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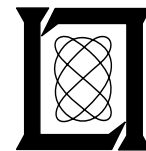
**Project Report
ATC-62**

**Beacon CAS (BCAS)
An Integrated Air/Ground Collision
Avoidance System**

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| 16. Abstract BCAS is a DABS-based airborne collision avoidance system that exploits the features of DABS discrete addressing and integral data link. This provides for a CAS with the unique capabilities of (1) cooperative threat resolution between BCAS and conflicting aircraft through the transmission of maneuver intent (to DABS-only aircraft) and the breaking (with other BCAS aircraft) and (2) coordination of CAS activities with the ground ATC control function through the DABS air-ground-air data link. All beacon-equipped aircraft in the vicinity of the BCAS are detected. ATCRBS-equipped aircraft are interrogated using a special Mode C interrogation. DABS aircraft are detected passively through periodic squitters emitted by all DABS transponders. Squitter-detected aircraft are tracked on altitude and only those aircraft that represent a co-altitude threat are discretely interrogated to establish a range/altitude track. The use of discrete addressing eliminates synchronous garble for the BCAS in the same manner as for DABS. This document provides a general description of BCAS from the viewpoint of its operational features and then describes the avionics package required to achieve this capability. | | | | | |
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OVERVIEW

BCAS is a beacon-based airborne collision avoidance system that utilizes DABS discrete addressing and integral data link to provide:

- Cooperation between the BCAS-equipped and conflicting aircraft by the transmission of maneuver intent (for conflicts with DABS aircraft) and tie breaking (for conflicts with other BCAS aircraft)
- Coordination of CAS activities with the ground ATC via the DABS air-ground-air data link
- Garble-free detection of DABS-equipped aircraft
- Accommodation of ATCRBS equipped aircraft during the transition to DABS.

INTRODUCTION

Over the past decade there has been a continued interest in airborne collision avoidance systems to provide air carrier aircraft with independent protection in regions outside of ground surveillance coverage.

DEDICATED CAS SYSTEMS

The initial approach to the airborne collision avoidance problem was the development of several collision avoidance system (CAS) hardware concepts using new avionics equipment dedicated to the CAS task. These systems share a common disadvantage that they only provide the desired protection against other aircraft which are similarly equipped or which carry special (remitter) equipment.

ATCRBS--BASED CAS SYSTEMS

Recently, consideration has been given to a collision avoidance system that makes use of the beacons carried for ground ATC purposes and hence does not impose the need for special avionics for unequipped (i.e., remitter-only) aircraft. Such a system has the advantage that it can provide immediate protection against collisions involving a significant fraction of the aircraft population. Two forms of beacon-based CAS systems have been defined which make use of ATCRBS transponders:

- Active - detection of nearby aircraft is based upon direct air-to-air interrogation
- Passive - detection of nearby aircraft is based upon listening to their replies to ground interrogators.

In operation the active system is limited by synchronous garbles and hence may not be able to function well in high density airspace. The passive system appears to have an advantage in high densities, but is limited to operation in areas that have a number of modified ground interrogators, and hence is not a complete independent system. In addition, the passive system requires relatively complex on-board processing.

BCAS - AN ATCRBS/DABS COLLISION AVOIDANCE SYSTEM

Both the dedicated and the ATCRBS-only CAS systems suffer from two additional drawbacks -

Communication with the ground is limited; therefore, CAS can possibly disrupt the ATC system and cannot be easily coordinated with automated ground control functions.

Communication between a CAS user and a conflicting remitter (transponder)-only aircraft is limited; therefore, an unexpected altitude change can possibly defeat the CAS escape maneuver.

If the CAS design incorporates DABS as well as ATCRBS transponders, all of the above drawbacks are eliminated. Specifically -

The system does not require that a detectable aircraft install new equipment which is not already needed for the ground ATC function.

Threat detection is improved, especially in high traffic densities, without the need for complex passive detection.

Signal interference can be reduced to and from the ground system by using discrete addressing.

Rapid transmission of information is possible between BCAS-equipped and DABS-equipped aircraft to permit cooperative threat resolution.

Rapid transmission of information is possible between BCAS aircraft and the ground to coordinate with the ATC system in areas under ground control.

Provision is made for the ground to inhibit or desensitize the airborne BCAS system if required in high density areas which have adequate DABS/IPC collision avoidance protection on the ground.

An orderly transition to a discrete-addressed system on the ground is assured.

The system will provide protection against beacon-equipped threats worldwide, including over the ocean.

OPERATIONAL SIGNIFICANCE OF THE DABS DATA LINK

The integral DABS data link provides a unique means for information transfer that gives BCAS added capabilities -

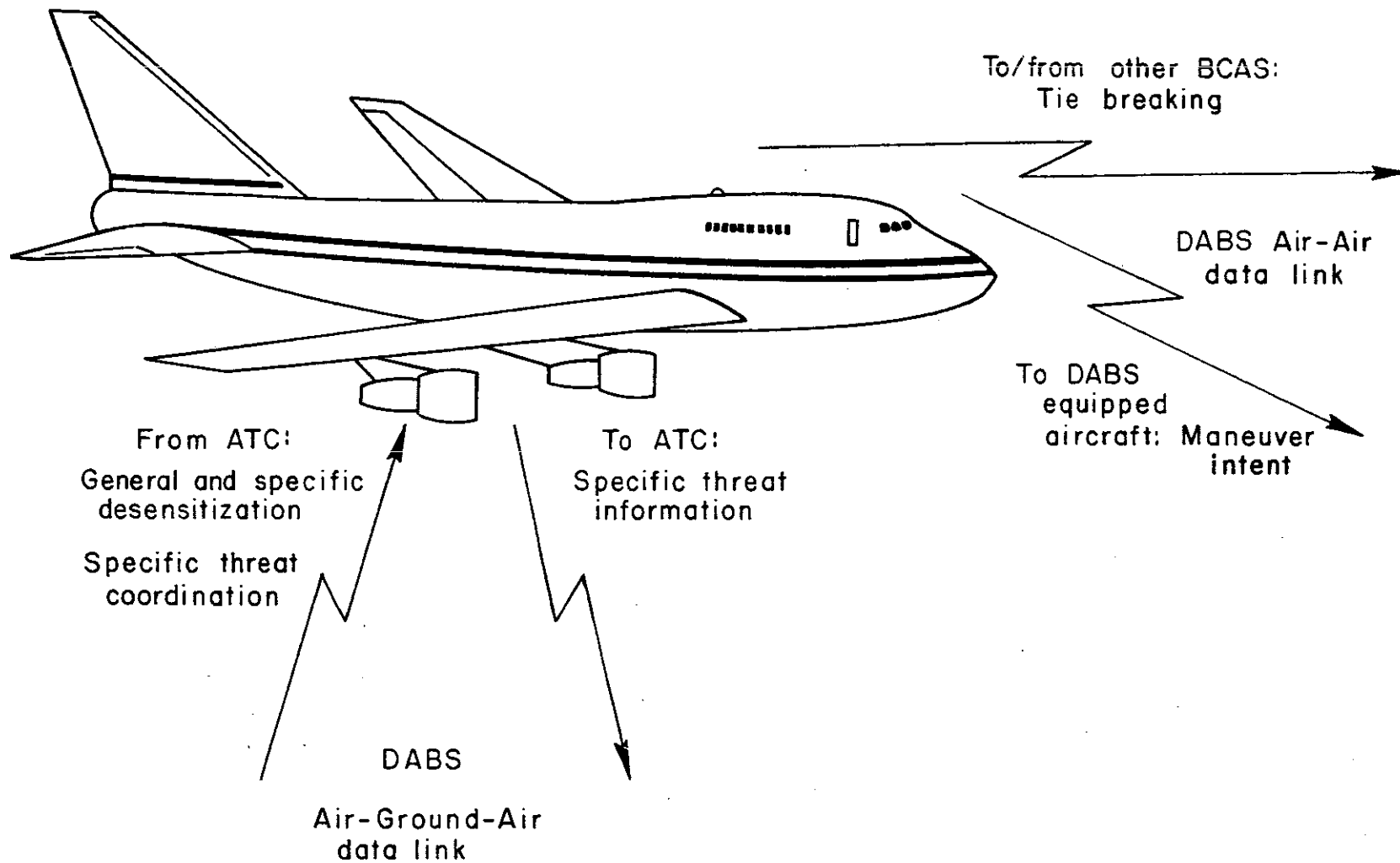
The air-to-air data link provides for cooperative action between conflicting aircraft allowing:

- Prevention of maneuvers by DABS-equipped aircraft which would defeat the BCAS avoidance maneuver
- Prevention of delay due to identical maneuver decisions in equipped aircraft (tie prevention)
- Transfer of aircraft capability or state data to enhance the CAS decision process.

The air-ground-air data link provides for coordination of CAS activities with ground ATC allowing:

- Desensitization of the BCAS system for specific threats or in certain regions
- Establishing the validity of detected threats with ground ATC.

These capabilities are examined in more detail in the following pages.



USE OF THE AIR-AIR LINK TO REDUCE BCAS THREAT LIMITS

The availability of an air-air link allows BCAS to interact differently with the three classes of detectable aircraft, depending on how it is equipped.

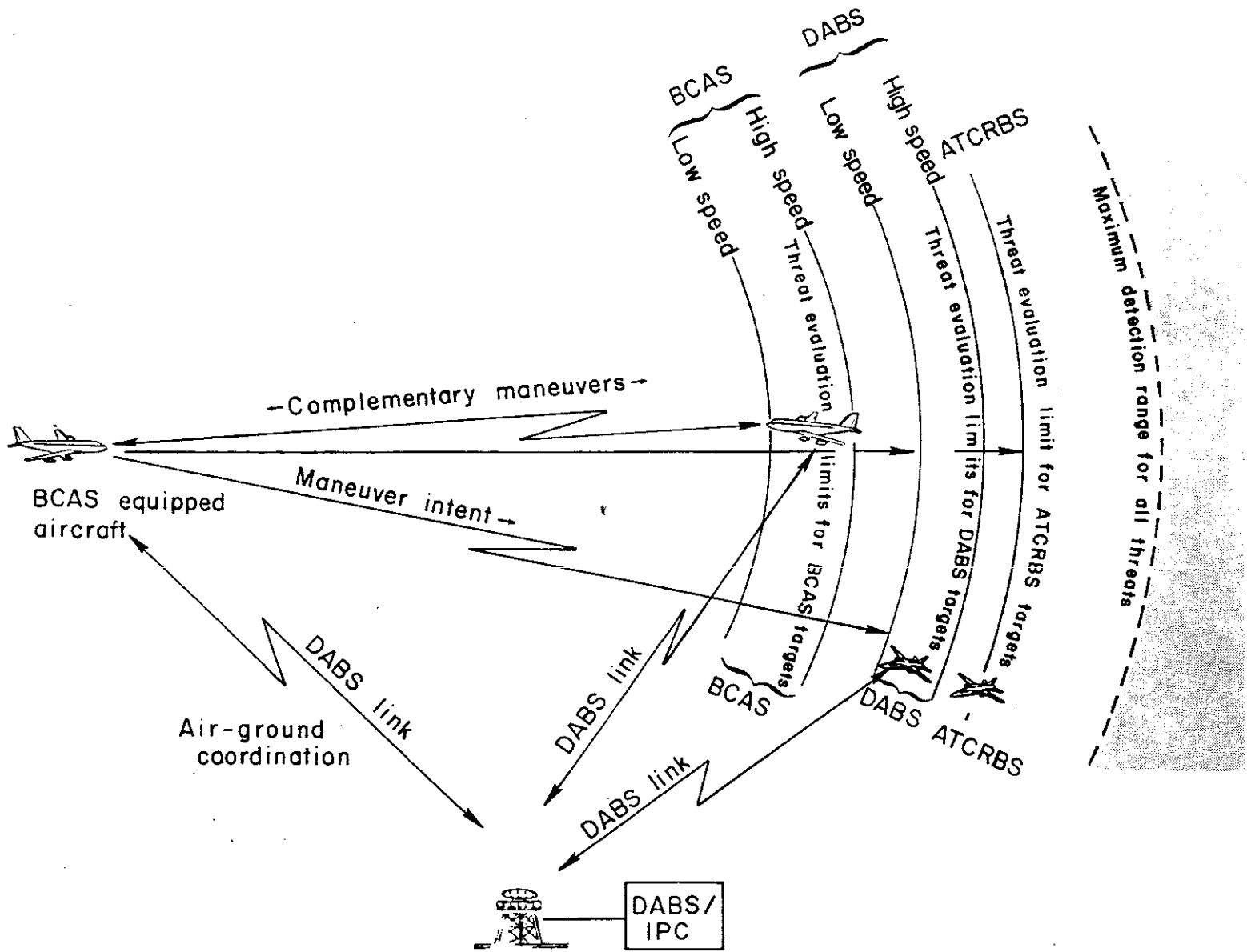
If the detected aircraft is equipped with:

ATCRBS-Mode C: There is no data link, therefore, no knowledge of aircraft capability and the possibility of an unexpected maneuver.

DABS/IPC: The data link provides knowledge of aircraft capability and allows BCAS-equipped aircraft to transmit maneuver intent that has the effect of a "don't climb" or "don't dive" indication. The DABS/IPC aircraft may make a complementary maneuver to increase separation distance.

BCAS: Provision may be included to prevent ties in the selection of an escape maneuver (by comparing DABS addresses), thereby, insuring that both aircraft maneuver in a complementary way to give the greatest separation for a given threat warning time.

BCAS can use different threat volumes for each class of target because of the different detection performance, degree of cooperation and available aircraft capability data for the three cases. When both aircraft are fully BCAS equipped, there can be minimum threat volumes and thus minimum false alarm rates and minimum interference with desired flight paths.



USE OF THE AIR-GROUND-AIR DATA LINK FOR COORDINATION OF BCAS WITH GROUND ATC

The air-ground-air data link between BCAS and ground DABS sensors provides for coordination of CAS activities with the ground ATC. A number of possible options are described to show the range of interactions supportable by the DABS link.

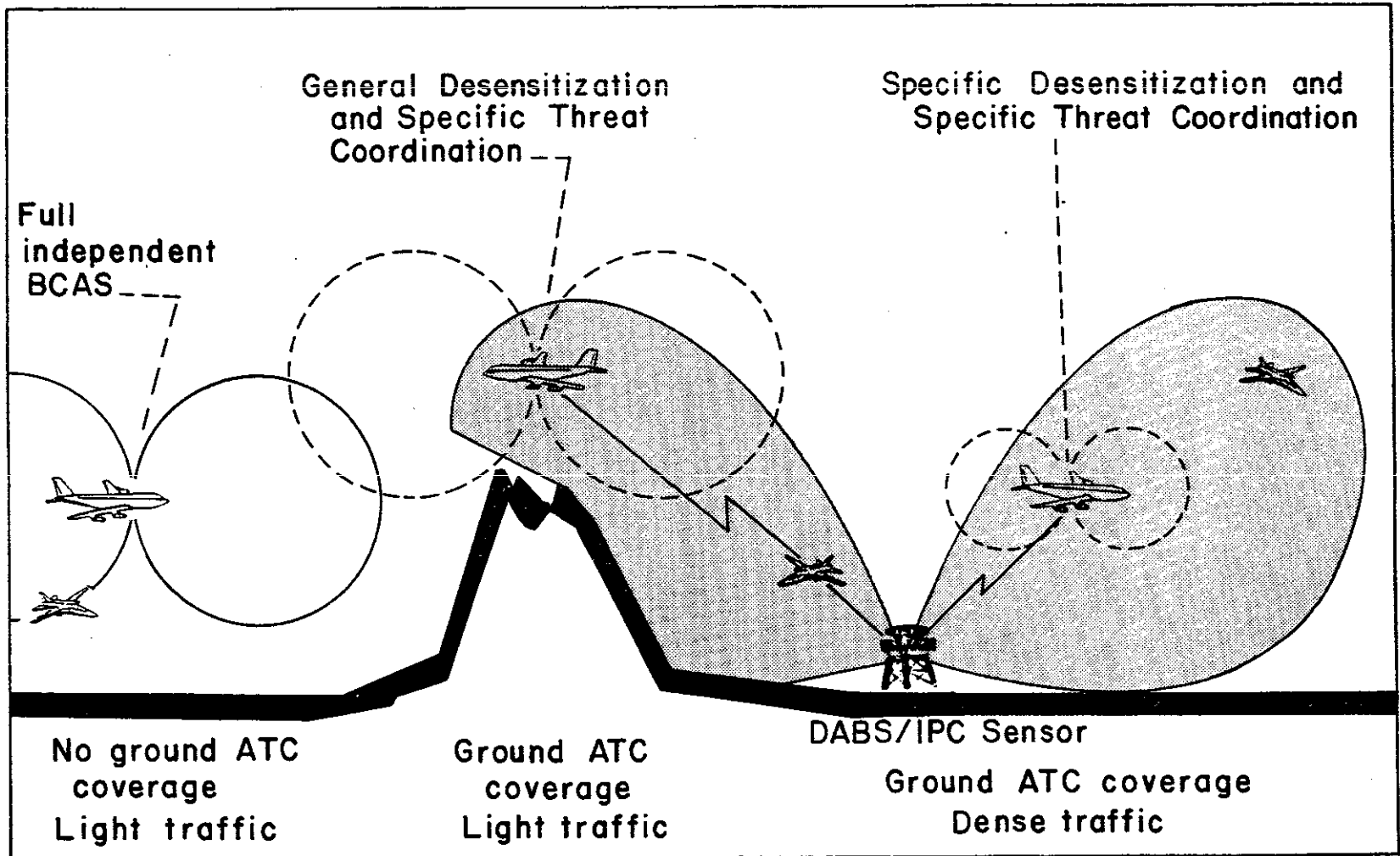
General desensitization - ground ATC (probably through IPC) modifies the basic threat volume for all BCAS aircraft within defined zones of ground protection.

Specific desensitization - ground ATC modifies the basic threat volume for a particular BCAS aircraft because of its particular flight situation, e.g. approach to close-spaced parallel runways.

Specific threat coordination - BCAS downlinks to ground ATC information on a specific threat at a preliminary state of threat development. Information included is range, range rate, altitude and ID (for DABS aircraft). The ground considers the threat potential for this specific pair and (1) if true, takes action while allowing BCAS to display the threat or (2) if not a true threat, uses the DABS data link to inhibit the display or to give other indication that the threat is not real.

This mode could serve as back-up to a single site IPC if BCAS can detect an aircraft but the ground DABS sensor cannot due to antenna shielding (this is operationally analogous to IPC for controlled aircraft).

The airborne equipment automatically reverts to full, independent BCAS operation whenever the DABS ground-air link becomes inoperative for more than a few scans. This provides a critical airborne backup capability in case of ground system or temporary link failure.

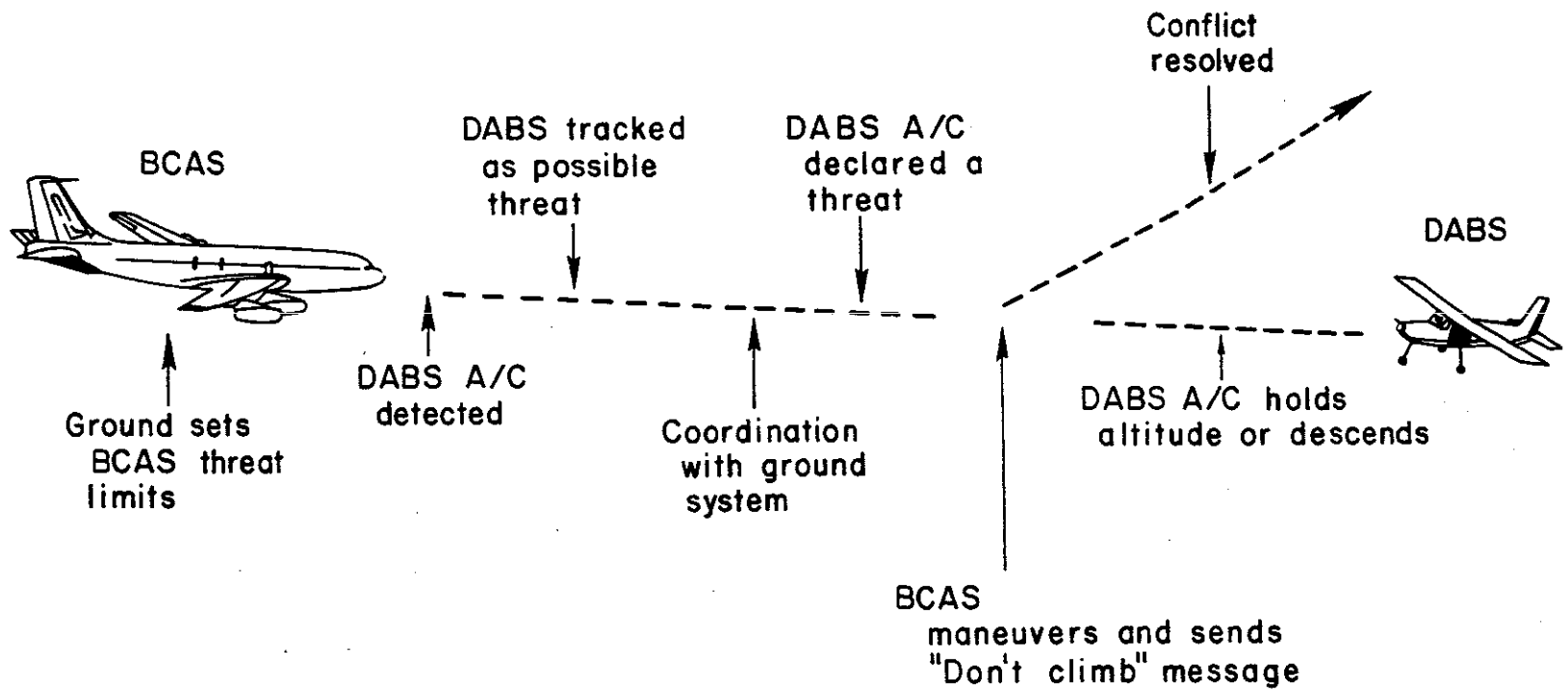


BCAS OPERATION

In operation, BCAS alternates between the DABS and ATRBS modes to provide updates to the CAS algorithm. At any moment, the BCAS performs surveillance on aircraft in several threat categories; from simple detection of non-conflicting aircraft to full range/altitude tracking for potentially threatening aircraft. The threat limits to be applied for conflict declaration are adjusted under ground control to conform to the level of protection currently provided by the ground system. In the event of a detected threat, the sequence of events is conditioned both on the class of aircraft represented by the threat and the presence of ground-based control elements.

A typical sequence of events for a BCAS/DABS encounter is presented in the figure. It is assumed that the illustrated encounter occurs in positive controlled airspace and that coordination with the ground system takes place before the maneuver command is presented to the pilot.

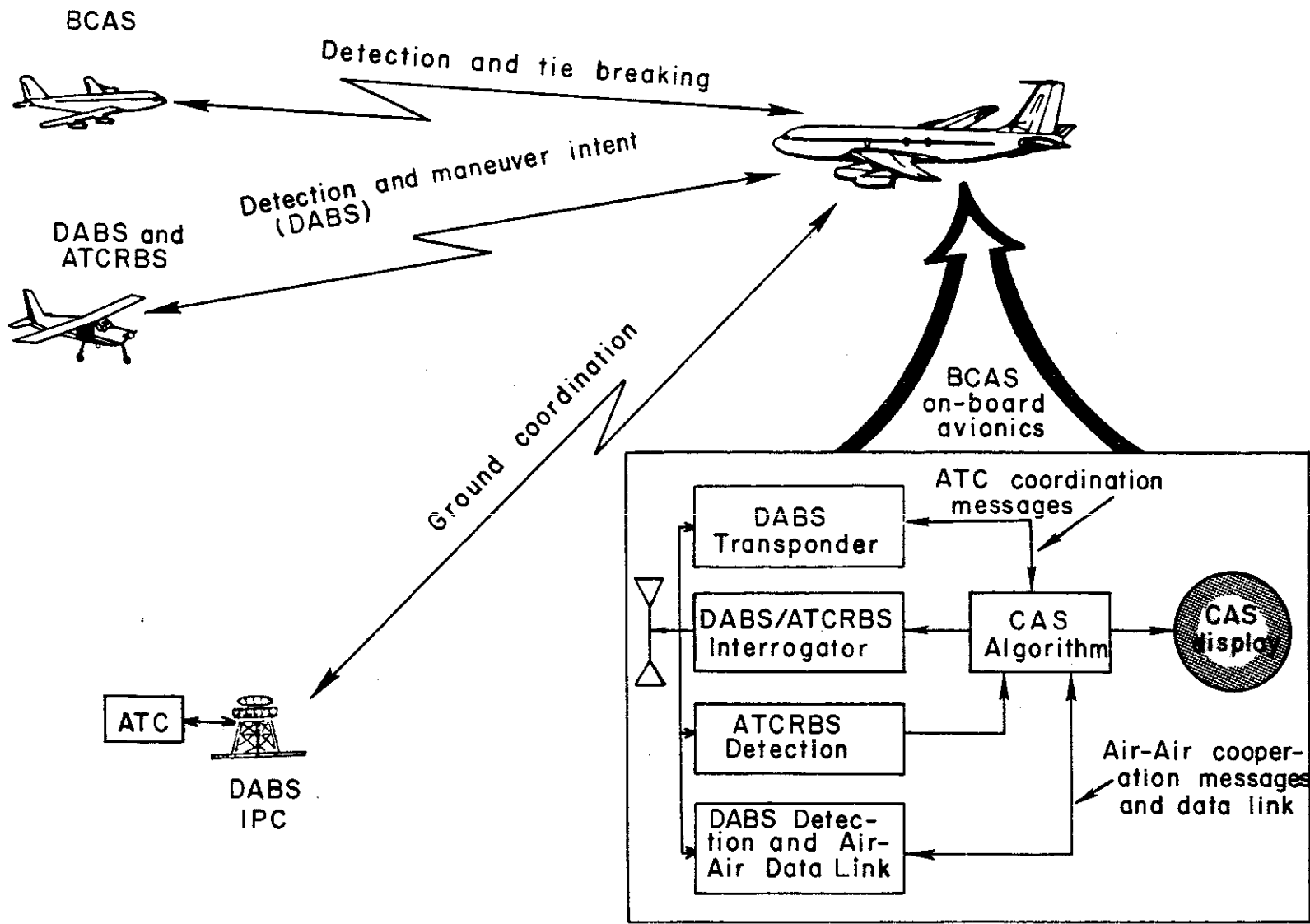
BCAS Operation: BCAS-DABS Encounter



BCAS AVIONICS

The BCAS avionics package has the capability of detecting nearby aircraft, evaluating their threat potential, and then resolving declared conflicts. Specific functions required to do this are shown in the figure.

- DABS Transponder - Supports ATC surveillance, and detection by other BCAS aircraft. Integral air-ground-air data link is used for BCAS-ATC coordination messages.
- ATCRBS Detection - Active transmission of special Mode C interrogations elicits replies from ATCRBS transponders. Aircraft in altitude proximity to the BCAS are tracked to develop range rate.
- DABS Detection - DABS are acquired passively through regular squitter replies transmitted periodically by all DABS transponders. Potentially threatening aircraft are discretely interrogated to determine range and range rate.
- Air-Air Data Link- This link is used for tie prevention and the transmission of maneuver intent. Other uses include transmission of aircraft capability for use in the detection and threat evaluation process.
- CAS Algorithm and Display - Detection and data link information developed as described above is evaluated by the CAS algorithm to determine the presence of potential collision threats. Declared threats are resolved through altitude maneuvers presented to the pilot on the CAS display. This process is performed (1) cooperatively with BCAS and DABS aircraft, and (2) with ground ATC coordination in positive control and mixed airspace.



BCAS DETECTION AND TRACKING OF DABS-EQUIPPED TARGETS

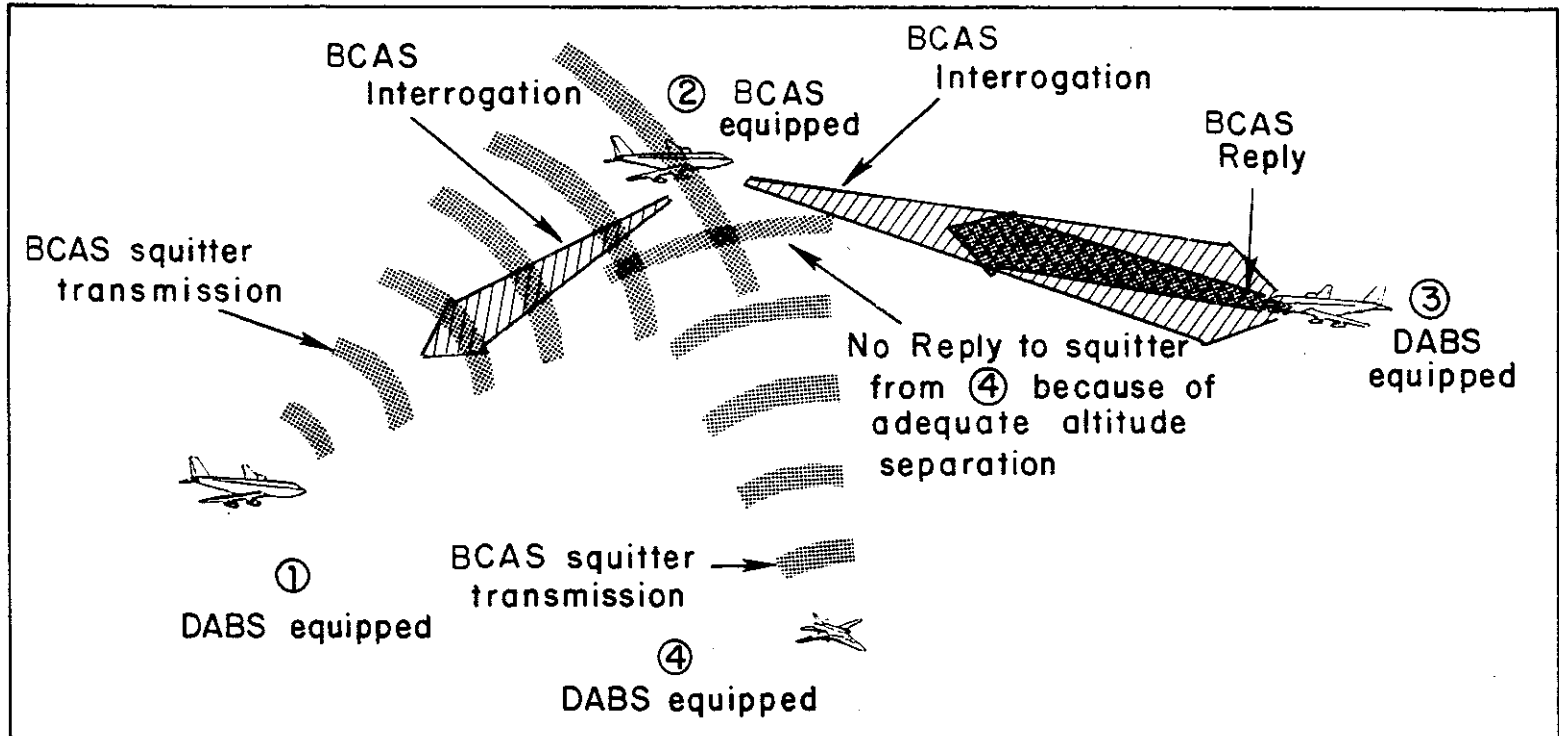
In BCAS, acquisition is accomplished by periodic squitter transmissions containing altitude, speed capability and DABS address. These transmissions are emitted by all DABS transponders. On receipt by a BCAS airborne receiver, the squitter is filtered against altitude threat limits centered on the user's own altitude.

Once acquired, the DABS aircraft is tracked in altitude via its squitter transmissions. An intruder whose altitude or altitude rate could bring it into conflict with the BCAS user is interrogated once to determine its range. If the intruder is also inside a given range threat zone, it is regularly interrogated and the resulting track data is fed to the conflict resolution processor. Aircraft at longer ranges are interrogated only as often as necessary to detect their entry into the threat zone, based upon their reported speed capability.

All interrogations are discretely addressed, thereby eliminating synchronous garble problems for the BCAS in the same manner as for DABS. (Note that DABS interrogation scheduling for BCAS is much simpler than for a DABS sensor due to the omnidirectional antenna and the relatively small number of aircraft which must be actively interrogated.)

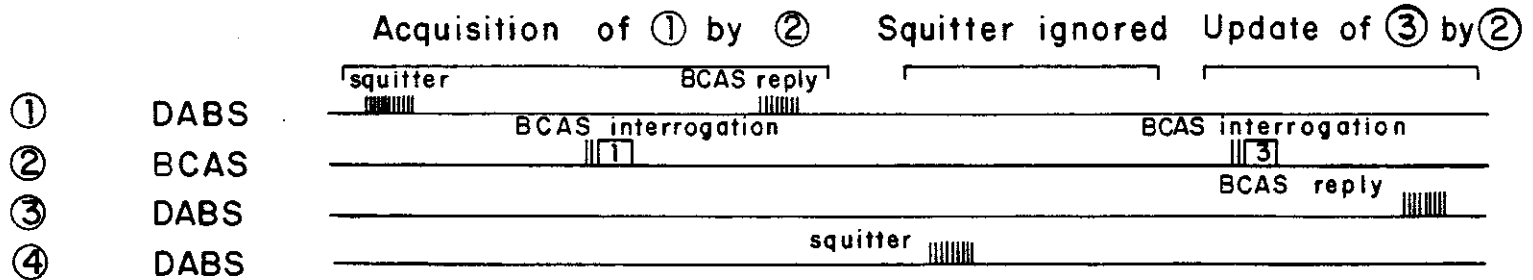
The use of squitter acquisition in combination with altitude filtering minimizes the number of transmissions required by the BCAS system and thereby minimizes interference. Provision is made to inhibit BCAS active interrogations and DABS squitter replies in areas of extreme traffic density.

Example of DABS Detection by BCAS



Aircraft Equipment

BCAS Transmissions



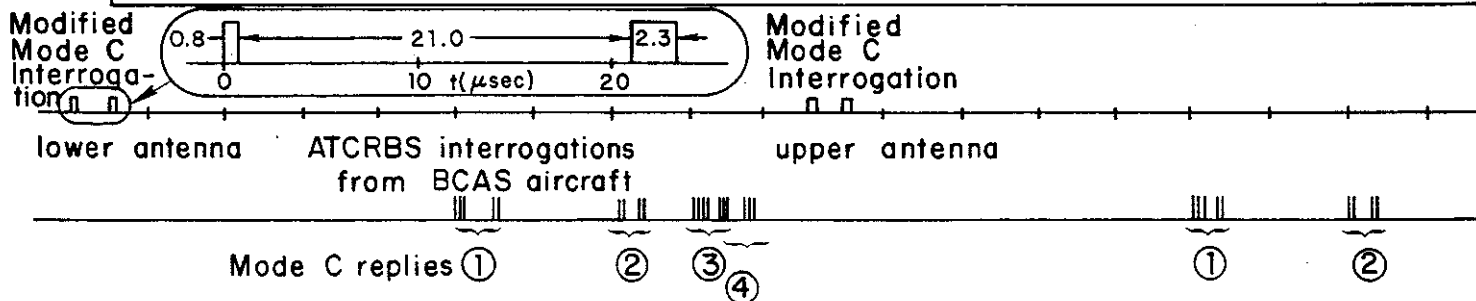
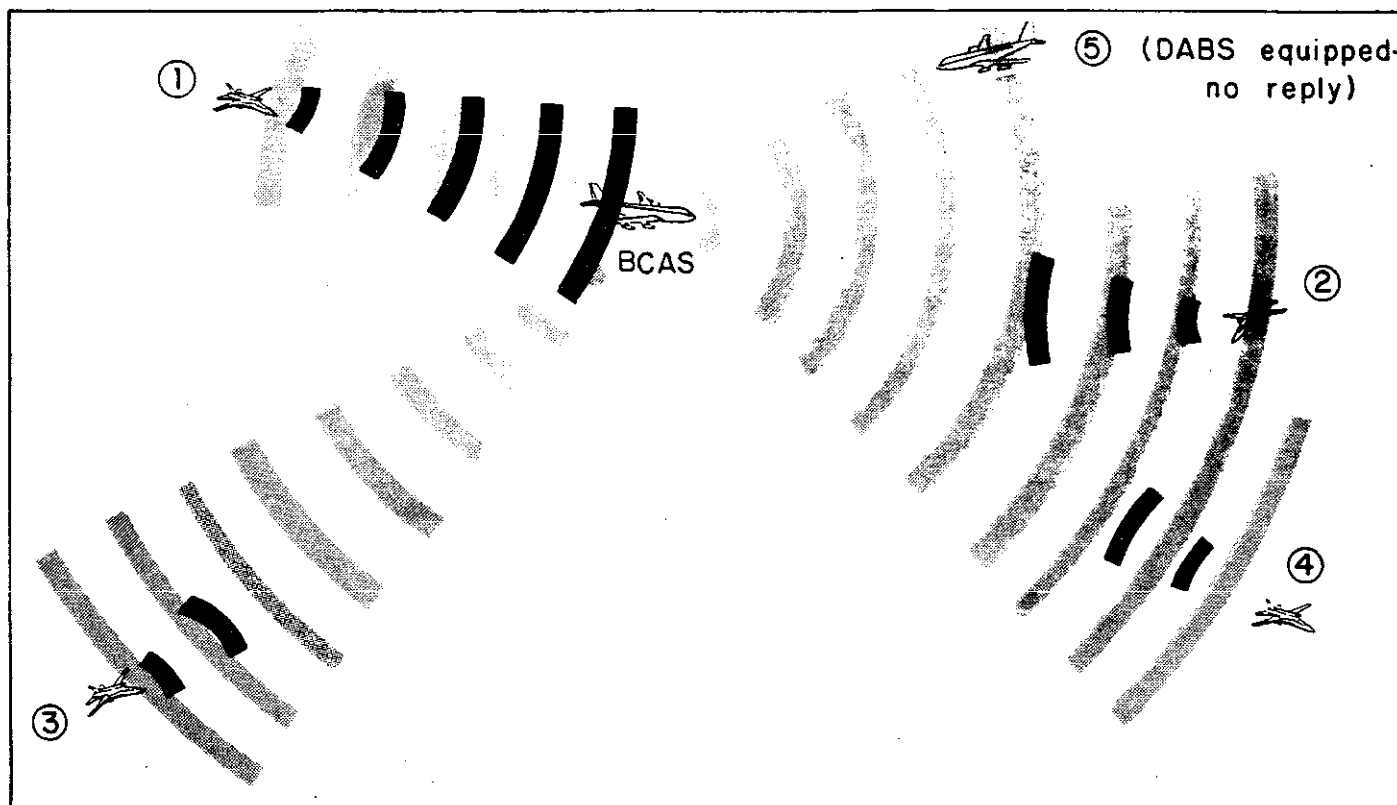
BCAS DETECTION AND TRACKING OF ATCRBS-EQUIPPED TARGETS

ATCRBS detection and tracking is accomplished by the transmission of a modified Mode C interrogation at an approximate 1-sec update interval. Mode C is used because the CAS logic requires measurement of range and altitude.

A modified Mode C interrogation elicits replies from ATCRBS transponders and no replies from DABS transponders; this is achieved by transmitting a wide P_3 pulse. In this way, as aircraft become DABS-equipped, they are removed from the ATCRBS population and do not contribute to the occurrence of ATCRBS synchronous garble.

Defruiting for the ATCRBS mode is accomplished automatically during update since fruit-initiated tracks will not be regularly updated and will, therefore, be dropped after a short period.

Example of ATCRBS Detection by BCAS



MODIFICATIONS TO DABS REQUIRED BY BCAS

Modest changes to the DABS design are required to support the BCAS functions described in this document. The most important is the requirement that all DABS transponders be able to transmit BCAS squitters and receive and decode BCAS air-air interrogations. Other changes to the transponder include the ability to detect the widened P_3 pulse of the BCAS Mode C interrogation and to respond to the squitter lockout control.

The DABS ground-air transmission must be modified to include the squitter lockout bit to selectively inhibit DABS transponders from transmitting BCAS squitters. All other air-ground-air transactions required for BCAS control and coordination can be handled via the DABS uplink and downlink communications formats and therefore require no changes.

The BCAS system requires no modifications to the existing ATRBS transponders or interrogators. It is anticipated that adequate link reliability will be achievable without requiring dual (diversity) antennas on DABS or ATRBS-equipped aircraft.

SUMMARY

Features/advantages of BCAS

- Cooperative threat resolution using the air-air data link
- Coordination with the ground ATC using the air-ground-air data link
- Garble-free detection of threat aircraft
- Accommodates ATCRBS-equipped aircraft during transition to DABS