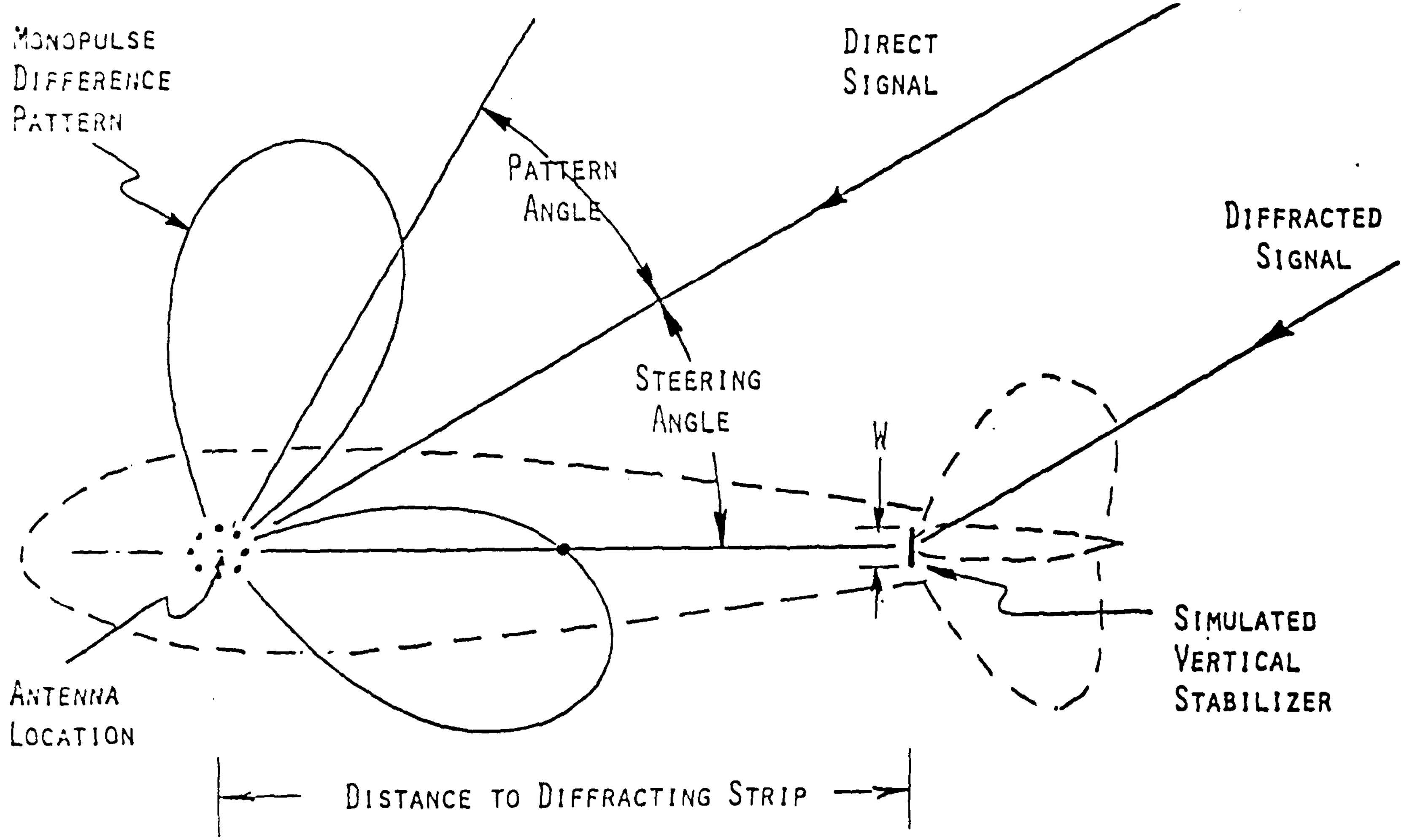
(SLIDE 18)

AIRSPACE DENSITY CAPABILITY
(A/C PER SQ NMI)

	OMNI	90^{0}	45^{0}	30^{0}
ATCRBS INTRUDERS	.04	.16	.32	.40
MODE S INTRUDERS	.30	.40	.40	.40

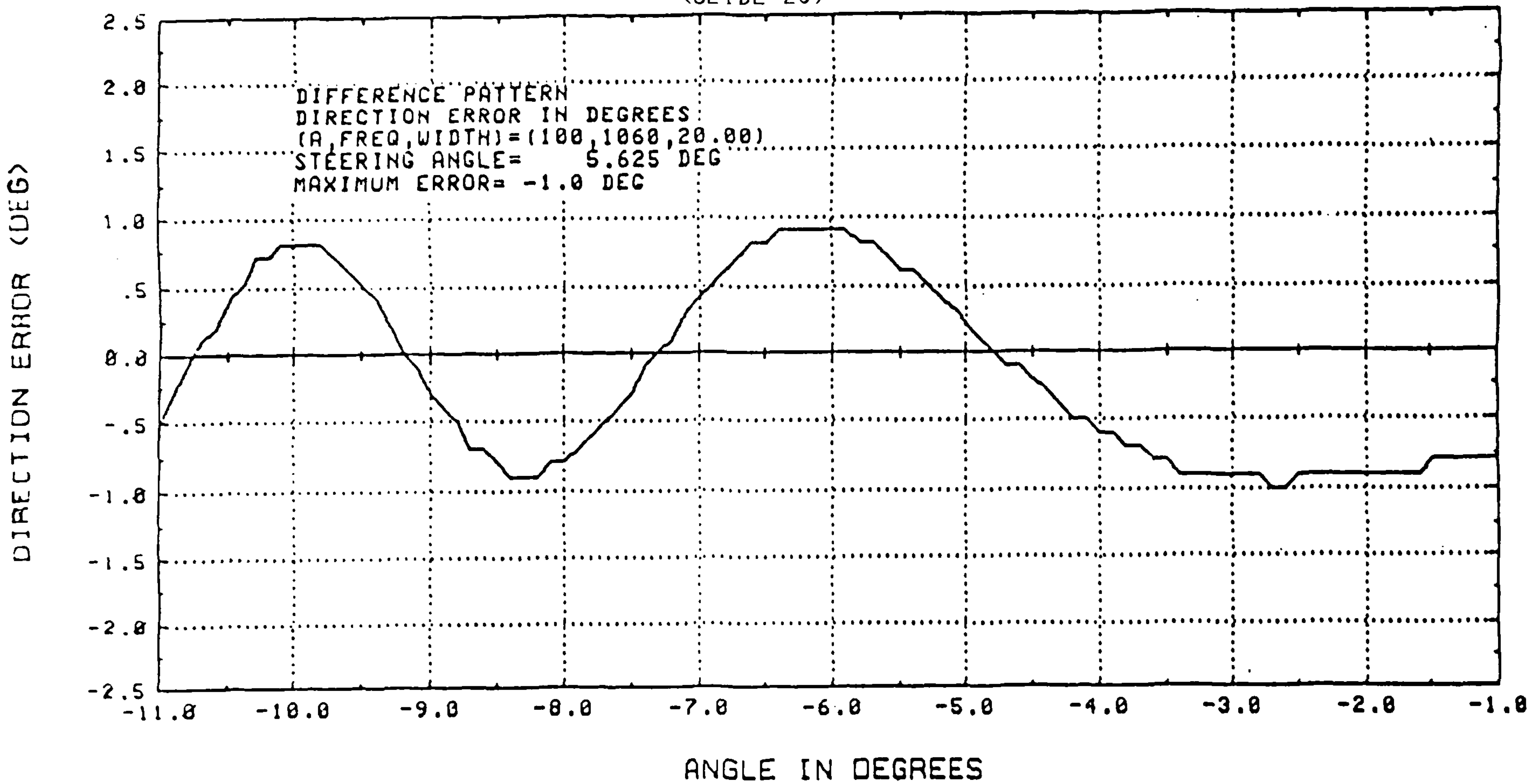
(SLIDE 19)

DIFFRACTION MODEL



ANGLE ERROR CAUSED BY DIFFRACTED SIGNAL AT 5.625 DEGREES RELATIVE TO AIRCRAFT TAIL

(SLIDE 20)



SUMMARY

(SLIDE 21)

- HIGH CONFIDENCE THAT A HIGH DENSITY TCAS II PROVIDING VERTICAL RESOLUTION CAN BE DEVELOPED IN THE NEAR TERM
- INTELLIGENT INTERROGATION SCHEMES PROMISE MINIMUM IMPACT ON GROUND ATC
- USE OF INTRUDER BEARING DATA FOR MISS DISTANCE ASSESSMENT AND HORIZONTAL RESOLUTION WILL BE MORE DIFFICULT

TCAS TECHNICAL SYMPOSIUM
July 22, 1981

RELATIONSHIP TO THE COMMUNITY

ROBERT W. WEDAN

FOUR WEEKS AGO, THE FAA ADMINISTRATOR SAID IN CONNECTION WITH THE TCAS DECISION THAT ENOUGH RESEARCH HAS BEEN DONE (ON THE WIDE VARIETY OF AIRBORNE COLLISION AVOIDANCE SYSTEM CHOICES). IT'S NOW TIME FOR IMPLEMENTING A DECISION. THE DECISION, OF COURSE, IS TO PROCEED AS RAPIDLY AS POSSIBLE TO IMPLEMENT SYSTEMS BASED ON THE TCAS CONCEPT.

DR. MILLER HAS DESCRIBED THE UPCOMING ACTIVITIES WHICH ARE PLANNED BY THE FAA TO MEET THE GOALS FOR IMPLEMENTATION. I WOULD LIKE NOW TO DISCUSS THE RELATED COMMUNITY ACTIONS THAT MUST ALSO TAKE PLACE. THEY FALL BASICALLY INTO THREE GROUPS:

1. THE FIRST IS TO DEVELOP THE STANDARDS AND SPECIFICATIONS WHICH PROVIDE THE ESSENTIAL PERFORMANCE AND OPERATIONAL GUIDELINES FOR THE DEVELOPMENT AND ACCEPTANCE OF TCAS EQUIPMENT.
2. THE SECOND IS TO COMPLETE THE DEVELOPMENT OF AIRLINE EQUIPMENT STANDARDS; i.e., ARINC CHARACTERISTICS TO INCLUDE TCAS-II.
3. THE THIRD IS TO MAINTAIN A CLOSE RELATIONSHIP THROUGH ICAO WITH OUR INTERNATIONAL AVIATION PARTNERS, TO INSURE INTERNATIONAL ACCEPTABILITY OF THE TCAS SYSTEM.

LET'S GO OVER THESE THREE AREAS IN A LITTLE MORE DETAIL.

REGARDING STANDARDS, OUR CURRENT FEELING IS THAT TCAS-II SHOULD BE COVERED BY A TECHNICAL STANDARD ORDER (or TSO). THIS IN TURN SHOULD BE PRECEDED BY A MINIMUM OPERATIONAL PERFORMANCE STANDARD (or MOPS) GENERATED BY THE RADIO TECHNICAL COMMISSION FOR AERONAUTICS (RTCA). AS CLYDE MILLER POINTED OUT, WE INTEND TO ACCOMPLISH THIS OBJECTIVE, THAT IS, A MOPS FOR TCAS-II, BY JUNE 1982.

FORTUNATELY, RTCA SPECIAL COMMITTEE SC-147 CURRENTLY EXISTS WHICH PROVIDES THE VEHICLE TO PRODUCE THE TCAS-II MOPS. INITIALLY, SC-147 WAS ESTABLISHED TO PREPARE A MOPS FOR THE ACTIVE BCAS. IT IS NOW MY UNDERSTANDING THAT THIS COMMITTEE HAS AGREED TO EXPAND THE SCOPE OF THEIR WORK TO INCLUDE TCAS-II AND WE EXPECT A REVISED TERMS OF REFERENCE WOULD BE ISSUED TO REFLECT THE CHANGE.

THE FAA TECHNICAL PROGRAM AND OPERATIONAL EVALUATION OF THE EQUIPMENT WHICH IS IN HAND WILL BE DIRECTED TO SUPPORT THE COMMITTEE IN THEIR WORK. THE PRINCIPAL TOOLS WE WILL BE WORKING WITH DURING THIS YEAR WILL INCLUDE THE LINCOLN LAB BCAS EXPERIMENTAL UNIT, MODIFIED TO USE AN ANGLE OF ARRIVAL ANTENNA. WE WILL CONTINUE TO OPERATE THIS EQUIPMENT TO GATHER MORE DATA ON THE PERFORMANCE OF THE SYSTEM AND TO GAIN VALUABLE OPERATIONAL EXPERIENCE, INCLUDING HUMAN FACTORS EXPERIENCE IN THE COCKPIT.

AN ADDITIONAL TOOL WILL BE THE SYSTEMS PROVIDED BY DALMO-VICTOR FOR EVALUATION IN AN AIR CARRIER ENVIRONMENT. THIS SYSTEM WILL ALSO HAVE AN ANTENNA WHICH MEASURES ANGLE OF ARRIVAL. THIS ANTENNA, AS WELL AS THE LINCOLN LAB ANTENNA, FALLS WITHIN THE $\pm 8^{o}$ PERFORMANCE CHARACTERISTIC DESCRIBED FOR INITIAL VERSIONS OF TCAS-II.

AT THIS TIME, THE FAA HAS NOT DETERMINED A FIRM NEED FOR A TSO ON TCAS-I. THEREFORE THE QUESTION OF THE NEED FOR A MOPS FOR TCAS-I IS STILL IN DISCUSSION. BUT LET ME SAY THAT THE DOCUMENTATION WE PLAN TO PRODUCE IN JANUARY 1982 WILL CONTAIN ESSENTIAL INFORMATION FOR THE INDUSTRY TO REFERENCE. IT WILL INCLUDE A SYSTEM DESCRIPTION FOR BOTH TCAS-I AND II. IT WILL REFERENCE THE LIMITS ALLOWED TO PREVENT INTERFERENCE WITH THE GROUND-BASED ATC SURVEILLANCE SYSTEM FOR TCAS-II WHICH WOULD BE APPLICABLE TO ANY DESIGN WHICH RADIATES AN INTERROGATION SIGNAL. FURTHER, THE DOCUMENTATION WILL CONTAIN THE SPECIFICATION FOR THREAT DETECTION RESOLUTION AND MANEUVER COORDINATION LOGIC THAT APPLIES TO ANY SYSTEM WHICH RESOLVES CONFLICTS BY VERTICAL MANEUVERS. THIS LOGIC HAS BEEN PREVIOUSLY PUBLISHED IN CONNECTION WITH ACTIVE BCAS DOCUMENTATION.

A MOPS FOR THE DABS TRANSPONDER IS PRESENTLY UNDER DEVELOPMENT BY RTCA. THIS MOPS HAS APPLICABILITY TO BOTH TCAS-I AND II BECAUSE, AS DESCRIBED EARLIER, THESE SYSTEMS CONTAIN AN INTEGRAL TRANSPONDER CAPABLE OF OPERATING ON MODES A, C, AND S. OUR DESCRIPTION OF TCAS-I WHICH IS TO BE AVAILABLE IN JANUARY WILL REFERENCE THE DABS (MODE S) MOPS AND THE PERTINENT SECTIONS OF THE TCAS-II MOPS; NAMELY, THE CROSS-LINK FORMATS, THE NATURE OF THE TRAFFIC INFORMATION FROM TCAS-II, AND ANY OTHER INFORMATION NECESSARY TO FACILITATE EARLY IMPLEMENTATION.

SO FAR AS AIRLINE EQUIPMENT CHARACTERISTICS ARE CONCERNED, THE FAA PLANS TO CONTINUE WORKING WITH ORGANIZATIONS SUCH AS THE ARINC AIRLINE ELECTRONIC ENGINEERING COMMITTEE. AS YOU MAY KNOW, ARINC CHARACTERISTIC 730 WAS ESTABLISHED TO COVER ACTIVE BCAS EQUIPMENT. WE BELIEVE THIS IS AN IMPORTANT STARTING POINT BUT THAT NEW WORK MAY BE REQUIRED TO COVER THE TCAS-II EQUIPMENT.

IN ADDITION TO OUR NORMAL COORDINATION ACTIVITIES WITH THESE COMMITTEES, RTCA AND ARINC, THE FAA PLANS TO HOLD PUBLIC MEETINGS, SUCH AS THIS, ON A PERIODIC BASIS. BY THIS, WE HOPE TO SHORTEN THE TIME TO COMMUNICATE WITH THE INDUSTRY ON ALL SUBJECTS VITAL TO IMPLEMENTING THE TCAS-I AND II SYSTEMS. THIS, OF COURSE, WILL INCLUDE PROGRESS ON OUR TECHNICAL WORK WHICH IS DIRECTED HEAVILY TOWARD THE ANTENNA DESIGNS WHICH WILL OPERATE IN THE HIGH DENSITY ENVIRONMENT DESCRIBED FOR TCAS-II. WE WILL ALSO REPORT ON OUR OPERATIONAL EXPERIENCES WHICH WILL INFLUENCE THE DESIGN OF COCKPIT DISPLAYS AND CONTROL.

NOW, ON THE SUBJECT OF OUR INTERNATIONAL ACTIVITIES:

LAST APRIL, THE INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO), IN A WORLDWIDE MEETING, DISCUSSED COLLISION AVOIDANCE SYSTEMS AND REACHED WHAT WE BELIEVE ARE VERY IMPORTANT CONCLUSION. THE DECISION MR. HELMS HAS MADE, FAR FROM COMPROMISING THOSE RECOMMENDATIONS, ENHANCES THEM IN MOST IMPORTANT WAYS.

ICAO CHOSE TO RECOMMEND USE OF "THE TERM SSR MODE S WHEN REFERRING TO THE SECONDARY SURVEILLANCE RADAR (ATCRBS) IMPROVEMENTS ENCOMPASSING THE CHARACTERISTICS OF DISCRETE ADDRESSING AND DATA LINK FUNCTIONS." WE AGREE AND HAVE ADOPTED THE ICAO TERM TO DESCRIBE OUR WORK ON DISCRETE ADDRESSING AND DATA LINK FUNCTIONS.

ICAO DEVELOPED RECOMMENDED GUIDANCE MATERIAL RELATED TO DESIGN FEATURES AND CHARACTERISTICS OF AIRBORNE COLLISION AVOIDANCE SYSTEMS. AMONG OTHERS, ICAO RECOMMENDED THAT "COMPATIBILITY AND FULL INTEGRATION WITH CURRENT WORLDWIDE AIR TRAFFIC SERVICES CAN BE ACHIEVED BEST BY OPTIMUM APPLICATION OF SSR

TECHNIQUES TO THE PROBLEM OF GROUND-BASED COLLISION PREVENTION AND OF AIRBORNE COLLISION AVOIDANCE." WE AGREE WHOLEHEARTEDLY.

THE ICAO COMMUNICATIONS DIVISIONAL MEETING RECOMMENDED THAT "STATES DEVELOPING GROUND-BASED COLLISION PREVENTION AND AIRBORNE COLLISION AVOIDANCE SYSTEMS SHOULD TAKE ACCOUNT OF ACTIVITIES UNDERWAY IN STATES AND INTERNATIONAL ORGANIZATIONS TO IMPROVE THE SSR SYSTEM BY ADDING DISCRETE/SELECTIVE ADDRESSING AND DATA LINK CAPABILITIES." OUR CHOICE OF MODE S DIRECTLY SUPPORTS THAT RECOMMENDATION, AND LAYS THE GROUNDWORK FOR AIRBORNE CAPABILITY TO UTILIZE DISCRETE SELECTIVE ADDRESSING AND DATA LINK CAPABILITIES WHEN GROUND IMPLEMENTATION OF SUCH SERVICES IS NECESSARY.

ICAO RECOMMENDED "THAT STATES DEVELOPING COMPATIBLE SSR IMPROVEMENTS AND AIRBORNE COLLISION AVOIDANCE SYSTEMS WHOULD TAKE ACCOUNT OF AIR TRAFFIC DENSITIES LIKELY TO BE ENCOUNTERED DURING THE LIFETIME OF THESE SYSTEMS. THE USE OF SSR MODE S SIGNALS FOR AIR-TO-AIR COLLISION AVOIDANCE INFORMATION EXCHANGE SHOULD BE CONSIDERED AS A LEADING CANDIDATE SIGNAL FORMAT TO ASSURE THE HIGHEST INTEGRITY OF THAT COMMUNICATION LINK." ONCE AGAIN, WE AGREE. OUR WORK ON TCAS-I AND TCAS-II IS IN FULL CONSONANCE WITH THIS ICAO RECOMMENDATION.

FINALLY, THE COMMUNICATIONS DIVISIONAL MEETING RECOGNIZED THE POTENTIAL VALUE OF AIRBORNE COLLISION AVOIDANCE SYSTEMS IN OVER-OCEAN OPERATIONS AND AREAS WHERE AIR TRAFFIC CONTROL SERVICES MAY NOT YET BE AVAILABLE. WE BELIEVE THAT THE CONCEPT OF TCAS-I AND TCAS-II CAN PROVIDE MAJOR BENEFITS IN SUCH AIRSPACE, AND THAT THIS CONCEPT WILL ENHANCE THE IDEAS DEVELOPED BY THE COMMUNICATIONS DIVISIONAL MEETING LAST APRIL.

THUS, OUR WORK ON TCAS-I AND TCAS-II IS FULLY COMPATIBLE WITH THE IDEAS DEVELOPED BY ICAO SO FAR, AND WE BELIEVE WILL ENHANCE THE CAPABILITIES ENVISAGED FOR THESE SYSTEMS BY THE COMMUNICATIONS DIVISIONAL MEETING LAST APRIL.

I'M SURE THAT YOU WILL AGREE THAT TAKEN TOGETHER, THESE INTERACTIONS WITH THE COMMUNITY, INCLUDING THE INTERNATIONAL COMMUNITY, WILL INVOLVE A LOT OF HARD WORK IN THE NEAR FUTURE. WE IN THE FAA WILL DO OUR BEST TO KEEP THE PACE UP TO MEET THE IMPLEMENTATION DATES. BUT COOPERATION BY INDUSTRY AND THE USERS IS ESSENTIAL. WE BELIEVE THAT THE DECISION TO MOVE WITH THE TCAS CONCEPT SHOULD PROVIDE THE STABILITY WE WERE ALL LOOKING FOR AND SHOULD PROVIDE THE INCENTIVES TO WORK TOGETHER TOWARD IMPLEMENTATION BEFORE THE END OF 1984

TCAS SYMPOSIUM

MR. K. HUNT

GOOD AFTERNOON. I AM PLEASED TO HAVE THIS OPPORTUNITY TO DISCUSS TCAS WITH YOU AND TO TALK FOR A FEW MINUTES ABOUT THE OPERATIONAL REQUIREMENTS FOR THIS TYPE OF EQUIPMENT.

THIS MORNING YOU HAVE HEARD ABOUT THE TCAS CONCEPT, SOME OF THE OPTIONS THAT WILL DETERMINE SYSTEM SOPHISTICATION, AND THE CAPABILITIES OF TCAS IN THE SPECTRUM RANGING FROM SIMPLE THREAT ALERT TO CONFLICT RESOLUTION. WITH THE DECISION TO PROCEED WITH TCAS BEHIND US, I WOULD LIKE TO TOUCH BRIEFLY ON SOME OF THE OPERATIONAL QUESTIONS REGARDING USE OF THIS SYSTEM. LET ME START BY DISCUSSING THE MORE CAPABLE TCAS II.

WE ARE FORTUNATE THAT THE WORK ALREADY COMPLETED IN THE DEVELOPMENT OF ACTIVE BCAS GIVES US A DEFINITE HEAD START TOWARDS A SUCCESSFUL IMPLEMENTATION OF THIS NEW SYSTEM. OPERATIONALLY, THIS HEAD START ON TCAS II ENABLES US TO DRAW HEAVILY ON OUR R&D EXPERIENCE TO DATE. WE CAN ALSO TAKE ADVANTAGE OF ADDITIONAL WORK ALREADY SCHEDULED FOR THE NEAR FUTURE. WHAT WE HAVE SEEN SO FAR IS ENCOURAGING HOWEVER I MUST CAUTION YOU THAT THERE IS STILL A SUBSTANTIAL AMOUNT OF WORK TO BE DONE.
AT A RECENT CONFERENCE I MENTIONED THE OPERATING REQUIREMENTS FOR A COLLISION AVOIDANCE SYSTEM ESTABLISHED BY THE FAA IN COOPERATION WITH THE AVIATION INDUSTRY. ALTHOUGH THE TCAS II CONCEPT IS NEW, THE REQUIREMENTS

REMAIN VALID AND I THINK IT IS APPROPRIATE TO REVIEW THOSE REQUIREMENTS TODAY.

- THE SYSTEM MUST DETECT 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

MANY OF THE OPERATIONAL QUESTIONS WE MUST ANSWER IN VIEW OF THESE REQUIREMENTS HAVE NOT CHANGED SIGNIFICANTLY WITH THE TRANSITION FROM ACTIVE BCAS TO TCAS II. THEREFORE I THINK THAT WITH SOME MINOR ADJUSTMENTS TO OUR SCHEDULED RESEARCH AND DEVELOPMENT WORK WE WILL BE ABLE TO PROCEED WITHOUT DELAY TOWARDS RESOLVING THE FOLLOWING ISSUES.

- IDENTIFICATION OF MINIMUM RESOLUTION COMMAND DISPLAY ELEMENTS
- EVALUATION OF THE USE OF BEARING/PROXIMITY INFORMATION
- EVALUATION OF COCKPIT WORKLOAD ISSUES
- ESTABLISHING OPERATIONAL PROCEDURES
- DEMONSTRATION OF SATISFACTORY DESENSITIZATION SCHEMES
- DEMONSTRATION OF SATISFACTORY OPERATIONAL PERFORMANCE

WE ARE WORKING WITH OUR RESEARCH AND DEVELOPMENT PEOPLE TO IDENTIFY THOSE ELEMENTS OF A RESOLUTION COMMAND 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 "DESCENT?" BY WORKING CLOSELY WITH INDUSTRY DURING OPERATIONAL TESTING, MINIMUM OPERATIONAL PERFORMANCE REQUIREMENTS WILL BE DEVELOPED TO DEFINE THESE ELEMENTS. FURTHER, THE EXACT PROCEDURES TO BE FOLLOWED BY THE PILOT IN THE EVENT OF A POSITIVE COMMAND, OR OTHER COMMANDS, HAVE YET TO BE DEVELOPED.

THE CAPABILITY TO DISPLAY THE BEARING OF THE INTRUDING AIRCRAFT, DICTATES A CAREFUL EVALUATION OF THE POSSIBLE DISPLAY FORMATS AND THEIR IMPACT ON COCKPIT DUTIES AS WE KNOW THEM TODAY. WE BELIEVE THAT THIS CAPABILITY WILL ENHANCE TCAS PERFORMANCE, PARTICULARLY AGAINST MODE A OR C TRANSPONDER EQUIPPED AIRCRAFT, BUT WE MUST INTRODUCE THIS LEVEL OF SOPHISTICATION TO THE COCKPIT IN A WAY THAT WILL NOT SIGNIFICANTLY ALTER NORMAL OPERATIONAL PROCEDURES.

IF SATISFACTORY METHODS OF DISPLAYING PROXIMITY INFORMATION ARE DEVELOPED, THIS CAPABILITY SHOULD PROVIDE A MEASURE OF PROTECTION NOT OTHERWISE AVAILABLE AGAINST AIRCRAFT NOT HAVING ALTITUDE ENCODING TRANSPONDERS. WE BELIEVE THAT IT SHOULD ALSO INCREASE A PILOT'S CONFIDENCE IN THE USE OF A SYSTEM THAT MAY CALL FOR AN IMMEDIATE RESPONSE IN ORDER TO AVERT A COLLISION. BOTH IN THE CASE OF BEARING AND PROXIMITY INFORMATION WE MUST PROCEED WITH CAUTION TO INSURE THAT THESE PRESENTATIONS DO NOT DISTRACT THE PILOT OR OTHERWISE INTERFERE WITH COCKPIT DUTIES AS WELL AS INSURING THAT THIS TYPE OF INFORMATION IS NOT MISUSED.

THE DESENSITIZATION ISSUE MUST STILL BE RESOLVED. WE, THE FAA AND INDUSTRY, MUST PERFECT WAYS TO REDUCE UNWANTED ALARMS WHICH AFFECT COCKPIT WORKLOAD AND PILOT CONFIDENCE. WHETHER WE ACCOMPLISH THIS BY A MANUAL SWITCH IN SOME CASES OR AUTOMATICALLY WITH SWITCHES TIED TO THE LANDING GEAR, FLAPS OR RADAR ALTIMETER, STILL NEEDS TO BE WORKED OUT.

LAST, BUT MOST IMPORTANT, IT MUST BE DEMONSTRATED IN THE REAL WORLD ENVIRONMENT THAT THE SYSTEM IS NOT ONLY CAPABLE OF PROVIDING APPROPRIATE THREAT ALERT AND COLLISION AVOIDANCE INFORMATION. BUT ALSO IS BOTH USEFUL TO AND USEABLE BY PILOTS IN EVERYDAY OPERATIONS.

I SHOULD EMPHASIZE THAT MUCH WORK HAS ALREADY BEEN ACCOMPLISHED ON MOST OF THESE ITEMS AND WE DO NOT ANTICIPATE ANY DELAY IN TCAS IMPLEMENTATION DUE TO THESE ISSUES.

IN LOOKING AT THE SIMPLER "THREAT ALERT" OR TCAS I EQUIPMENT WE DO NOT SEE ANY SUBSTANTIAL OPERATIONAL IMPACT. THE DEVELOPMENT OF OPERATIONAL PROCEDURES SHOULD NOT BE DIFFICULT WHEN NO MANEUVER ADVICE IS GIVEN BY THE SYSTEM. OUR VIEW IS THAT THIS TYPE OF EQUIPMENT WILL BE MOST USEFUL IN VISUAL FLIGHT CONDITIONS BY ASSISTING THE PILOT TO ACQUIRE TRAFFIC THAT HAS MIDAIR POTENTIAL. A SUBSEQUENT MANEUVER BASED ON A VISUAL SIGHTING SHOULD NOT DIFFER SIGNIFICANTLY FROM AN UNEQUIPPED AIRCRAFT MAKING THE SAME TYPE OF MANEUVER. WE APPRECIATE THE FACT THAT ANY TYPE OF THREAT ALERT IS LIKELY TO CAUSE INCREASED USE OF ATC FREQUENCIES TO CONFIRM TRAFFIC - PARTICULARLY WHEN OPERATING IFR - BUT IT IS TOO EARLY TO ASSESS WHAT IMPACT THIS WILL HAVE ON THE AIR TRAFFIC ENVIRONMENT. ADDITIONALLY, WE JUST DO NOT KNOW AT THIS POINT THE LEVEL OF SOPHISTICATION TO EXPECT FOR ENHANCEMENTS OF SYSTEMS THAT FALL IN THE RANGE BETWEEN SIMPLE TCAS I AND TCAS II. INDUSTRY INNOVATION WILL BE THE MAIN FACTOR HERE. AS THE CAPABILITIES OF THREAT ALERT EQUIPMENT INCREASE THERE IS AN OBVIOUS NEED FOR MORE PRECISE PROCEDURAL GUIDANCE, AND MORE ATTENTION TO OPERATIONAL FACTORS. THIS IS PARTICULARLY TRUE IF A THREAT ALERT DISPLAY PROVIDES A SUGGESTED OR IMPLIED MANEUVER. IF A TCAS I SYSTEM IS DEVELOPED THAT HAS THE CAPABILITY OF GIVING COLLISION AVOIDANCE MANEUVERS, WE SEE NO DIFFERENCE, IN THE NEED FOR OPERATIONAL EVALUATION AND PROCEDURES, BETWEEN THIS TYPE OF TCAS I SYSTEM AND TCAS II.

AS YOU KNOW, THERE IS NO REGULATORY ACTION PLANNED TO MANDATE THE IMPLEMENTATION OF TCAS, AND I THINK IT WOULD BE WORTHWHILE TO MENTION HOW WE INTEND TO ESTABLISH OPERATIONAL PROCEDURES. ACTUALLY WE DO NOT FORESEE ANY DRAMATIC CHANGE FROM THE WAY WE NORMALLY DO BUSINESS. IN THE CASE OF A CERTIFICATED CARRIER, APPROPRIATE PROCEDURES AND TRAINING REQUIREMENTS WILL BE ESTABLISHED AND APPROVED THROUGH THE PRINCIPAL INSPECTOR AT THE CERTIFICATE HOLDING OFFICE. THIS ACTION WOULD BE SUPPORTED BY DIRECTIVES FROM THE APPROPRIATE HEADQUARTERS FUNCTION. FOR THE GENERAL AVIATION USERS, INFORMATION WILL BE MADE AVAILABLE THROUGH GENERAL AVIATION DISTRICT OFFICE SAFETY PROGRAMS AS WELL IN THE AIRMAN'S INFORMATION MANUAL. AS IS THE CASE WITH ANY NEW SYSTEM, WE INTEND TO PUBLISH ADVISORY CIRCULARS TO PROVIDE GUIDANCE TO THE AVIATION COMMUNITY ON AIRBORNE PROCEDURES AND THE GENERAL USE OF TCAS.

IN SUMMARY, WE HAVE A LOT OF HARD WORK AHEAD OF US BEFORE WE CAN IMPLEMENT TCAS, BUT THE GOAL IS REALISTIC AND I THINK THE RESULT WILL BE A SAFER NATIONAL AIRSPACE SYSTEM. THE SUCCESS OF THIS PROGRAM WILL DEPEND LARGELY ON THE AVIATION COMMUNITY AND FAA ACCEPTING THE CHALLENGE TO RECOGNIZE AND RESOLVE THE REMAINING ISSUES AND WORK TOWARDS A TIMELY IMPLEMENTATION OF THIS SYSTEM. I AM LOOKING FORWARD TO ANY QUESTIONS YOU MAY HAVE AT THE PANEL DISCUSSION.

THANK YOU VERY MUCH.

TCAS TECHNICAL SYMPOSIUM

AIRWORTHINESS CERTIFICATION CONSIDERATIONS

By

M. CRAIG BEARD

DIRECTOR OF AIRWORTHINESS

TCAS TECHNICAL SYMPOSIUM

AIRWORHTINESS CERTIFICATION CONSIDERATIONS

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M. CRAIG BEARD

DIRECTOR OF AIRWORTHINESS

OBJECTIVE: IN DEVELOPING THE AIRWORTHINESS CERTIFICATION PROGRAM FOR IMPLEMENTATION OF TCAS I AND TCAS II, OUR OBJECTIVES WILL BE TO KEEP THE REGULATORY BURDEN ON THE EQUIPMENT MANUFACTURERS, AND FOR AIRCRAFT INSTALLATION APPROVAL TO AN ABSOLUTE MINIMUM. IN FACT AT THIS POINT IN TIME WE SEE NO NEED TO DEVELOP NEW AIRWORTHINESS REGULATIONS ON EQUIPMENT DESIGN OR INSTALLATION.

TCAS I:

- AIRCRAFT INSTALLATION APPROVALS WIL BE PROCESSED ON A "NO-HAZARD" BASIS. FAA EVALUATION OF THE INSTALLATION WILL BE DIRECTED TOWARD ENSURING THAT:

  - THE INHERENT AIRWORTHINESS OF THE AIRPLANE IS NOT DEGRADED

STRUCTURE

ELECTRICAL SYSTEM INTERFACE

INTERFERENCE WITH OTHER AIRCRAFT SYSTEMS

- THE TCAS I DISPLAY AND WARNINGS NOT TO PROVIDE MISLEADING OR CONFUSING INFORMATION TO THE PILOT.

- WE PLAN TO DEVELOPE NATIONAL POLICY GUIDANCE TO OUR FIELD INSPECTORS TO FACILITATE APPROVAL OF TCAS I INSTALLATIONS ON A "FIELD APPROVAL" BASIS, THUS OBVIATING THE NEED TO PROCESS INSTALLATION APPROVALS THROUGH THE MORE LABORIOUS SUPPLEMENTAL TYPE CERTICICATION (STC) PROCEDURES.

- IF A MINIMUM OPERATION PERFORMANCE SPECIFICATION (MOPS) IS DEVELOPED IN THE FUTURE FOR TCAS I COMPONENTS, WE WOULD PROBABLY DEVELOP A TECHNICAL STANDARD ORDER (TSO)*:

  - SO THAT EQUIPMENT MANUFACTURERS THAT WANTED TO PRODUCE THE EQUIPMENT UNDER A FAA TSO AUTHORIZATIN COULD DO SO VOLUNTARILY.

  - SO THAT INSTALLERS OF THE EQUIPMENT COULD LOOK FOR THE TSO AUTHORITZATION LABLE TO ASSURE THEMSELVES THAT THE EQUIPMENT THAT THEY PURCHASE MEET BASIC DESIGN AND PROODUCTION QUALITY CONTROL STANDARDS.

- THE SAME TSO COULD BE USED FOR TCAS I WITH CERTAIN ENHANCEMENT FEATURE. THE LIMITS ARE UNCERTAIN AT THIS TIME.

TCAS II:

- A MOPS IS EXPECTED FOR THE BASIC TACAS II EQUIPMENT, AND THE FAA PLANS TO ISSUE A TSO ON TCAS II, INCORPORATING THE MOPS BY REFERENCE.

- AIRCRAFT INSTALLATION OF TCAS II SYSTEMS WOULD BE EVALUATED BY FAA FOR THREE (3) PURPOSES

  - TO ENSURE THAT THE INHERENT AIRWORTHINESS OF THE AIRCRAFT IS NOT DEGRADED - AS EXPLAINED FOR TCAS I

  - TO ENSURE THE SYSTEM DISPLAY DOES NOT PROVIDE MISLEADING OR CONFUSING INFORMATION TO THE FLIGHT CREW, AND

  - TO ENSURE THE SYSTEM AS INSTALLED BE OF A KIND AND DESIGN APPROPRIATE TO ITS INTENDED FUNCTION (REF. FAR § 23.1301, § 25.1301, § 27.1301 and § 29.1301)

- AN ADVISORY CIRCULAR WILL BE DEVELOPED AND PUBLISHED TO SET FORTH ACCEPTABLE INSTALLED PERFORMANCE CRITERIA FOR TOTAL SYSTEM EVALUATION.

*<u>NOTE</u>: TECHNICAL STANDARD ORDERS ARE NON-REGULATORY (i.e. VOLUNTARY) STANDARDS THAT MAY BE USED BY AN EQUIPMENT MANUFACTURER TO GAIN FAA APPROVAL IN THE FORM OF A TSO AUTHORIZTION OF THE EQUIPMENT DESIGN AND PRODUCTION QUALITY CONTROL SYSTEM. TSO AUTHORIZATIONS DO NOT CONSTITUTE AIRPLANE INSTALLATION APPROVAL. THESE MUST BE OBTAINED SEPARATELY WITHIN AS AN AMENDMENT TO THE AIRCRAFT TYPE CERTIFICATE, AS A SUPPLEMENTAL TYPE CERTIFICATE (STC) or by "FIELD APPROVAL" PROCEDURES AS A MAJOR ALTERATION (FAA FORM 337).

U.S. Department
of Transportation
Federal Aviation Administration
Systems Research &
Development Service
Washington, D.C. 20590

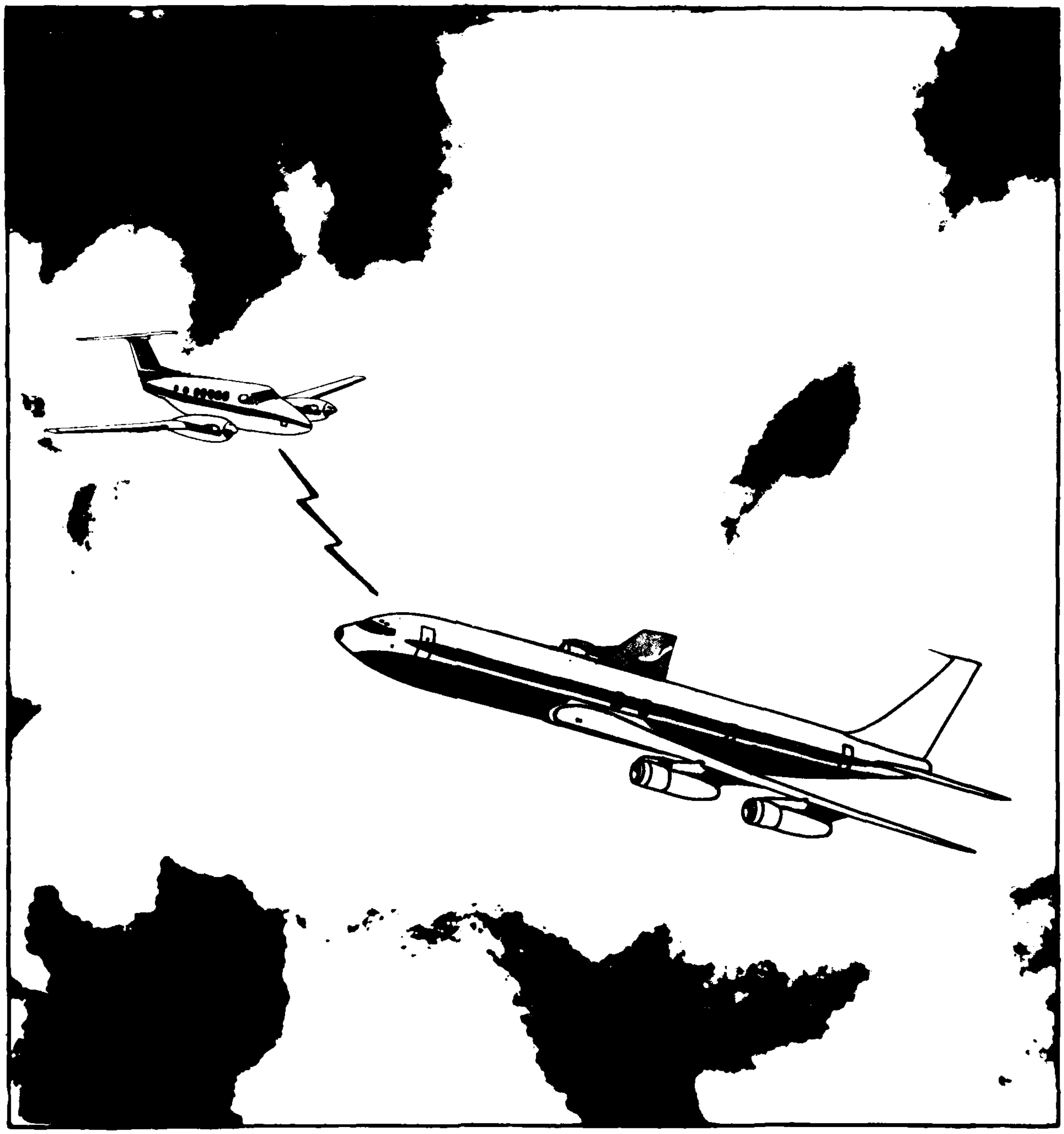
TCAS

Threat Alert and Collision Avoidance System

Symposium

TRANSCRIPT OF PANEL DISCUSSION

July 22, 1981



PROCEEDINGS

MR. ALBRECHT: Well, if you're ready, now the fun part begins. You've met all of our panelists earlier this morning, except perhaps Ray Alvarez, Deputy Director of Air Traffic Service and I have to mention Sieg Poritzky, Director of OSEM. In the second row, in reserve when we need them, there is Walt Luffsey's right arm, Tony Broderick. Neal Blake will be here in a little while and Mr. BCAS himself, Marty Pozesky. We're open for questions. Everybody understood everything perfectly this morning, right?

Yes, sir? Would you identify yourself and your organization?

COL VOLKSTADT: Lieutenant Colonel Volkstadt, United States Air Force. When you were covering the TCAS-1 and the TCAS-2, I found great difficulty in determining what was the highest level TCAS-1 and the lowest level TCAS-2. My interpretation was, from the comments that were said by the members that were giving us the presentation, that a high level TCAS-1 was a Dalmo-Victor unit and a low level TCAS-2 had to have PWI.

The second part of the question is, other than the FAA, who do you know that wishes to have PWI on an aircraft?

MR. ALBRECHT: For the first part of that question I'd like the program manager to answer. Clyde?

DR. MILLER: Bill, if not in the presentation, I think certainly in the handout, the individual handout as opposed to the package, there's really quite a clear description of what a minimum TCAS-2 is. I think we've also been clear on the description of a minimum TCAS-1.

TCAS-1 then, can presumably fill in that whole range from the minimum TCAS-1 up to but not including a minimum TCAS-2. Once you become a minimum TCAS-2, then you're a TCAS-2 and it can be enhanced in the ways we've described. So I think the answer to the first part of the question, really is fairly clear. Although, as the Administrator said and as we've said, one can use quite a lot of imagination in filling in the TCAS-1 options, and that's intended.

MR. ALBRECHT: I suspect before we're through we'll talk about enough options and possibilities so that it might be a little clearer, Colonel.

On the second part of the question, who wants the PWI, let me give that to Mr. Poritzky.

MR. PORITZKY: I think most of the people who flew the Active BCAS identified firily early-on that there would be additional value to having a direction to look. That isn't a universal feeling, but, I think it was the feeling of many.

I think there are other people who feel that and who have felt for many years, that some form of cockpit display of traffic is of great value. There are many potential uses for it and I suspect there are people here in the audience who have talked to that point.

What is made available by TCAS to the small aircraft, the TCAS-1 equipped owner, is some indication of a direction to look. Now, you can call that a PWI or not, as you see fit. In the case of the TCAS-2, again the capability of knowing where the threat is, which is not of interest to everyone but of interest to many, is provided. When you carry TCAS-2 further, again as you'll see in some detail in the Minimum Requirements statement, the possibility is there for further uses of cockpit displays of traffic. A controversial issue but it's been a controversial issue for years. The means is there to provide it, the decision to provide it is up to the user.

MR. ALBRECHT: There was a question next to Colonel Volkstadt.

MR. HERNDON: My name is Bill Herndon, Pan Am, and my question is to Mr. Wedan. As regards your statement regarding the ground portion of MODE-S or DABS and the deferment, as I understand it, of that decision, sir, as to when the agency will install the ground sensors, the communication links, and I guess the computers that are made possible or the capability to be able to use that. When will such a decision be made and will we have assurance that following administrations will stand by this TCAS-2.

MR. ALBRECHT: Well, let me answer that question for Bob. There is basically no change in the program we've described for the past few years as far as DABS is concerned, with this single exception: The new Administrator has made a decision that he will personally review all of the major FAA systems that are coming up for implementation. And that includes DABS. It includes the computer replacement program, it includes ATARS, it includes a number of systems that are going to be subject to his review between now, and and at latest the end of October.

We contemplate no basic change in attitude or in implementation decision but it's subject to the Administrator's review. Now, he expects to have those decisions well-publicized, particularly to the extent they represent any change in what we've indicated in the past, by the end of the year.

MR. NELSON: Lauren Nelson, Eastern Airlines. Wouldn't it seem appropriate that if you expect the airlines to install the DABS transponders in the airplanes, that we would think it appropriate for the FAA to install the DABS interrogator equipment on the ground in order to take advantage of the additional ability or additional utility that the DABS equipment can provide on the ground? Not only for basic ATC, I would think that ATC would want the TCAS information that the TCAS-2 unit is sending out?

MR. ALBRECHT: That's a very reasonable statement and we expect that's what will happen. In terms of reasons for using the DABS format, perhaps I could talk again to Mr. Poritzky.

MR. PORITZKY: Thank you, Al. I think there's sort of a clear message if you look at the Minimum Requirements for TCAS-1 and TCAS-2 as we laid them out this morning. You'll notice in there that the TCAS-1 and TCAS-2, as you correctly indicated, contain a transponder capable of Mode A, C, and S. Also, in both TCAS-1 and TCAS-2, we talk, as a minimum, about the capability for Comm A, B, and C, data link capability.

You also know that in order simply to receive the air to air messages, (in the case of a TCAS-1, to simply receive the air to air messages from a TCAS-2) all it takes is the Comm A receive capability. However, the minimum requirement as we are postulating it is for Comm A, B, and C. the message is pretty obvious. If you remember the Administrator's speech and press release, he said clearly he wants the implementation of TCAS-1 not simply to do the TCAS job, but he wants the capability for the ground to air link as well. That's the reasons the Comm A, B, and C functions are there. Now, the implementation decisions have not been made. But clearly, if there were not a pretty sound indication that the MODE-S data link functions that we've talked about are coming, it would obviously be foolish to require Comm A, B, and C capability in that transponder. You have to read between the lines to that extent because, as Al said, the decisions haven't been made yet.

MR. NELSON: I guess my point is, I just do not see these as separate programs but an overall part of the same program.

MR: PORITZKY: They are.

MR. ALBRECHT: They are. There's no question. The problem is, I think, we have to lay it out and be absolutely honest with you. This Administrator has elected to review parts of the overall system, the overall program. And I don't want to commit him until he's finished that review but we don't expect there to be any major perturbations.

MR. QUINN: Jack Quinn, Naval ____________ Corporation. Yet that implication is that if you install DABS capability in a transponder, you're increasing that cost by something like two or three to one, rather than having a system that could operate with the existing aircraft transponder.

MR. ALBRECHT: Norm, you want to talk to that point?

MR. SOLAT: Our indications are that the cost of the transponders for that kind of capability increases, perhaps, on the order of some 20 to 30 percent and not two or three to one, just for that capability and the interface.

MR. QUINN: Where did that come from?

MR. SOLAT: This comes from some studies which have been done for us by the ARINC Corporation.

MR. QUINN: Could we get those studies?

MR. SOLAT: I think it's part of the public domain. I'll be happy to make those numbers available to you.

(INSERT TO RECORD:

	ATCRBS	DABS(LSI)
TRANSPONDER	850	1239 - 1293
ENCODER	650	650
	1500	1889 - 1943
		(26% - 30%)

The above costs for DABS are derived from a draft report performed for FAA by ARINC Research Corp. The final report is to be published shortly.)

MR. ALBRECHT: If we have them, you can have them. No problem.

MR. QUINN: But your comment is 20 to 30 percent over the existing aircraft transponder? I mean, I think that's important.

MR. SOLAT: Yes, those are - if I recall correctly - I think those are the numbers we come up with.

MR. QUINN: That's for everything? That's for the display?

MR. SOLAT: That's for the transponder.

MR. QUINN: Come on, I mean, we're putting in a system.

MR. ALBRECHT: Norm, I think your numbers are subject to question. But in terms of basic DABS transponder costs, that's right. If you don't have a breakdown, perhaps we can get it before this meeting is over.

MR. SOLAT: Why don't we get those numbers. The numbers that I quoted, I believe are accurate with respect to just the transponder and the interface. I don't believe we talked about the installation costs and the antenna costs as part of that.

(INSERT TO RECORD:

ACQUISITION COST OF TRANSPONDERS
(IN CONSTANT 1980 DOLLARS)

Transponder Configuration	Components	
	Discrete	LSI
Basic Surveillance DABS	1,614	1,239
Basic DABS with Antenna Diversity	2,054	1.679
Basic DABS with 3db Higher Power	1,617	1,242
DABS with Comm A and B	1,663	1,293
DABS with Comm A and B and ATARS	2,093	1,592
DABS with Comm A, B, and C	1,830	1,413
DABS with Comm A, B, and C and ATARS	2,261	1,719
DABS with Comm A, B, C, and D	2,227	1,781)

MR. ALBRECHT: And, you know, if you go back to the DABS, ATCRBS situation and the argument and what should the FAA do in terms of mandating, that issue, of course, has not been settled. It hasn't had to be settled. But we think it's one that's coming up fairly quickly.

MR. WEDAN: Al? Just for clarification, is the question comparing the DABS transponder with an ATCRBS as modified to handle the functions that have been described?

MR. QUINN: Anyway you want to interpret it.

MR. WEDAN: Okay.

MR. ALBRECHT: Well, we'll get you a straight answer.

MR. MCGLOWN: Lance McGlown, Frontier Airlines. A question was left suggesting additional research about sensitivity. Wasn't the intent, one, to require the scanning antenna to help resolve this sensitivity problem, and, does that mean, then, that the RBX is still a possibility or is that out?

MR ALBRECHT: I think the most straightfoward answer is the RBX is not considered a possibility at this time. I think the comment on the desensitization method was intended to say that's kind of left open. There are many people, I think, who recognize that a manual desensitizer isn't the best way to do things in all cases and there are various other options in terms of how one can do that. The Administrator's intent is to maintain airborne systems, TCAS-1, TCAS-2, that are, indeed, independent of ground equipment. That doesn't mean you can't have a desensitizing means that can determine its range, for example, and desensitize itself accordingly. So, the comment was intended to say that's an open item as far as we're concerned, and we really entertain your comments and suggestions.

MR. BULEY: My name is Bob Buley and I'm in Flight Operations at Republic Airlines. As such, of course, we're one of the larger operators of the two-man crew airplane and we're very concerned about this CDTI. And if I can quote from Mr. Helms' press release here, he has said the TCAS-2, "will have an integral scanning directional antenna with direction-finding accuracy capable of supporting a cockpit display of traffic information."

Now, my question is, if we have a TCAS-2 unit not having this cockpit capability, is this unit an acceptable TCAS-2 unit? And if so, would you support a system, airline system, using the modified IVSI indicator such as Dalmo Victor is using on their production model?

MR. ALBRECHT: Sieg, you want to volunteer?

MR. PORITZKY: I'm not sure I quite understood all of the question. What we've said, I believe, is the following. You know you quoted correctly what Mr. Helms said, and in that - within that question is the subquestion, what is the minimum requirement to support a CDTI as we've talked about CDTI.

Clearly, an eight degree antenna, plus or minus eight degree antenna that was talked about this morning, can give you, in your airplane and in the partner TCAS-1, an o'clock position as where to look. That is the minimum requirement.

Now, if you read the handout it also says that we believe that we want to go further. We want to provide an antenna which can provide for the false alarm reduction which is inherent in an antenna on the order of one or two or two and a half, three degrees. From this: distance, filtering for reduction of false alarms and potentially for the horizontal maneuver. That antenna is not yet here. If you heard correctly what Clyde Miller was saying this morning, that is a development item. We're confident it can be built; it is not yet here. There is far less technical risk now for this period in an eight degree antenna. That's number one and that represents the minimum for now.

As we indicated in the minimum requirements statement, we will expect to change the TSO when the better antenna capability and that better resolution capability is demonstrated. Now, the relationship to the CDTI is a different question. There is no spec for what a minimum CDTI is and as several people here have said, it is not a part of TCAS. We, as you know, as someone mentioned this morning, we have a joint program with NASA to explore CDTI, the benefits, the liabilities of CDTI. to the best of our knowledge so far, a CDTI, in order for it to accommodate all functions that have been thought of, monitoring active and passive functions, will require an accuracy on the order of two degrees.

Now, that is when you look at all CDTI functions. There are some CDTI functions, and the research is now going on, which will require much less accuracy than that. And certain functions surely will be usable with an eight degree antenna. But to get all you want out of a CDTI, we think it will take something on the order of two degrees.

MR. ALBRECHT: Now, there was a second part to the question on the Dalmo Victor indicator. Again, this is, perhaps, a regulation problem but I suspect no one will tell you you can't use it. Now, if it doesn't meet the minimum requirements as have been specified this morning, then you would be expected to upgrade the system when those requirements can be met.

MR. BULEY: I want to clarify one thing on that. That is simply that we don't want a CDTI. We don't want it. All we want in the cockpit is the information that requires a collision avoidance maneuver. That's all. I don't like the trend. And Mr. Helms' statement that is leading us in that direction. We're trying to keep our fellows busy outside the cockpit and with important inside cockpit duties. It sounds to me like you're trying to transfer the whole ATC system up into the cockpit. And we don't want it. We want cooperative effort.

MR. ALBRECHT: Well, it's refreshing to be accused of that for a change. I can assure you that's exactly not true. But if you read Mr. Helms' statement carefully, he did say the system should support a CDTI capability and this is based upon other folks who kind of think this would be a good thing to have.

Let me repeat the comment Bob made this morning. If you haven't picked up the document "Minimum Requirements for TCAS-2 and TCAS-1" outside, it will sort of help you tomorrow and the next day when you're trying to think this over and decide what was said. Because it's our best effort to give you a summary of the minimum requirements of both of those systems.

Next question? Yes sir?

MR. VANN: Ernest Vann. Would you mind just delineating the differences between T and B or whatever initials you have, CAS systems? And also indicate if you've upgraded to TCAS, why didn't you think of that at BCAS level? In other words, if you've got antennas in TCAS, what did you have in BCAS? Could you just give a precise difference between BCAS and TCAS?

MR. ALBRECHT: Well, I'm going to ask Clyde Miller to give you the differences between the T and the B. A major event took place since we talked solely about BCAS - that was the advent of a new Administrator. And, you know, this is a very talented man and he took a lot of time, to go into, in depth, our whole separation assurance program. So I will, in a positive sense, give him credit for that change. Clyde.

DR. MILLER: The principal differences between an Active BCAS and a minimum TCAS-2, I think is easy to state. It's the high density capability in the minimum TCAS-2 which the Active BCAS did not have. And with the capability, cross-link maneuver intent information from the TCAS-2 to a TCAS-1.

Now, not to detract from Al's comment about the initiative of our Administrator, I'm pleased to say both of those ideas, in one form or another, were in fact in the active BCAS development program. Not in the national standard, but they were part of people's thinking. there was a thought that, gee, if you're in conflict with a fellow that has a DABS transponder, even though he doesn't have a BCAS, you should let him know that. You shouldn't let the poor fellow go on thinking everything is fine when you know full well you're about to have a collision if you don't move out of the way. And that, in the active BCAS program, was sort of called the cooperative intruder feature. In fact, we at various times thought that we should have a cooperative intruder feature and not have a cooperative intruder feature and at the moment, it was out.

The idea of using sectorized interrogations as an opportunity to work in higher density areas has occurred to people. And there were, in fact, some thoughts I don't want to tell you too much about because we're not in the position, from the traffic point of view, to do that. There were some thoughts that had come to us to pursue that approach.

So the TCAS-2 is really a very natural extension of things that were going on in the Active BCAS program at the time the Administrator came on board.

MR. GRAHAM: Thank you. I'm Jack Graham, McDonnell Douglas. I'd like to ask Dr. Miller, if the Federal Requirements were for an operation in high traffic density areas that did not include CDTI or PWI functions, would it be possible that the system would have a similar antenna system.?

DR. MILLER: The answer to that question, I'm sure is yes. The high density opertion requires the directional interrogation or the sectorized interrogation, if you like. The PWI function, even at a 8 degree bearing accuracy level, requires direction finding on receive. I'm sure you may be aware - as you saw in my talk, they were described really as sort of two different functions. Here's how we do the sectorized interrogation. Now here's how we do the direction finding on receive. So direction finding on receive is an additional function, an additional feature. It does, in fact, require additional equipment in the aircraft.

I can't give you an accurate idea of how much additional equipment or percentage-wise how much additional. In the early active BCAS stage, when we interrogated omni-directionally, we thought that the provision of an 8 degree RMS PWI bearing capability would add, perhaps, 30 percent to the cost of an active BCAS unit. I couldn't give you a percentage in terms of the TCAS-2 because it is a somewhat more complicated piece of equipment but that 30 percent number might give you equipment costs on the order of $5,000.00 perhaps. And if someone wants to use that number seriously, I would like the opportunity to refine it. But, you know, in an air carrier quality unit, that may be about what you're paying for the 8 degree RMS PWI to the clock position, kind of a fairly simple display board.

MR. ALBRECHT: Next question.

MR. PORITZKY: Let me add one point. I think Clyde missed one point in your question.

The other point is whether or not you like bearing information displayed in your own aircraft, in order to transmit to the TCAS-1, information on bearing, bearing range, altitude differential and intent, you need to have bearing in the TCAS-2 airplane. And certainly Mr. Helms felt very strongly about the importance of providing that new service to the TCAS-I. His part of the requirement for the detection of bearing information is the TCAS-2.

MR. ALBRECHT: All right. Next question?

MR. FINK: My name is Harold Fink. I'm with the Airline Electronic Engineering Committee and I'm chairman of SC-147, the RTCA committee charged with writing the new TCAS MOPS. The first question is to Mr. Alvarez. In Active BCAS there was a requirement to coordinate maneuvers with ATC. That requirement has now been deleted. How do you feel about that?

MR. ALVAREZ: To be honest with you, the Air Traffic Service never really had a firm requirement. We wanted to evaluate the capability and see if, in fact, it could be integrated into the system and give us something that we could operationally use to figure out, after the maneuver took place, how to flow the aircraft back into the system and how to flow the system. You get into timing problems, air traffic control problems, relationship between the pilot and the controller in that instance.

Personally, it doesn't bother me at all that the RBX system is gone. As Mr. Hunt mentioned before his talk, we'll be doing a lot of analysis on the operational impacts and as soon as we know what the magnitude of maneuvers will be, we'll do some simulations to see what the potential impacts on the system will be and we'll develop procedures to handle those impacts.

So at the present time, until we do more analysis and see what some of those impacts are going to be, we really don't know what the impact on the system is.

MR. FINK: Okay, the second question is a little bit more technical and addressed to Dr. Miller. When do you expect the surveillance logic to be published for TCAS? That is that portion - not the CAS logic - but the surveillance logic that looks at the multiple segments?

DR. MILLER: Harold, we anticipate that we will have our associates at Lincoln Laboratory working hard on that. I don't want to understate it. There's been some thought about that already. You'll recognize that we already interrogate one aircraft more than once because we have this whisper-shout sequence we go through. That gives you a problem to sort out. You say, I've got more than one reply from the same fellow. How do I get these duplicate replys and make them one so that when I'm going to do my tracking, I don't generate a lot of additional targets from the same set of targets.

And it turns out that this beam interlacing or this beam scanning, even with interlacing, is really the same problem with, perhaps, one more dimension. We'll whisper-shout and we'll scan, both. But it's very much the same processing problem and we think - let me change that. I think it has very much the same solution, so there's not a lot of concern that that's a new technical hurdle for us.

MR. FINK: Only in time. It's going to take, you know, some period of time. I'm concerned personally because I saw some figures on your slide that disturbed me very much. You probably know they disturbed me.

DR. MILLER: I understand that.

MR. FINK: Somebody said, "which figures?" That's the figure - June 1982 for a MOPS.

DR. MILLER: Harold, I want you to know that I've said to others today, before now, I'm sorry I didn't call you about that.

MR. ALBRECHT: Harold, again, as I think we'll say a little later, we're trying to encourage as much participation from the community as possible. Also, on top of that, there's a real desire to get on with the job so if we can find ways, you know, we'll do our part but if we can find ways of going through the bureaucratic procedural business a little faster, we sure need to look for them.

Next question? Yes?

MR. CHAPMAN: Hello, I'm Alan Chapman from Transport Canada. If I read Mr. Hunt correctly in his presentation, he said there's presently no legislation in the mill to make the installation compulsory. In view of the Administrator's speech the other day, I imagine that in due time it will be compulsory and I wonder if you could tell me to which class of aircraft you would expect the TCAS-2 to apply and whether the requirement would also apply to foreign carriers operating in the United States?

MR. ALBRECHT: Well, I'll give my friends here time to think about the foreign carrier question but in terms of will TCAS-1 or TCAS-2 be mandatory, Mr. Helms is very sincere in saying he does not want a mandate. He would like very much not to mandate. He's going to, of course, watch what goes on and if, in his view, if mandating becomes necessary in terms of providing the desired levels of safety, then that would be a serious consideration. But there has been no decision to mandate either of those systems.

Now, in terms of the applicability of the mandate, in case it should happen, what's the answer?

MR. HUNT: We really haven't put much thought into that, yet. We haven't discussed that at all, so far. At the present time our understanding is what everybody else's is, it's not a mandatory program at this time. We'll have to look at it. I can't answer you right now.

MR. ALBRECHT: Well, that being the answer, that certainly, then, would become a serious consideration to look at.

MR. HANNA: Ron Hanna, American Airlines. The first comment goes to Mr. Wedan in his opening remarks. He mentioned such a great turnout was encouraging for support for TCAS. Representing the airlines, I'd have to say that's not necessarily so. And it goes back to an unfortunate accident that occurred back in the mid 70's at Round Hill when the airlines were invited to Washington to take part in a gigantic ballgame and we found that in the infield and the outfield it was Congress, on the pitcher's mound was the FAA, at bat was the ground or training, and catching was the airlines and all appropriate users.

After the excitement died down, why, a slider was thrown and it was called GCAS, Ground Collision Avoidance, otherwise known as GPWS. The airlines caught the ball but it was very expensive for us. But when we found the ball had arrived, the cover was not in very good shape. In other words, it was technically deficient and as a result we suffered many operational penalities because of it. The crews lost confidence in it. We managed to get it sorted out after a year or so but it was a great struggle.

Now we're faced with another ballgame also collision avoidance. The same infield and outfield and pitcher's mound is FAA once again. At bat this time is another aircraft and catching, once again, is the airlines and appropriate users.

We thought we had the signals all figured out, where the FAA was going to throw us a high, fastball as the best way to strike the batter out, hopefully. We were prepared to receive it but unfortunately the pitcher went to the showers, to the relief of many, a new pitcher was put in and the very first thing he does without consulting the teams is throw us a slider which has a curve on the end of it.

From our standpoint, we're not necessarily here as supporters, necessarily. But we are here trying to figure out which way the ball is going to break, left or to the right. We're trying to figure out how much this is going to cost us, usually double and triple, the closest we can tell with American Airlines is it's in the area of 30 to 36 million. we won't talk about where the funds are going to come from before we approach them about ADAP. But last of all, we hope that the cover is going to be sewn on the ball properly next time so we won't go through the same struggles that we had last time. A very, very important consideration in the operation of the airlines.

That's all leading to my question here. I may have missed this in the presentation, but is the ploy an enhancement of the ATC surveillance system capable of handling .3 aircraft per square nautical mile in 1990? And .4 aircraft per square nautical mile in the year 2000? If not, won't there be a temptation to use TCAS as a crutch to hold up the weak links in the ATC system? We'd rather see the ground system developed and we're going to see what we can do about that. I don't think there is a great deal but we want to live within the environment. We want to make sure that it's not going to be a safety problem. That's our big concern.

MR. ALBRECHT: Ed?

DR. KOENKE: With regard to the ability of the ground system to operate in .3 or .4 air space, there is some informatin that is available. ECAS has done a simulation and they have basically come up with some results which indicate that the ATCRBS system as it exists today can operate acceptably in those environments. there is some concern in the community as to whether or not that is absolutely true or not. The result is based on simulation.

Certainly, with an upgrade to MODE S, there would not be a problem operating those environments. Does that answer your question?

MR. HANNA: What is planned in the ATC to handle this number of aircraft? I would like to know how it's done. Is there enough capability going to be built into the system to handle it.

DR. KOENKE: Oh, in terms of the controllers being able to handle - yes. There are a series of improvement to the Air Traffic Control system that we're looking at in terms of automation, for example, Automated en-route air traffic control system, metering and spacing, and that kind of thing. We're also looking at separation concepts. In fact, we had a meeting not too long ago to discuss that issue in Atlantic City, with the User Committee.

MR. ALBRECHT: Ray, from an operational point of view, why don't you answer the question.

MR. ALVAREZ: The numbers that are mentioned by Ed and also by the Administrator are kind of scary to us in the Air Traffic Control System, also. For those of you who were here about a month ago or so, we kicked off the National Air Space Review, which is intended to fine-tune our present system, find out those places where we have bottlenecks and problems in our air spacing procedures and fix those.

Ed mentioned the en-route metering program. We have two or three versions of enhancements to the metering program and flow control programs to help us. We've also got the replacement of the computer system, we have some automation enhancements coming down the line.

The bottom line, however, is that there's only a finite capacity at certain airports. We have a lot of capacity in the en-route system and a lot of the satellite airports, depending on where this volume goes, it may or may not give us a problem.

But to ask if TCAS is being developed to supplement the system? Yes. Is it being developed as a crutch to handle our inefficiencies? I don't believe so. I think that our system will evolve and our air traffic control system will handle the demand on the system, it will be spread over more hours of the day than it is today but we have a lot of capacity left in the system and we are doing those kinds of things in air traffic to handle what we think is going to be the increased demand on the system of the future.

MR. ALBRECHT: And from an R&D sense, we certainly are concerned with system capacity, with meeting the growth. It's a major driver in terms of our programs. We expect for the foreseeable future we'll be able to handle problems but we're working pretty hard to do it. Next question?

MR. CLARK: Weldon Clark with TWA. Unless the TCAS-2 can include a version essentially identical to the previous Active BCAS, there will be no collision avoidance in the new Boeing 757, 767, since the installation ordered by a number of airlines is the ARINC 730 system.

My first question is, would the ARINC 730 be an acceptable minimum TCAS-2 system? If the answer is yes and the airlines install them, will they be assured of a reasonable return on their investment, such that it could be used over a period of time before they would have to put in the additional capacity that you talked about as the enhancement of the TCAS-2?

MR. ALBRECHT: For some reason, we thought this might be a question. Sieg. We have a fairly carefully prepared answer that will go in the record, we'd like to read to you.

MR. PORITZKY: Obviously, as Al says, that's a question we thought mmight conceivably arise.

I think it's very clear that the Administrator does not want to do anything that prevents a carrier or anyone else from achieving collision protection at the earliest possible date. At the same time, he said that he believes, many of us believe, that TCAS-2 represents the right direction to go. So let me read you the way I think we feel now. Solely in order to provide earliest possible collision protection, FAA will consider approving collision avoidance system, as TCAS-2, without directional interrogation or receive capability during an interm period if adequate performance and interference protection can be demonstated. We would hope that the applicant would also demonstrate provisions for upgrading system performance to the capabilities of the minimum TCAS-2. Obviously, for such systems the cross-link capability need not include - cannot include, of course, transmission of relative azimuth.

The question of density also rises as to the capability of these systems which on an interm basis, are provided by users, by applicants, without directional capability sufficient to meet the densities we've talked about: .3 by 1990; and .4 by 2000. FAA again only in the interest of achieving increased safety at the earliest possible date will consider approving, on an interm basis, lesser density capability if the applicant demonstrates adequate performance and interference protection in the applicable density environment, and appropriately compensates for any inherent limitations of the device. Those are the crucial elements, I think that is the answer to the question.

MR. ALBRECHT: Let me ask a similar but little different question that has to come up sooner or later. A little different question might be, if someone wants to install an Active BCAS with an omni antenna in a carrier airplane, what will our attitude be in this case? And I think the answer comes back that none of these two gentlemen to my right would prevent you from doing that, subject to the no hazard condition and upgrade potential.

However, if in the future, the Administrator decides that the TCAS-2 needs to be mandated, then that system would have to be upgraded to the minimum requirements for the mandated system.

COL. VOLKSTADT: I hate to take up your time like this and be the only one that is out here to snipe at the FAA, but you give me many opportunities to do so. You say, in your answer when you're talking about interference, using the same equation for both the Active BCAS and for the TCAS, they both come out of the national standards, so the interference is not an issue as far as this is concerned.

I question some of the density figures that you're using and the fact that it appears that a lot of the density figures are based upon the fact that there will be no change in the increase of numbers of aircraft; the increase as it has been going in the past, which has been based on years before. There seems to be an indication that you have taken into consideration that when we talked about DABS, we talked about cutting down the fruit levels to about a quarter of the present as far as the aircraft is concerned. So we talk about high densities in terms of aircraft rather than the changeover into the DABS system.

If it is, indeed, going to be a TCAS-2 and a TCAS-1 system, then we're going to have several aircraft up there with the DABS transponder on board.

The changeover to the directional antenna, I think you will find that the constituency of users that I represent here have an awful lot of aircraft that are not going to be able to put your large antennas on board. There is no way that we'll be able to participate in that system because there's no room on those aircraft.

I think that there are some of those aircraft that happen to fly in your natioal airspace system, there are times that you'd like to have that capability to determine where the airlines are. You're going in a direction that I wonder whether or not this is a public forum now where you're looking for comment or you're telling us what you're going to do? And the fact that your Administrator has come out with his pronouncement by himself, without public comment to determine whether or not anybody wants this pronouncement. So I'd like to find out if this is an open forum in which you're looking for public comment to be used to adjust the FAA's position as far as how you're going to handle the national airspace system?

MR. ALBRECHT: It's a little of both, Colonel.

In terms of the minimum TCAS requirements, those are essentially not negotiable at this time. The Administrator did decide that he wanted to make a decision, he published that decision. But if you notice, some of the requirements in there, particularly the one for the narrow beamwidth - narrow beam antenna, was indicated for TCAS-2 as a future potential. And it was indicated there were some technical risks involved in that antenna.

Your implication that it must necessarily be large isn't shared by everyone in the world and we have a technical difference, which we expect to thoroughly and openly explore with the community in these meeting we've talked about.

But in terms of the basic TCAS-1 and TCAS-2 minimum requirements, we aren't here to negotiate those at this time. I think to the extent we can provide a technical dialogue, we're certainly willing to do so. And we're not going to have all the answers yet. But this is not a policy making meeting.

Next question.

MR. NELSON: Lauren Nelson from Eastern, again. The advisory circular which will provide the acceptable installed performance criteria, do you have a target date for this?

MR. BEARD: No. We certainly don't. It's a matter of laying down the way we see working toward the air worthiness certification issues. Obviously, it depends on when we can get the TSO out and when we can understand the systems a little bit better to put this policy information out.

Our normal procedure for advisory circulars is to publish it publicly in a draft form and receive your comments so there will be an opportunity to participate in the development of that advisory circular.

MR. NELSON: Does that mean before anyone wants to install one?

MR. BEARD: I don't know how to answer that question. I would imagine so.

MR. ALBRECHT: In case we run out of questions, we have an IOU, which is a breakdown of DABS transponders and ATARS transponders costs with and without equipment. We'll publish that completely in the record and we'll give you the references for it so you can tell where that came from.

(NOTE TO THE RECORD: Previously inserted)

MR. NELSON: Could you include the antenna and the display data as well?

MR. ALBRECHT: We'll give you what we understand about the system. We'll give you what we've got.

MR. HERNDON: Bill Herndon, Pan Am, again. A question for Dr. Miller. You mentioned rates of unwanted and false and missed alarms. Where is that per 100 hours? What rates for missed, falsed and unwanted do you expect from the TCAS Model A and Model B if they are available?

DR. MILLER: Well, the kind of data we have now we haven't seen any false alarms and Lincoln Laboratory and Mitre Corporation, correct me if I'm incorrect - we have not seen any false alarms in the Active BCAS. We have seen some squibs of false tracks sit in the computer, but they don't generate alarms and there are technical reasons for that, actually.

I forget, frankly, what spec we have been using in the Active BCAS program. I think we said that in the ATCRBS Mode we would have no more than one false alarm - was it 200 hours? That was the DABS Mode. It's really kind of a moot point, you know. The surveillance work that has been done in that area seems - in our 250 hours and now more than that of flying, we haven't seen a false alarm. The unwanted alarms, by which I mean an alarm on traffic that is there but not an imminent collision risk - the false alarm - I'm not trying to split hairs but those of you who have done this with us previously, a false alarm is an alarm on a ghost. There's no airplane there but the computer or the surveillance system thinks that there is an airplane there. And that occurs for a certain set of technical reasons which, by and large, have been cleaned up.

The unwanted alarm is the situation in which there is really an aircraft there, you get an alarm on the aircraft but it's no collision threat. That aircraft's doing the right thing and you're doing the right thing. And the collision avoidance systems sometimes have a tendency to do that because they don't have knowledge of intent.

The number that we used in the January BCAS program was germane to the relatively low density like .02, .03, .04. Active BCAS experience was that we'd expect to see one unwanted alert in about every 50 arrivals for an air carrier aircraft into that kind of airspace - Houston today, Washington, D.C., today. So that was really the best number that we have.

If you say extrapolate that information to .3 or .4 airspace, I can't do it. I frankly don't know what the number is.

MR. HERNDON: And you don't know what effect TCAS, of its two flavors, what have you, on that rate?

DR. MILLER: On what?

MR. HERNDON: On that unwanted alarm rate. And forgive me for doing this but we are very disturbed by that number. We would expect an unwanted alarm rate very, very low, many orders less than that. Do you expect the TCAS number, as you call it, Model A or Model B, would be better?

DR. MILLER: Much of the reason for what we're doing in the Piedmont evaluation is to look at these so called unwanted alarms. For example, we have said any alarm that occurs in our flight testing of the active BCAS, when we were not flying intentional close encounters, when we're operating the normal traffic operation, that those alarms were unwanted alarms. That's what they were. And we said one in 50.

In fact, we find that in Denver, as an example, I'm not sure I should tell stories like this, we almost had a first fight between the air traffic controller and our pilot. They were arguing about whether or not the alarm was unwanted because there was some close proximity. The pilot liked a great deal less than the controller.

In fact, some of these unwanted alarms are not unwanted to some pilots, in any case. So really, we're looking to the Piedmont evaluation, where we're going to operate the equipment for 900 hours or so on the in-service air carrier which will operate as it normally would, no special provision in the way those aircraft operate, so we better understand when do they occur and what would be the circumstanes of following them, et cetera. And I think we'll know a whole lot more about that in spring of next year.

And it is always true and it's true of all the collision avoidance systems, conflict alert, ATARS and BCAS and TCAS, that if you don't like your unanted alrert while you're in normal traffic operations, you turn it down. And when you do that, you have less protection.

MR. ALBRECHT: Let me repeat again. We will have another session as soon as we have enough information to make it worth your while. But in the meantime, please don't hesitate to come and see us, talk to us, or whatever. We've really got an open door in this whole area and would really like to hear from you. Now, today in this period, most of the question have been from either airlines or DOD and the Air Force. Are there any GA folks who'd like to poke at us?

_______: I'd like to ask who's going to be responsible for the location of this direction antenna? That's what I'm concerned about. In other words, you've got a 747, a 727, a 737. And we all know how antenna patterns vary depending on the direction that you're looking at. When you're talking about angles of getting down to 8 degrees, who's going to be responsible for seeing to it that that antenna is placed in the right places in that aircraft?

MR. ALBRECHT: Well, in a sense - I'm speaking out of turn because it's really these gentlemen to answer, that antenna placement is a design problem like other antennas, the calibration required here perhaps is a lot finer. But normally, what's the responsibility?

MR. BEARD: I think you've really answered it. The installer that seeks system approval brings his proposal to us and we evaluate it and give consideration to the factors that you mentined. Now, most likely it will mean that for a given type of aircraft, it will be in the same location, because one somebody learns something, why relearn it over and over again. But there won't be a constraint that says you can only put it one place on the aircraft. It will be up to the installer to select the placement and to show its effectiveness.

MR. ALBRECHT: I think it's virtually impossible for the FAA to make a systems decision without having a few people feel it should be a little different. But we're off on this one and we're going to work with it and we certainly want your help and support. And your complaints or your problems. We're not trying to, in anyway, inhibit your ability to come talk to us.

Way in the back row?

MR. _____________: I'd like to ask Ray - is it fair to asume that this system and the accommodations you're going to have to make when maneuvers result in escape maneuvers, it's fair to assume that we can expect ATC to handle less arrivals and departures in terminal areas?

MR. ALVAREZ: I don't think you can make that assumption because I don't see this as a problem in those areas where we have a high density airport. I don't see the escape maneuvers being issued in a place like JFK, Chicago, et cetera. Because most of the traffic or all of the traffic in that kind of airspace is controlled now.

I see this system being more applicable to a VFR tower or non-radar facility where you have traffic flying through the patterns and those escape maneuvers will, in fact, impact specific aircraft. But I don't see it impacting the capacity of a large airport.

MR. ____________: Can we assume then, that (inaudible) all positions?

MR. ALVAREZ: I'm not sure of the rationale of your question. You're talking about, you know, a system that's going to give you a maneuver to avoid aircraft. And we don't run traffic as close as that. You're going to get alarms, you're going to get information on traffic, but as far as an escape maneuver in a high density airport, I don't visualize that happening.

MR. ALBRECHT: I think Sieg wants to volunteer again.

MR. PORITZKY: Yes. I think a couple of things. Obviously, FAA does not want to recommend, propose, or push a system that makes things worse. And that should be pretty evident.

There was a discussion, that Monsieur Pontant, from France, will remember, at the Communications Divisional Meeting in Montreal, which is pertinent to this. There was a great deal of worry about aircraft maneuvers, the what if's, doesn't air traffic control get all screwed up when there is a maneuver as a result of a close encounter? And the answer that we gave, that the U. S. gave at that meeting was relatively simple. It said, several things are obvious. You don't want to make things worse, in the first instance. In the second instance, if a collision avoidance system is offered which continually or too often provides for unwanted maneuvers or unneeded maneuvers, it's a bad system and shouldn't be in the airplane, period. If the system is proven to be sound, and I can assure you we will do and obviously the installer will do what he can to make that system a good system that doesn't false alarm very often, that very rarely gives a false maneuver. When that maneuver is recommended, the right answer is that the pilot will damm well make the maneuver and then talk to air traffic control.

The maneuvers are not very wild, to begin with. They should not happen very often. When they happen, the collision should obviously be avoided. Air traffic control is the guy you talk to next. And I think that's really the simple answer to the question.

MR. ALBRECHT: Like an emergency?

MR. PORITZKY: Yes, sir

MR. ALBRECHT: Way back.

MR. HERMANN: My name is Joe Hermann. Until a few years ago I worked for the FAA and spent quite a number of years on the Air Traffic Control Radar Beacon System, ATCRBS. One thing which was quite obvious, that the ATCRBS would never go without the full cooperation, participation, and the support of the Department of Defense. That's the reason we have a good airspace system today, because DOD has cooperated with the FAA.

I don't see that support today and it disturbs me greatly. Would you like to comment?

MR. ALBRECHT: Our cooperation, across the board, on FAA programs with DOD I think is pretty good. We have formal and informal routes and I think they work very well.

We've certainly, I think, had a fairly tight coordination loop on DABS, on BCAS and on air traffic control related things.

The Colonel's comment that everyone wasn't consulted before Mr. Helms made his decisions on TCAS-1 and TCAS-2 is very valid. It's true. And Mr. Helms has his reasons, which we've tried to express to you.

Now, in the minimum requirements for TCAS-2, those were modified to the point where it was felt, sincerely, that they could be met very soon by all operational users. I think we have an obligation to get together with DOD and work out those problems and we certainly will.

To the extent the lack of appreciation of what we've done by the Air Force in this meeting indicates a lack of cooperation and coordination, I think that's misleading. To the extent we need to do more homework with DOD, we certainly will. And whatever we come up with will recognize their problems as well as civil aviation.

Yes, Frank?

MR. WHITE: Frank White, ATA. I would like to ask Dr. Miller a question. In Mr. Helms' press release he states that the users will voluntarily equip the TCAS-1. And by your own definition, that is a DABS transponder. Now, if we're going to have any significant implementation of TCAS-1, obviously those will be DABS transponders.

Also, in your model you showed us, you talked about everybody being TCAS-2 and then talked about a density problem which obviously is invalid because if they were all TCAS-2, they would all be that transponder. So my question to you is, when are you going to look at the question realistically and recognize what percentage are going to be DABS transponders and not assume they're all going to be ATCRBS?

And how about DABS on the ground? How are you going to handle the density of .3 or .4 without DABS on the ground? It doesn't fit.

DR. MILLER: There are a couple of parts to what you say Frank. There's the question of .3 airspace. Ed pointed out, and I know very few people who feel that it's otherwise, that if you look at transponder equipage in L. A. Basin today, that you can find .1 airspace. If you look at national transponder equipage, you say, gee, there are a lot more aircraft out there than that. There may be twice as many aircraft as that. There may be .2 airspace in L. A. today, which would imply something like 60 aircraft with 10 nautical miles.

Now, there's some difficulty with that and some people find that difficult to believe. For myself, I called up a good friend of mine who works in the sector field office at Long Beach, which is supposed to be the hot spot, and I said, do you believe in .3 airspace? and I told him what that meant and he said he thought that up over Disneyland it was more than that. He said you could find more than 90 aircraft within 10 nautical miles on a busy Sunday afternoon. Clearly, not all those people have transponders on them.

So there is a dilemma and the ground system aside now, there is a dilemma for TCAS-2. And the TCAS-2 dilemma would be this - well, let me say for Active BCAS. And TCAS-2 is, perhaps intended to solve this dilemma. The dilemma is this. Your Active BCAS would work well in much of the national air space unless people went out and bought transponders and put them on their aircraft so the BCAS could see them. Then the BCAS wouldn't function anymore because there would be too many transponders.

Now, I don't say that facetiously and that's certainly not true of the whole airspace. But there are significant regions of airspace, and the L.A. Basin is one of the best examples, there's some more of that on the East Coast, which is perhaps half of the L.A. Basin problem, where you can foresee .1, .2, I don't know how far that does, densities. And so the TCAS-2, approach, if you like, is a recognition that if it's as easy as it may be - and I'll be sorry I said it that way, to get from a .04 Active BCAS to a .2 or .3 or .25 something that makes sense in terms of the immediate future, then perhaps that something that's worth doing in the near term.

Now, you say, well, it would be an easier problem to solve if many of those had DABS transponders. And I suppose that's true. And I just frankly don't know, Frank, where one would propose to draw that line. And I guess the current positon - I'm a little out of my water now - is why don't you guys draw the line and let us comment on that.

MR. ALBRECHT: Well, before we do that, Frank, the implication that there will not be DABS equipment on the ground is not correct. What I think I said is that this Administrator, as all administrators, is in series with an implementation decision. That's true on MLS, that's true on some other programs that are basically through the R&D cycle and are ready to spend F&E money to get in the field.

The comment is, he has not decided how to implement. If you want a personal opinion, I don't think there's any change in what we've told you before that we're going to do.

Once more?

MR. WHITE: But obviously, if you look at cost/benefit, Al, and you make two or three DABS installations, it's a heck of a lot better spending of money than making 4,000 TCAS-2 installations. If you want to solve the high density problem. Now, that's just plain dollars and cents.

MR. ALBRECHT: Well, as you know, it costs.

MR. WHITE: If we spend our money on TCAS-2, you know, and then you decide to put in DABS, you might as well throw the money down the drain.

MR. ALBRECHT: No, that's not true. Sieg, you want to try once more?

MR. PORITZKY: I think we keep saying it. TCAS-2 is nothing more than an Active BCAS which is improved. It's improved in two ways. It's improved for high density operation with the sector interrogation, adaptive interrogation around the airplane, and directional receive capabilities. It provides information to the unequipped aircraft about the TCAS-2 location at a very low cost.

Now, in Mr. Helms' view (and mine for that matter - I don't matter a hell of a lot, but he does). The information exchange between TCAS-2 to TCAS-1 should be of very high value to GA. And, therefore, implicitly to the carriers. So even if you retreat on the density question, which I don't think anybody's going to do sitting at this table it does not mean one should go ahead and use the Active BCAS omni, because it doesn't meet the two basic new requirements.

Al has said that he believes that there will be ground implementation of MODE S data-link functions. We're not prepared to commit to that, but even if we were to commit to that tomorrow, I don't believe it would change the TCAS-2 characteristics, the minimum characteristics that we've talked about.

MR. ALBRECHT: Craig and Ken will have to leave in about 15 to 20 minutes. Are there any regulatory or flight opertins kinds of questions you could address to them?

MR. CLARK: The name is Jim Clark from British Airways. You said you're very conscious of the international scene. Your tort laws are completely different. How do you see your way through the morass of the consequences of aviation airline equipment inducing a collision because it's not followed correctly or the directions it gives are not followed correctly by a TCAS operator?

MR. ALBRECHT: Which one of you good men would like to address that question? I'm sure we can give you the kind of answer you want right now.

MR. PORITZKY: There is one point that is fundamental and I think it's an error in what you said. When a TCAS-2 sends information to a TCAS-1, it does not send instruction. It says, "I am here with respect to you," and perhaps it goes further and says, "and I'm going to climb." That is informational in character and is not an instruction or a command.

MR. ALBRECHT: When we talked about international cooperation, I'm afraid I was talking as an R&D man. There are a whole gaggle of legal problems I wouldn't touch. In terms of system coordination, I think we've done a pretty adequate job.

MR. CLARK: I accept Sieg's criticism of my comment about the instruction. But advisories have different ways of being followed occasionally. And if this induces a situation, who takes the responsibility? You, or the airline, or the TCAS-1 equipped airplane, in the courts following?

MR. ALBRECHT: Well, I guess part of the answer, which I can't give you, is, what does the precedent say in situations like this? I hate to miss one but we'll have to write you.

MR. PORITZKY: That's going to be a long letter.

MR. GIPSON: My name is Paul Gipson from Republic Airlines. And I've got a couple of questions for Dr. Miller. The first one has to do with the sector size for directional interrogation. you stated in your briefing this morning that you were going to use 22 1/2 degrees with four overlaps for every section. Is that firm? I mean, is there any other option? Have you determined that's the best way to do it? If somebody came up with a better way to do it, would that be acceptable? Or are we locked into that?

DR. MILLER: Paul, you're absolutely not locked into that. What I was trying to do in that talk was describe what is really the current Bendix design approach. I'm not even sure, at all, that their design approach will stay there. There are any number of variations in signal processing techniques, sectorization and overlapping that one might undertake or propose to meet a density requirement of .3 or .4. And it is not proposed that we would restrict the options for achieving the density requirement by some combinations of those techniques.

What I was representing was simply that is the current Bendix design approach.

MR. GIPSON: Have there been any studies undertaken to prove or disprove any other theories on this?

DR. MILLER: There was the one slide that I showed that said we'd asked Lincoln to review, or Lincoln had taken it upon themselves to review the Active BCAS data and to extrapolate the BCAS performance as a function of airspace density. And I think there was one column on that slide that said that you could achieve, we thought, a .32 airspace capability with, I think, 45 degree sectors and some other whisper-shout and other signal processing enhancements. So there, if you like, is sort of an alternative that suggests itself, at least at the .3 airspace level.

DR. KOENKE: There was another slide that I showed with regard to the antenna performance as a function of density and when Clyde showed his slide, I was remarkably encouraged because those are the results of two independent analyses. I hadn't seen Clyde's slide before and the numbers are fairly right on.

Now, either they use the same analysis techniques as I did, which I doubt, or maybe they made the same mistakes I did. But is encouraging.

MR. GIPSON: I've got one more question. As regards the DABS national standard, if I remember correctly, the DABS national standard as published included certain protocols for the RBX and a few other things. Are there going to be revisions to the DABS standard for these things, to take them out or are they going to be left in or what can we expect in the way of national standards now?

DR. MILLER: The RBX message formats are described in the Active BCAS national standards and do not impact the DABS national standards. We envision no impact on the DABS national standard. In fact, I think I said that in my TCAS-1 talk. We think that's perfectly adequate.

You know, the DABS national standard says, this is how messages are structured but it doesn't describe the whole universe of possible messages. And the active BCAS national standard then says, now here are some new messages, at least in terms of the DABS national standard, same structure but new messages which are used for RBX coordination, et cetera, and other national standards will continue to do that. Data-link service will continue to do that.

So we won't change the DABS national standard but we will, when we update the Active BCAS national standard and make it the minimumm TCAS-2 national standard, make revisions there to reflect the cross link and other features.

MR. ALBRECHT: Colonel?

COL. VOLKSTADT: I have a question for Mr. Beard and one for Mr. Poritzky. The one for Mr Beard has to do with the innovations you talked about as far as the TCAS is concerned. In SC-147, when we're looking at the BCAS, indications were there that we would have to take what the FAA has already tested as far as the software is concerned and use that as the verification validation for the CAS in order to have an installation certified.

If we're going to have innovations as far as a TCAS is concerned, how would we go about obtaining certification for its use and assure ourselves that we're safely within the system?

MR. ALBRECHT: While he's thinking about that, there are some enhancements where we would, indeed, want to do as we did in the BCAS case, to make sure that software algorithms were ones that have been tested and proven. There are others, perhaps in terms of antenna design, where we wouldn't in anyway want to put on that restriction.

For example, if someone can provide received or activity with an onmi directional antenna, that's fine. We don't really intend to propose restrictions that don't need to be imposed.

Would you like to add to that?

MR. BEARD: I don't know that there is a lot to add to that, Al. Except to say, I think our TSO's would probably address the minimum definition of TCAS-1, the minimum definition of TCAS-2. It would not preclude enhancements. We have many TSO's that exist where the equipment manufacturer can add bells and whistles to it, and as long as he doesn't take away from the basic objective of the standard, that's perfectly acceptable. He can still get a TSO authorization.

I believe on this we might put some limits on how far you can grow and still call it a TCAS-1 and then we'd get into the system interference and these considerations. I think it's probably a little early to try to answer in anymore detail than that.

MR. ALBRECHT: I think it takes judgment in each case. I don't think there's a good general answer.

COL. VOLKSTADT: The question I have for Mr Poritzky, sir, when you were talking about the data link and the installation of the MODE S as far as part of the TCAS, you were talking about having the A, B, and C available as far as the transponder was concerned. I'd like to know if you were talking about A and B as far as air-initiated or ground-initiated, and whether or not some of the formats that we'll require when we're looking at the BCAS with the RBX will now be eliminated as far as TCAS is concerned so we can look at a MODE S transponder that would be part of a TCAS installation that would have the 56 bit short message only?

DR. KOENKE: The first part I think I heard was the Comm A versus the Comm B and the Comm B is air-initiated. Okay? That is the format.

With regard to the short message, which would be the surveillance reply, I guess - is that what you're referring to?

I'm asking the question.

COL. VOLKSTADT: According to the DABS national standard and also the BCAS national standard, there is a Comm B. Part of it is air-initiated.

DR. KOENKE: Right.

COL. VOLKSTADT: You want to give a message. The other part is your answer to the Comm A, which is ground-initiated.

DR. KOENKE: That's right. Both.

COL VOLKSTADT: If you can divide them up so that you do not need an air-initiated Comm B to have Comm B capability, as far as we have been able to determine in evaluating both the national standards, the only need for an air-initiated Comm B at this time for the things that have been published, is one in an ATARS, which says that I have to send you an air-initiated Comm B if all of a sudden I don't have ATARS or my level of capability changes.

There are several other ways to do it so that you would not have to go the expense of having an air-initiated Comm B. There appears to be no requirement at all as far as TCAS is concerned to have an air-initiated Comm B. As far as the installation of a TCAS, what we're looking at is a MODE S transponder, as part of the TCAS installation. If we look at some of the formats that are there and we can eliminate some of the formats, as we're cutting down on our coordination and our ground coordination for the airborne element, it appears that you could readjust some of the formats and go with the short message which could also cut down as far as the transmitter capabilities cluttering up the transponder.

DR. KOENKE: Okay, let me try. The air-initiated part of Comm B, you're right, is not required, I don't believe, as the minimum for the TCAS functions. But it is required for reply to a Comm A. Okay?

The Comm A is used primarily for the threat advisory cross-link function. All right? And it does require a reply. It's also used for the TCAS-2 to the TCAS-2 maneuver coordination function. I would say that probably as an enhancement to TCAS-1 to encourage utilization of data link and give the pilot more capability to initiate requests from the ground for data link, that the Comm B air-initiated could be considered as an enhancement.

In terms of the MODE S, when you talk about short message, there is no Comm A, Comm B short message. It's a surveillance interrogation and reply. That's the short, 56 bit message. I don't believe that there's sufficient room in there to include the range-bearing altitude and maneuver information that's required in the minimum for the cross link function.

COL. VOLKSTADT: I would have to agree with that answer. I would like to suggest, when you have presentations like that and you have operational people who are going to be in your audience, if you're going to show a message from a TCAS-2 to a TCAS-1 and part of that message is the fact that you're below him, climbing to his altitude and you're going to be above him when you clear him, and he looks out his window, which is what that information is for, and he sees me out there in an F-16 climbing to his altitude, I think we're going to have a little problem.

MR. PORITZKY: Well, obviously. I think the point, though, that we were trying to make - and there are lots of decisions to be made on that and obviously that remains an open issue. I think the point we were trying to make is that when you look at a buyer with a relatively small amount of money, who considers buying a TCAS-1, to buy only that portion of the MODE S format to get that communication from the TCAS-2 is foolishness. What we want, of course, is to provide the capability for a safety data-link function. We want to make available, and surely that buyer wants to make available for himself, the capability of data-link messages from the ground with automation, clearance delivery, weather sequences or what have you. That's the reason for suggesting that as the minimum requirement.

The agreement on the message exchange, obviously there is lots of discussion yet ahead.

MR. ALBRECHT: One more?

MR. _________: Thank you. I feel the need to make a frank comment because I feel we're not having a open discussion. And the thing that's inhibiting is the position taken by the FAA that the minimum requirements as stated are not negotiable. They apparently - the Administrator has taken that position. When, in fact, there's widespread doubt as to whether all those requirements are in fact useful, functional, or low cost. And until we get down to a point that we can talk about it, we're not going to make much more progress. When can we talk about these minimal requirements?

MR. ALBRECHT: Well, the comment stands in terms of TCAS-1, TCAS-2 minimum requirements not being negotiable. On the other hand, you know, I'm not going to stand here and say we won't listen to anybody, anytime you've got a case you want to make. So if you have some serious concern with those requirement that have been established as firm, I suggest you do what everybody else does. You tell us about it and we'll get back at you.

MR. GIPSON: My name is Paul Gipson, Republic Airlines. I've gotone more thing I want to ask you about or talk about, I guess. It's one of the first things we brought out and I guess most of the airlines here are concerned about it. And that is the apparent requirement for including manual control of desensitization of the system in the aircraft.

Now, please educate me if I'm wrong but the way I understand the interrogating antenna system with directional antennas is to reduce, to eliminate the need, for desensitization. And if that's true, then why do we still have to worry about aircraft configuration inputs for desensitization inputs?

DR. KOENKE: The directional antenna - the directional interrogate portion of the directional antenna does not have anything to do with desensitization, per se. What it allows you to do is to operate into high density airspace. And in the minimum requirements, the statement with regard to desensitization was very carefully worded and it says: "Sensitivity adjustment must be provided independent of the ground ATC system and must automatically reset to an appropriate level in the event of a power interrupt and upon initial turn-on."

Now, it does not say that it's manual and it does not say it's automatic. It says a sensitivity adjustment must be provided.

MR. GIPSON: Well, Mr. Hunt talked about radio altimeter input, landing gear input. Now, if that's not manual input provided thrugh aircraft configuration, which would only be put in one time, we'd have to configure an aircraft for worst case possibilities. And after that, you know, when the airplane's out flying around in Mississippi, if it's configured for O'Hare, well, that's just the way it is. And, you know, we'll have a problem with decreasing the capability of the system in places where the increased capability is required.

MR. ABLRECHT: Well, Ken wasn't trying to tell you how to do it. He was trying to say this is an open option. There's lots of ways you can think of doing that.

Norm, do you and Clyde want to add anything?

MR. O'NEILL: Jack O'Neill, U.S. Air, and I've got a couple of questions. In what we used to call passive BCAS, dead for sure, and we understand the FAA will not be providing the Northeast - South Center directional information on the interrogators as part of either ATCRBS or MODE S. And the MODE S environment is for a passive or a trimodal TCAS. Are we correct in our understanding that what we used to call passive BCAS has been dropped for both ATARS and MODE S flights?

MR. ALBRECHT: Well, passive BCAS didn't have too much to do with ATARS. But i think there are two parts to your question. Is papssive BCAS dead? If passive BCAS can make a contribution to the minimum requirements or the determination of horizontal direction as we've specified, then it's a technique that can be used but there will be no North Pulses.

MR. O'NEILL: Okay, and the second one. Comparing ATARS as we presently define it, with what we now know about TCAS-2, does the FAA agree that prior to the availability of the directional antenna we talked about this morning, and because of the better threat determinants and multi-vertical and horizontal avoidance maneuvers inherent in ATARS, that ATARS would have less impact on the ATC system - at least a lower impact on the ATC system than TCAS would?

MR, ALBRECHT: Go ahead, Ed.

DR. KOENKE: Obviously, with the ground base system and in ATARS where you've got information on intent and information that's specific to an airport, you can probably do a better job of desensitization than you can do with an airborne unit.

The question, I think, is whether you can do an adequate job with the airborne unit in terms of desensitization. And I believe you can.

MR. ALBRECHT: Jack, apparently, I'm coming across a little hard-nosed, and I think it's worth saying that Mr. Helms has enunciated principles. He's a decision man. He recognizes that some need to be made or they go on for years, so he made some.

On the other hand, earlier we said to the community, please, let's talk about these things in RTCA and other forums and hash them out. So I'm not telling you it's open season but I'm trying to tell you we're willing to talk and consider any reasonable issue.

MR. FINK: Based on Mr. Poritzky's previous prepared comment about whether an Active BCAS would be acceptable as an interim measure on newly produced airplanes, would FAA support the initial writing of a MOPS based on Active BCAS to provide some TSO for that device?

MR. ALBRECHT: I don't think we would. The comment we made, or I made, was that if someone wanted to put an Active BCAS on an airplane, that no one would prevent him from doing that as long as it could be done in a non-hazardous way.

However, given a requirement in the Administrator's mind to mandate a TCAS-2, let's say, then that Active BCAS system would have to be upgraded.

MR. FINK: The decision has been made, then, that it's perfectly acceptable for the new aircraft to roll off the line with ATCRBS transponders? Yes?

MR. ALBRECHT: Yes.

MR. FINK: Thank you.

MR. GERRARD: I'm Billy Gerrard, Western Airlines, and I have a question for Dr. Miller. I'd like to know, maybe you could outline for me, some of the developmental efforts that the FAA is planning for the ____________ visual antenna or Drexell antenna. You mentioned in your briefing that you expected this TCAS-2 to be flying by next June and I was under the impression that we're still quite a long way off on a real accurate relative bearing antenna. Could you tell me just a little bit about your developmental efforts?

DR. MILLER: I did not mean to say, if I did, that we expected to have a TCAS-2 aircraft in hand by June of next year. The Bendix program is to develop and deliver - or would be to deliver the basic minimum TCAS-2 in September of next year and about six months thereafter, to have the enhanced TCAS-2 which would have the more elaborate directional antenna features installed.

So it is not proposed to have that TCAS-2, the enhanced TCAS-2, certainly not proposed to have that by the middle of next year.

MR. ALBRECHT: No, you're at least a couple of years away from a two degree antenna of that order. but there are more folks than Bendix working the problem. We're not restricted to that one source.

MR. __________: What about the 8 degrees antenna? Is someone working that problem?

DR. MILLER: Yes, there may be some confusion. One can ask the following question: If we were to put an Active BCAS with APWI display in the FAA 727 aircraft and go flying around the country and we didn't let you look at the antenna and we didn't let you look in the avionics bay, you could probably tell the pilot that he's flying a TCAS-2 and he wouldn't know the diference between that and a minimum TCAS-2 unless he flew into some areas of the L.A. Basin where he might have some difficulty with surveillance. Surveillance in the active BCAS now appears, from what data we've looked at, to break up somewhat in the L. A. Basin.

But across the rest of the country, today, it seems to be working quite well. So what I proposed when I was talking about operational evaluation, I said we were going to go on with the Piedmont test because for all practical purposes, most places that Piedmont flies looks like a TCAS-2, if you like. It certainly looks like an enhanced TCAS-1, called Active BCAS. And we're going to go on and do our cockpit simulatinn work in the same context and then early next year we would probably use the Lincoln Laboratory angle of arrival Active BCAS experimental unit to configure this sort of air carrier TCAS-2ish test bed that we would use for evalution.

And the point is, while we're just talking about the 8 degree RMS bearing accuracy PWI rigamarole, those two units really look very much the same. So for the operational evaluation, crew procedures, operational effectiveness work et cetera, that's a perfectly acceptable and valid test bed. So maybe I confused things a little bit in that sense.

MR. ALBRECHT: Well, it's been kind of a long afternoon. We really do invite you to come talk to us, to ask us questions, to get in the act. And we expect to get together with you soon in another 45 to 60 days. Thank you very much for showing up.

(End of proceeding as recorded.)

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